University of Strathclyde
Department of Economics

Regional economic and environmental analysis.

Presented in fulfilment of the
requirements for the degree of
Doctor of Philosophy

2012

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Declaration of Authenticity and Author's Rights

This thesis is the result of the author's original research. It has been composed by the author and has not been previously submitted for examination which has led to the award of a degree.

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Acknowledgments

I am sincerely grateful to my principal PhD supervisor, Professor J. Kim Swales of the Fraser of Allander Institute and Department of Economics at the University of Strathclyde, to whom I owe the greatest debt. Kim has shown immense patience and wisdom in guiding me through the last two years of this PhD. I remain greatly indebted to him for all his advice, help and support in the preparation of this thesis.

I would like to thank my secondary PhD supervisor Dr Karen Turner of the Division of Economics at the University of Stirling. The research in this thesis was supported through a studentship obtained by Dr Turner as part of a wider research grant. I collaborated extensively with Dr Turner during the period when she was my principal PhD supervisor; prior to her move to the University of Stirling. I benefited greatly from this interaction, and learnt much during this time. This research was supported by an ESRC-Scottish Government collaborative studentship (Studentship Award No: ES/G031673/1). I would like to thank both these organisations for their financial support.

Throughout the last three years a number of people have provided helpful comments on aspects of this research, and I am grateful to them for taking the time to do so. I would particularly like to thank participants at: the Regional Science Association International (British and Irish Section) in Glasgow, Scotland (2010), Cardiff, Wales (2011) and Galway, Ireland (2012). In addition, I extend my thanks to those who have contributed comments during departmental seminar presentations in the Department of Economics at the University of

Strathclyde.

I also benefited from discussing the work in this thesis at the Scottish Graduate Programme in Economics Annual Conference in Peebles (2010) and Crieff (2012). I would like to thank Professor Paul Hare of Heriot-Watt University and Dr Alasdair Rutherford of the Division of Economics at the University of Stirling for their comments and feedback in 2010 and 2012 respectively.

I would also like to thank the academic and administrative staff, as well as my fellow PhD students, in the Department of Economics at the University of Strathclyde. For the past three years they have helped make the department a lively, friendly and challenging environment to carry out research. It wouldn't have been the same without them. I thank in particular Ms. Janine De-Fence who shared an office with me for a time; she endured my bad habits and eccentricities with grace and remarkable good humour. I also thank Dr Patrizio Lecca for his assistance and patience in helping me get to grips with the CGE model.

I would also like to thank Dr Christa Court who ensured that I was kept 'in check' throughout the past three years, and who while collaborating on research related to this thesis proved to be an excellent co-author and a ruthless editor. I am also grateful for her enduring friendship.

Finally, I would like to thank family, friends and loved ones for their unfailing patience and good humour during the past three years.

Abstract

Scotland has a set of legislative targets to reduce its greenhouse gas emissions, measured on a territorial basis, introduced by the Climate Change (Scotland) Act 2009. In addition, the Scottish Government have adopted as a 'national outcome' target a reduction in the emissions embodied in Scottish consumption activities. These targets differ in terms of whether the emissions embodied in exports are included (territorial) or whether the emissions embodied in imports are included (consumption) in the emissions total.

The first area of work in this thesis is quantifying the different emissions totals that can be calculated under both of these accounting principles using the currently available data for Scotland. Using the input-output framework, we explore the construction, and the implications, of this range of measures. We also identify some wider issues that arise in the adoption of different emissions targets for a region within an interdependent national economy.

The second area of work focuses on understanding the sectoral level relationships which underpin national output and CO_2 emissions in Scotland. It is often the case that the focus of policy and public debate is on 'the number' (i.e. the emissions total) and changes in it. Underpinning this 'number', however, is a series of complex economic relationships at the sectoral level which we want to better understand. We seek to better understand these relationships in Scotland using the tools of linkage and key sector analysis.

The final strand of work in this thesis looks to explore the compatibility of the current focus of economic policy in Scotland on increasing export demand, with the environmental objectives of reducing Scottish territorial and consumption emissions. There is great emphasis placed by the Scottish Government on the economic impacts of investing in 'green' industries, while little is said of the environmental impact of more general growth in export demand, even though this is a clear economic policy priority.

Using a CGE model framework, we explore the implications on both the territorial and consumption emissions totals of a general increase in export demand with flow migration and no-migration. These two cases provide interesting insights on both the long-run impact on these emissions totals, as well as on the dynamic adjustment to the long-run total.

The analysis in this thesis answers a number of interesting research questions, and uncovers some additional questions which will be the focus of future research. It is clear that the economy and the environment are interdependent. What needs to be better understood is which parts of the economy impact on the environment, how trade influences the impact of our economy on the environment, and how economic and environmental policy objectives are interdependent.

Chapter 1

Thesis prelude

1.1 Brief overview

This thesis is structured around 3 main chapters. Each chapter represents a different approach to analysing the relationship between the economy and the environment in Scotland. The chapters are designed to be complementary and to build upon each other in a logical order. Chapter 2 describes the baseline toolbox and input-output methodology that are relied upon throughout this thesis. In addition, Chapter 2 establishes the central concepts and illuminates the key debates in the carbon accounting literature. In applying different national emissions total calculations in Chapter 2, we focus on the key data requirements and the central messages, relationships and implications of the different measures used.

Having investigated and examined the national emissions totals in Chapter 2, Chapter 3 tries to understand the sectoral level relationships that underpin the main results and conclusions of Chapter 2. Using the tools of key sector analysis, we seek to determine the key pollution sectors in the Scottish economy. There are a range of different measures that have been proposed to measure sectoral linkage strength and hence identify key sectors. For comparison purposes we carry out this key sector analysis for both sectoral output and sectoral emissions.

There are still further measures that could be considered in the context of understanding the sectoral relationships underpinning the national emissions totals. One example of this would be by using a multiplier decomposition approach. We do not pursue this strategy here. Instead we investigate a range of standard linkage measures, as well as different approaches to weighting these measures using additional sectoral level information. We also extend some of the more traditional linkage measures by using newly developed approaches to hypothetically extract sectors from the economy, both individually and in groups, to assess their individual and combined impact on national output and CO_2 emissions.

Chapter 4 recognises that economic change has implications for national emissions totals. Having established the baseline emissions totals, and the different conceptual and methodological approaches to calculating different emissions totals in Chapter 2, Chapter 4 moves the analysis forward to consider the economic and environmental impact of economic change. Specifically, in Chapter 4 we investigate the important issues posed by the tension between the Scottish Government's economic growth and CO_2 reduction policies and targets.

1.2 Motivation & Approach

The Scottish Parliament passed the Climate Change (Scotland) Act in 2009 (Scottish Government 2009), setting out the territorially based legislative emissions targets that the Scottish Government were required to address themselves to. The territorial based emissions total is the sum of the emissions generated within Scotland, and is also known as the territorial accounting principle (TAP) emissions total. There had been a debate prior to the passage of this legislation about the approach that should be used to calculate the national emissions total. Some argued against the TAP targets which were enacted, on the basis that it was not a true reflection of the effect that Scotland has on the environment.

People making this argument usually also advocated the adoption of a consumption based emissions total or consumption accounting principle (CAP) emission total. This is where the national emissions total is reflective of the emissions embodied in the goods and services that the nation consumes, regardless of the location where the embodied emissions were released. The reason, at least in part, why consumption based targets were not adopted was because of the difficulties that arise in the calculation of such measures[1], and the implications of this for international comparability.

Aside from the practical difficulties in formulating CAP measures, there has been a wider public debate about the nature of emissions reduction commitments that different countries are making. The landmark international accord known as the Kyoto Protocol agreement[2] is perhaps the best known 'territorially based' set of emission reduction commitments. The Kyoto Protocol was an agreement between signatory states about the degree to which their country would reduce their territorial emissions relative to a given base, however in doing so it exempted a whole series of (mostly developing) countries from making any effort to abate the emissions they generate.

This created a situation where one group of countries were enacting tougher environmental regulations, taxes, and targets to reduce their contribution to global emissions at the same time as another group of countries were able to expand their emissions without penalty. It has been argued that the current arrangement, where developing countries are exempt from making any reduction in their emissions, be replaced by developed countries adopting CAP based emissions targets.

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[1] CAP measures require a significant amount of both economic and environmental data. For a 'full' CAP measure, it is necessary that the emissions content of domestic and imported inputs into the production process and the emissions content of imported final demands be known. This requires information on the production processes and emissions intensities of each sector in each region whose output the nation of interest consumes. This is a significant amount of data, and helps explain the scarcity of CAP measures in use. There have been attempts to estimate emission totals in line with the CAP, and we discuss these in detail in Chapter 2.

[2] The Kyoto Protocols are a separate but component document to the United Nations Framework Convention on Climate Change (UNFCCC) which was agreed in Kyoto, Japan on 11th December 1999. This is sometimes colloquially referred to as the 'Kyoto agreement'. It is the Kyoto Protocols, not the UNFCCC, that bound developed countries to reduce their emissions. The full text of the Kyoto Protocols is available from: `http://unfccc.int/resource/docs/convkp/kpeng.pdf`

The principal reason that developing countries were exempted from the original Kyoto agreement reductions in emissions generation was that these countries were undergoing the process of industrialisation which would require, in the short term at least, increases in their emissions. To mandate that developing countries reduce their emissions during this period might, it is argued, hamper their economic development and lead to a worsening of long-term environmental and economic conditions in these countries[3]. Nevertheless there have been calls for countries in the developed world to adopt CAP based emissions measures, and use these as the basis for their own emission reduction targets.

Notwithstanding the considerable data difficulties that such measures pose in their construction, the Scottish Government have accepted, as a 'National Outcome' target the reduction of the emissions embodied in Scotland's consumption activities (Scottish Government 2011*b*). This may be a commendable objective, but how can progress be measured against this target? Chapter 2 of this thesis will outline some of the measures that can be constructed using the currently available data to estimate a CAP emissions total for Scotland. Further, we will compare our estimates to those calculated by researchers at the University of Leeds on behalf of the Scottish Government[4].

This is important for a number of reasons, not least of which is that we ought to have some transparent and objective means of measuring progress towards meeting each National Outcome target. In addition, while the emission reduction targets currently embodied in the Climate Change (Scotland) Act 2009 are TAP targets, if we are to have an informed debate about whether we should instead adopt a CAP based targets- or indeed adopt targets constructed on some other basis- we must be clear on how each alternative measure can be calculated.

Even once the basis for calculating the national emissions total is agreed, it

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[3] However, it might also be argued that were developed countries, in order to meet these CAP targets (thereby taking account of the emissions embodied in their imports), to impose a levy on imports in relation to the emissions embodied in these imported goods, that it might depress demand for these imports. CAP emissions targets in developed countries may, in this way, hinder economic growth in developing countries.

[4] Available online at: `http://www.scotland.gov.uk/Resource/0039/00392289.xls`.

is not always clear how these national targets and policies translate into action and the attribution of legal responsibility among agents in the economy. In the case of climate change targets, this manifests itself under the current TAP emissions targets with the question: which sectors should we target to reduce our emissions, or under CAP with the question: which category or categories of final demand should be targeted to reduce these emissions? Chapter 3 of this thesis addresses this issue.

In addition, it is clear that the Scottish Government (like many governments) have competing economic and environmental strategies. The Scottish Government are keen to boost export sales, as well as reducing their TAP emissions. Increases in domestic economic activity to meet export demand would be expected *ceteris paribus* to lead to additional environmental impacts. A policy strategy, based only on these two policy objectives, might demand a sectoral policy to reduce the emissions in those sectors with a greater share of sectoral export demand as well as an emissions intensive supply chain. These sectors would be the sectors which would we ranked highest by an export weighted environmental backward linkage measure outlined in Chapter 3.

With territorial emissions targets in Scotland, there may be some tension between policies aimed at increasing domestic economic activity and these targets. The close relationship between economic activity and territorial CO_2 emissions was particularly obvious in the context of the recent recession where the decline in economic activity caused a drop in Scotland's territorial emissions, which was considered as a gain towards Scotland meeting its climate change targets[5].

In the context of Scotland's export growth strategy, this tension gives rise to another possibility, namely the adoption of a consumption based emissions total. This would be where Scotland's national emissions total is the sum of

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[5] This was reflected in the UK Committee on Climate Change, the advisory committee to the Scottish Government under the Climate Change (Scotland) Act 2009, advising the Scottish Government that the decrease in economic activity during the recent recession allowed them to consider setting tougher short term targets for emissions. The Committee on Climate Change suggested that a target of a 23% reduction in emissions in 2010-2012 against the base year of 1990, instead of the previously recommended 20% target, seemed achievable in light of the recent downturn in economic activity (Climate Change Committee 2010).

the emissions embodied directly and indirectly in our consumption activities, regardless of where the goods we consume are manufactured. In order to assess the impact on different emissions totals of this kind of export growth, we extend the analysis in Chapter 2 using a computable general equilibrium (CGE) modelling approach.

The reason for adopting a CGE modelling approach is that increases in export demand in Scotland, which leads to an increase in domestic economic activity, also leads to an increase in domestic prosperity and consumption. On the one hand there is a potential increase in domestic emissions to satisfy this increase in export demand, this would be expected to, *ceteris paribus*, push up our territorial emissions total. This would suggest that perhaps Scotland's economic and environmental goals were incompatible.

On the other hand, increases in export demand increase domestic economic activity, domestic prosperity and hence consumption. This potentially increases the emissions embodied in our domestic consumption. This would be expected to increase a consumption based national emissions total. It is therefore not immediately clear whether a territorial or consumption based emissions total would be most affected by an increase in external demand for domestic produce.

The more realistic CGE modelling approach allows us to assess the dynamic adjustment of the economy, and its environmental impact, towards its long run level following an export shock. Following McGregor et al. (1996) a pure demand shock like this in a CGE framework will approximate an input-output result in the long run, which means that with no supply constraints the main advantage of the CGE model here is in allowing us to assess the dynamics of the adjustment to the long-run equilibrium territorial and consumption emissions totals.

In addition to which, we consider the impact of introducing a restriction on in-migration on the territorial and consumption emissions totals with the same exogenous increase in export demand. In this case, with a supply constraint, in the long run prices change. This provides another useful case to help us understand the impact of general export growth on CO_2 emissions totals in Scotland.

1.3 Research questions

By the end of this thesis, the following questions should have been answered:

1. What was Scotland's CO_2 emissions total in 2004 under different accounting principles, and using different estimation methods?
2. What was Scotland's emissions embodied in its trading activities (exports and imports) in 2004?
3. What are the implications of different emissions accounting principles in terms of the policy incentives they provide?
4. What are the implications for Scotland of adopting its own territorial emissions targets?
5. Which sectors are making the biggest contribution to Scottish emissions in 2004, based on their direct pollution and on the emissions embodied in their supply chain?
6. What are the different environmental linkage measures that can be formed, and how useful is each measure?
7. What policy insights can environmental key sector, and in particular key linkage analysis, provide on the relationship between the economy and the environment?
8. What predictions might be formed about the sectors which, in the face of growth in export demand, would generate the greatest additional amount of pollution in Scotland?
9. What is the potential collective contribution of groups of sectors to emissions generation within Scotland in 2004, and how useful is this information?

10. What is the response of the Scottish economy to a uniform increase in export demand?
11. Which sectors would generate the greatest increase in emissions following a uniform export shock, and how do these compare with the carbon backward linkage ranking weighted by export final demand?
12. What is the implication for different emissions totals of a uniform growth in export demand?
13. Do the results for the changes in the emissions total with a pure export shock differ with the introduction of a supply constraint (e.g. no migration)?
14. How do the emissions per capita in Scotland differ with an export shock in the cases with and without flow migration?
15. How do the simulations carried out in Chapter 4 help inform policy, with particular reference to the compatibility of export led growth and different emission accounting principles?

Chapter 2

Pollution accounting in Scotland

2.1 Introduction

The Scottish Parliament agreed climate change legislation in 2009 (Scottish Government 2009). The center-piece of this legislation was a set of territorial emission reduction targets. These committed Scotland to greater emission reductions by 2020 than those implied by the existing legislation, i.e. the UK Climate Change Act and the Kyoto Protocols which form part of the United Nations Framework Convention on Climate Change, which to this day still cover Scotland.

A crucial part of the climate change debate centers on what sort of targets to set and what these targets should cover. Different schools of thought have emerged about whether these targets, and the national emissions balance[1] that was to be used, should focus on the emissions generated by production activities here in Scotland, or on the emissions embodied in what Scotland consumes.

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[1] The literature refers to the total of a countries national emissions as the nation's emissions balance. While this terminology is perhaps unfortunate, we adopt it from time to time in this thesis for consistency with the literature. A better term is perhaps simply 'emissions total' which is the term we mostly use in this thesis.

The option also exists to create a hybrid measure which combines these two approaches. Indeed the option also exists to adopt an altogether different 'principle' to attribute emissions to administrative units (regions, countries, etc).

The main difference between the territorial, production based, emissions total and the consumption based emissions total is the emissions embodied in our trading activities. The consumption based emissions total includes the emissions embodied in our imports from other countries. The territorial emissions total includes domestically produced emissions embodied in our exports to other countries. The difference between the territorial emissions total and the consumption based emissions total is the balance of emissions embodied in trade[2].

The existing emission reduction legislation and agreements at the time the Climate Change (Scotland) Act was being considered all focused on the emissions that each country produced (i.e. the territorial approach). This was also the approach which was adopted by the Climate Change (Scotland) Act (Scottish Government 2009). The debate about the basis on which to calculate the national emissions total recognised the international precedent that had been set through the Kyoto Climate Change accords, and also recognised the difficulties posed by adopting a consumption based national emissions total.

There has been sustained interest in both the academic and policy communities in constructing consumption based emissions totals, however the data requirements of this type of emissions measure are such that a range of simplifying assumptions have been needed to operationalise these measure[3]. These assumptions are not without criticism, as we will soon see, with different researchers adopting different approaches depending on the particular application and data availability.

Despite the Climate Change (Scotland) Act setting only territorial emissions

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[2] There is an issue here which complicates this simple definition slightly. Essentially this general definition is true, but depending upon how the emissions embodied in imports and exports are calculated, this need not be strictly correct in practice, even if it is in principle.

[3] A recent House of Commons Energy & Climate Change Select Committee report (available here: `http://www.publications.parliament.uk/pa/cm201213/cmselect/cmenergy/488/488.pdf`) looked in detail at these issues and concluded that while it was not straightforward to calculate these consumption measures for the UK, this should not be used as an excuse by the UK Government for not trying to estimate consumption based emissions totals.

targets, Scotland currently has as one of its National Outcomes: "reduc[ing] the local and global environmental impact of our consumption and production" (Scottish Government 2011*b*). This makes clear that, despite the Climate Change (Scotland) Act focusing its attention on territorial emissions generation, the Scottish Government believe that reducing the emissions embodied in our consumption activities is also important.

Given that reducing the emissions embodied in our consumption activities is a National Outcome target for Scotland, even if the only legally binding emission targets are territorial based targets, the measurement of the emissions embodied in Scottish consumption is of some importance. This chapter attempts to fill a gap in our current knowledge by considering a range of alternative consumption based emissions totals, which can actually be calculated using the currently available data for Scotland. This is done by utilising different assumptions and approaches based on an input-output modelling approach. We can then compare these different national emission totals.

The focus of this chapter is therefore on examining different approaches to accounting for Scotland's emissions, both from a territorial and consumption perspective. In doing so we examine and discuss the data issues that are involved in constructing these different emissions totals. There are a range of simplifying assumptions that have been used in the literature to calculate consumption based emissions totals, and we review and discuss these here as well.

2.2 Different accounting methodologies

The seminal paper exploring different carbon emissions attribution methodologies was Munksgaard & Pedersen (2001)[4]. They argue that there are two main 'principles' that could be applied to emissions attribution; the production ac-

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[4] Proops et al. (1993) first raised the issue of consumption responsibility for GHG emissions, although the first explicit formulation in terms of CAP and PAP (or as we call it here TAP) belongs to Munksgaard & Pedersen (2001). As Bastianoni et al. (2004) point out, the literature on Ecological footprints (which are a consumption based measure) dates from 1996 with Wackernagel & Rees (1996).

counting principle (hereafter TAP) and the consumption accounting principle (CAP).

Under the territorial accounting principle “the producer is responsible for the CO_2 emissions from the production of energy, goods and services” (Munksgaard & Pedersen 2001, p328), while under the consumption accounting principle “the consumer is responsible for CO_2 emissions from the production of energy, goods and services” (Munksgaard & Pedersen 2001, p328). In terms of national emissions totals these two principles can suggest vastly different results. For instance in Munksgaard & Pedersen (2001) the TAP emissions total for Denmark was 63.4 million tonnes of CO_2 in 1994, while the CAP emissions total for the same year was 56.5 million tonnes of CO_2.

The TAP, when applied to national emissions, considers each country to be responsible for the emissions produced within their own territorial border. This includes all domestic production emissions and direct household emissions. Under the CAP, a country is responsible for the emissions embodied in their domestic consumption activities (i.e. consumption by domestic households, businesses and the government) which includes the emissions embodied in imports[5].

The extent of the difference between the TAP and CAP emissions total will depend on the size, sectoral composition and emissions content of domestic exports and imports. A subsequent paper (Bastianoni et al. 2004) points out that these two principles could lead to paradoxical results.

Take a country that does not make anything itself (perhaps only assembling already manufactured parts) and imports everything that it needs. Such a country could presage “a paradoxical situation of a high standard of living coupled with a very low level of GHG[6] emissions” (Bastianoni et al. 2004, p254). The converse (a country with a low standard of living and very high GHG

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[5] It should be noted here that both the TAP and CAP measures include the direct pollution generated by household activities (this includes household activities like driving cars, burning fuels at home etc). In this sense, both CAP and TAP measures agree that the emissions generated by the direct activity of a country’s households should be added to that country’s emissions total.

[6] GHG stands for green house gases. See `http://unfccc.int/ghg_data/ghg_data_unfccc/items/4146.php` for more on GHG’s.

emissions) is clearly possible as well: where a country serves an export market but has "to 'pay' for the CO_2 associated with something they will never benefit from" (Bastianoni et al. 2004, p254).

Now, the latter statement is not strictly true in the sense that the exporting country clearly does benefit in terms of income from selling the exported goods. This is one reason why the debate over TAP and CAP is contentious- which of the two trading partners should ultimately bear what share of the responsibility for the GHGs? Should it be the country benefiting from the use of the good or the country profiting from the sale of the good?

The recent Copenhagen and Durbin UN climate change summits, of 2009 and 2011 respectively, have demonstrated the difficulties that arise in securing a global climate change deal with binding targets for all nations. This includes reaching agreement on the accounting principle to use to calculate national emissions totals and hence assign a measure of responsibility to countries for a share of global pollution. Instead regional and national laws, as well as global agreements, choose their own accounting framework depending on the competing motives of those involved.

The fact that air pollution cannot be contained within national boundaries will always lend support to those arguing for a CAP perspective (often thought of in terms of a Carbon footprint) where the externality that is imposed by consumers of polluting goods is reflected in the national emissions total of those consumers, instead of on the country satisfying these consumption demands. A competing school of thought, those arguing for a TAP approach, will always be able to argue that since jurisdiction does not extend beyond national boundaries, neither can pollution abatement responsibility.

The TAP aligns with the responsibility of policymakers to affect production behaviour without having to address the domestic consumption behaviour that a CAP measure might require. Adopting a TAP measure sidesteps difficulties in the measurement of consumption emissions, political difficulty in achieving behaviour changes and the inability of any domestic government to affect the production processes underlying imported goods.

The difficulty in formulating rigorous CAP based measures (largely due to data issues) has made official applications sparse (a notable exception is the CAP calculation based on the domestic technology assumption (DTA) approach undertaken by Statistics Denmark (see Rueda-Cantuche & Amores (2010, p994)) and their utilisation as emissions targets nearly non-existent.

We noted earlier that to operationalise these measures using the currently available data, some assumptions need to be made. We will outline these assumptions shortly. We take a couple of different approaches to estimating a CAP emissions total. Some utilise only the domestic (Scottish) input-output model, while others also utilise the input-output model of one of the domestic (Scottish) economy's main trading partners (here we utilise a UK production structure as a proxy for the RUK production structure).

These approaches do not provide us with a complete emissions footprint, in the sense of identifying each trade flow (and the country specific production and pollution technologies) separately within the model. However by making these assumptions we obtain an insight into the emissions relationships embodied in our trading behaviour. Using this type of approach, carbon footprints have already been estimated for a number of countries.

The data requirements of a 'full' footprint measure are such that this measure is unlikely to be fully and 'ideally' operationalised. The closest that will probably ever be obtained will be based on approximations and assumptions to overcome data gaps, or will be done at a highly sectorally aggregated level[7]. Recent work to construct a world input-output database (`www.wiod.org`) may help in this regard, although the level of sectoral aggregation is currently unknown, it will cover the 27 EU countries and 13 other countries (it is due for public release in Summer 2012).

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[7] See (Miller & Blair 2009, p160) for more on the issues raised by the aggregation of input-output accounts.

2.2.1 Brief review of the literature on estimating consumption emissions

In order to produce estimates of national carbon footprints (sometimes indirectly by examining trade balances), without full interregional international databases, different approaches have so far been taken. Pan et al. (2008), for instance, examined the balance of emissions embodied in trade (BEET) for China. The BEET approach uses region specific economic and environmental data to estimate the emissions embodied in the bilateral trade between each pair of regions/countries to establish if the emissions embodied in a region or country's exports are greater than those embodied in its imports. Peters & Hertwich (2006) calculated a consumption based emissions total for Norway using an 8 region interregional input-output model to allow for regional variations in the production and pollution technology used to produce Norwegian imports.

Druckman & Jackson (2009) carried out an analysis for the UK using a quasi-multi region input-output model. Their approach was essentially to utilise domestic production technology and import weighted pollution technology to estimate the emissions embodied in imports (which is similar to what we do later in the DTA (OECD) case). They then use this approach to examine household responsibility for CO_2 emission (Druckman & Jackson 2009). Lenzen et al. (2004) used a multi region input-output (MRIO) model for 4 countries (Denmark, Germany, Sweden and Norway) and the ROW.

Mäenpää & Siikavirta (2007) looked at the Finnish case using different treatments for the emissions embodied in trade (including the use of proxy values for the emissions embodied in imports), as did Westin & Wadeskog (2002) for Sweden. Hertwich & Peters (2009) carried out a carbon footprint analysis encompassing 72 nations using the GTAP database (at a highly sectorally aggregated level). Finally, a regional carbon footprint was calculated for Wales (Turner et al. 2011b) using the same DTA approach used here.

Similarly there are papers that look at sub-national consumption driven carbon measures in multi-region models, e.g. McGregor et al. (2008) for Scotland and the RUK, and Ha et al. (2009) who looked at 6-region model of the USA (5 states and the rest of the USA). In addition, bespoke carbon footprints have been estimated for a range of other groups or institutions, for example: for representative households in Ireland (Kenny & Gray 2009), for the Scottish Parliament (Wiedmann & Minx 2007), for the American health care industry (Chung & Meltzer 2009), for the Internet (Baliga et al. n.d.) among many others.

The closest analysis for Scotland to the work that we undertake in this chapter has been carried out by a team of researchers at the University of Leeds, commissioned by the Scottish Government. The results of their estimates of Scotland's consumption emissions for the period 1998-2009 are available online[8] and have been since 30 Apr 2012. The difficulty in understanding the basis of these consumption emissions estimates is the absence of any particularly detailed documentation explaining the origins of these data.

A summary report is available[9], but even this 'methodological summary' is vague in certain key aspects. It is clear that the authors are undertaking some form of environmentally extended input-output analysis. It is clear that they have made some adjustment for the emissions embodied in trade. It is not clear what data are used in the calculation of these emissions. In the methodological summary document the authors suggest that their work is an update of earlier work undertaken by the Stockholm Environment Institute (SEI) for the Scottish Government estimating the GHG and Ecological footprint of Scotland between 1992-2006[10].

The SEI report shows that the methodology used in that analysis was a two region environmentally extended input-output model (UK and ROW), called REAP. It is clear that one of the 'innovations' of their model is estimating the final demand in a particular territorial area, in this application it is used to

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[8] `http://www.scotland.gov.uk/Resource/0039/00392289.xls`

[9] See: `http://www.scotland.gov.uk/Resource/0039/00392171.doc`

[10] The report they reference is available from: `http://www.scotland.gov.uk/Resource/Doc/289580/0088635.pdf`

estimate Scottish final demand. Why this is necessary when Scottish input-output data including Scottish sectoral final demand are available from 1998-2007 is unclear. Indeed, why a seemingly elaborate methodology is applied to generate UK input-output tables (based on a disaggregation of the Eurostat 2007 UK supply table and ONS supply tables for 1992-2006) rather than simply using the Scottish tables provided by the Scottish Government is not clear either.

The basis for their calculation of the ROW region in their model is work undertaken to construct a technical coefficients matrix in the Netherlands for 1997. This is based, at least in part, on the GTAP database. The interested reader is referred to the full SEI report for more information on their approach[11]. Reading the full technical details of the analysis it is clear that SEI researchers made significant data assumptions.

The authors note that they are able separately to identify Scotland within their model and thus create a three region environmentally extended input-output model, but that for cost reasons this has not been done. Most of the work in this model has been devoted to creating the 2 region (UK and ROW) input-output database and estimating Scottish final demand. As noted earlier it is unclear why this is the preferred route rather than using available Scottish data. Work has also gone in to estimating the emissions content of imports using a range of different data sources.

Our understanding of this research is that it is applying output-CO_2 multipliers to their estimates of Scottish final demand. Setting aside the estimation of the emissions intensity of imports from ROW, this is likely to prove quite problematic. As a simple example, there are sectors, for instance Tobacco, which do not exist in Scotland, but do in the UK. It is not clear whether, and indeed how, this type of issue is addressed in the SEI/University of Leeds model. The most recent University of Leeds technical summary[12], suggests that the SEI results have been updated in light of the 'recently available' supply and use tables

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[11] The report is, as noted earlier, available from `http://www.scotland.gov.uk/Resource/Doc/289580/0088635.pdf`.

[12] `http://www.scotland.gov.uk/Resource/0039/00392171.doc`.

for 1998-2007. It is not clear, however, whether they have incorporated these Scottish datasets into their two region model, or whether they have just used these data to provide Scottish final demand estimates.

Our guess, based on a reading of the University of Leeds technical summary accompanying these numbers, is that the latter approach has been followed. This again involves applying UK average production and pollution technology to Scottish consumption demand. The only Scottish-specific aspect of this analysis therefore is the inclusion of an estimate of direct household emissions in Scotland based on the Scottish Environmental Accounts[13].

We will see later in this chapter the impact that assuming a UK pollution intensity (or pollution technology) has on the emissions estimates we calculate for Scotland. This is a separate, but related, issue from applying a UK output-pollution multiplier as the University of Leeds researchers do, which will have its own impact on the total emissions estimates. The SEI and University of Leeds estimates are nonetheless the closest parallel to the work undertaken in this chapter. To summarise: the SEI/University of Leeds estimates use a more sectorally disaggregated approach than we do here and produce a time series of emissions estimates. In doing this they incorporate a seemingly more elaborate methodology for estimating the emissions embodied in imports from the rest of the world. They also utilise a UK-ROW multi-region input-output model which incorporates feedback effects between the UK and the ROW, but in which they apply UK pollution intensities to Scotland.

Our approach here uses Scottish specific economic data, including data on the sectoral composition of imports, as well as Scottish-specific environmental data for the largest polluting sector. This allows us to examine the impact of using Scottish versus UK environmental data, and implicitly to see whether the University of Leeds assumption of UK pollution technology for all sectors is important in obtaining their results. We also incorporate data from the OECD to allow us to examine differences in the pollution intensity of production in the

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[13] see: `http://www.scotland.gov.uk/Topics/Statistics/Browse/Economy/SNAP/expstats/EnvironmentalAccounts`

different regions/countries that Scotland imports from. We compare our results with the SEI/University of Leeds results later in this chapter.

Most of the studies listed in this section utilise input-output analysis as the framework under which they formulate their consumption based emissions measures. For reasons that will become clear in the next section, demand driven input-output models (modified into environmentally extended models) are ideally suited to this type of analysis. We shortly outline the two most frequently discussed input-output systems, the demand driven framework developed by Leontief (1951), and the supply driven system developed by Ghosh (1958). Before discussing the models in detail we outline the structure of the underlying input-output database in the next section.

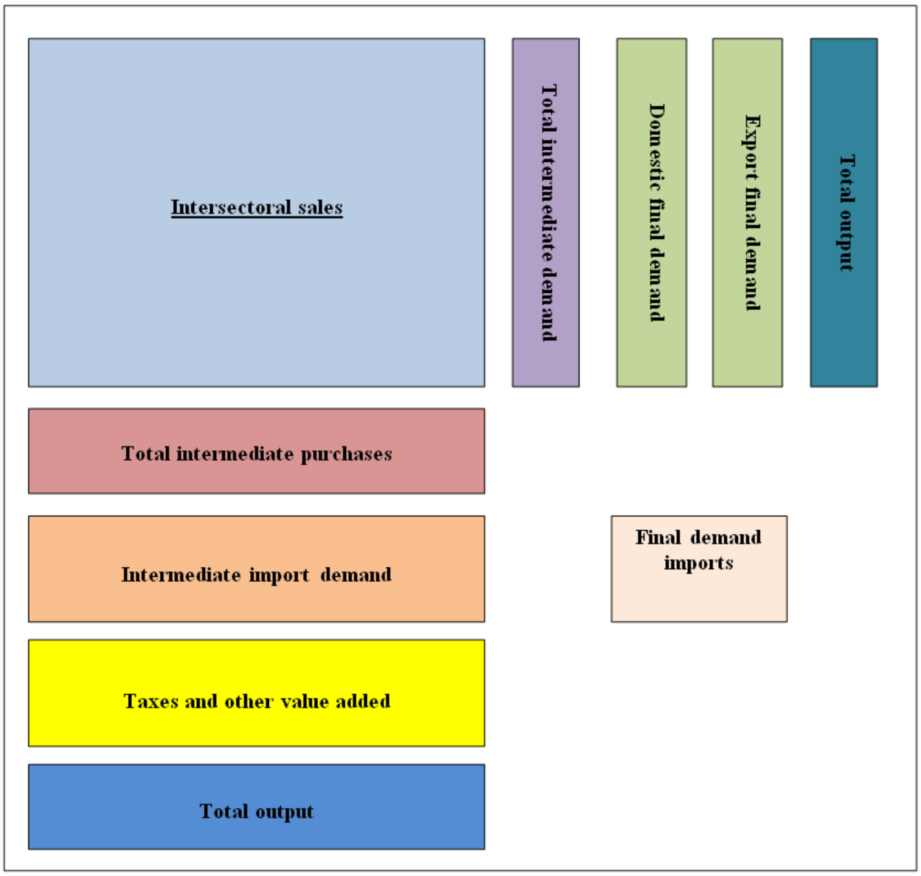
2.3 A brief outline of the input-output accounts

In this section we give a brief overview of the information in the input output accounts. We pay particular attention to what information is contained within these accounts, and any natural identities that exist. Figure 2.1 below provides a simple schematic of an input-output account.

The top left (intersectoral sales) portion of the input output accounts gives the intersectoral transactions (in the Scottish case these are in £million) between the n sectors of the economy. This is an n x n matrix. Each column contains the purchases by the corresponding column sector from each of the n row sectors. Similarly each row gives the intermediate sales of that row sector to each of the n column sectors. The red rectangle represents the total intermediate purchases of the n sectors, which is the sum of column entries for each sector; this is a 1 x n vector.

The rectangle below the 'total intermediate purchases' vector is labelled 'intermediate imports' (a 1 x n vector). This gives the value of sectoral imports (i.e. the total value of imports by each column sector). This may, depending on the database, be broken down by trading partner. In the Scottish input-output

Figure 2.1: Schematic of a single region input-output database



tables trade with the rest of the UK (RUK) and the rest of the world (ROW) are separately identified. This makes the intermediate import rectangle above a m x n matrix of m trading parters (2 in the Scottish case) by the n sectors. The rectangle to right of the 'intermediate imports' matrix is the matrix of final demand imports. This gives the value of imports by each p category of final demand, making this an m x p matrix.

The yellow rectangle is labelled 'taxes and other value added' (a k x n matrix where k represents the different categories of taxes and other value added). This matrix gives the value of taxes on sectoral output (product taxes) and the value of sectoral gross value added[14]. For each column sector, the sum of these three rectangles equals total sectoral output in the blue rectangle at the bottom. This represents the input side of these accounts.

The sum of the row entries of the intersectoral sales matrix for each sector equals total intermediate demands (the purple rectangle). The light green rectangle represents the final demands for each of the row sectors output. This traditionally includes demands from a number of different categories of final demand. In the Scottish case these categories are: household final demand, NPISH (not for profit institutions serving households), local government final demand, central government final demand, GFCF (gross fixed capital formation), valuables, changes in inventories, RUK export final demand and ROW export final demand.

The sum of each sectors' row entries of the intersectoral sales matrix (i.e. total intermediate demand for each sector) and each sectors final demand, **must** sum to total sectoral output in the final (turquoise) rectangle on the right (total output). Crucially, recalling that the name of this account is the input-output account, total sectoral output based on sectoral inputs (the blue rectangle) must equal total sectoral output based on sectoral output (the aqua rectangle). Put differently: the sum of each sector's purchases is equal to the sum of its sales. It is this simple account that forms the basis for both the demand and supply

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[14] This is broken down by payments to employees, payments to government (subsidies and non-product taxes) and gross operating surplus in the Scottish input-output tables.

driven input-output systems.

It is worth recognising, before we introduce both of these input-output models using matrix algebra, that each model considers different elements of the above database to be exogenous to the model. In the demand driven model final demand is taken to be exogenous, and final demand therefore 'drives' this model. In the supply driven model, 'value added' is kept exogenous and therefore 'drives' the supply driven model. In each model the treatment of the intermediate transactions matrix is different, these differences will now be outlined.

2.4 Different types of input-output system

Input-output models originated in the work of Wasilly Leontief in 1928 in a paper entitled 'Die Wirtschaft als Kreislauf' (Bjerkholt & Knell 2006) culminating in his work in the early 1950's which presented the input-output system in something like its present form. The application of these systems to economic problems goes back nearly as far (Bjerkholt & Knell 2006). It has been noted that some of the underlying ideas are even older (notably Francois Quesnay's 'Tableau Economique' (Rose 1995, p295)). The use of input-output models for economic analysis grew rapidly in popularity after the Second World War (Bjerkholt & Knell 2006).

The input-output database outlined in the previous section is taken, in constructing input-output models, to represent a static accounting general equilibrium framework for the specific economy and year that it covers. The purpose of this section is to outline, in full using standard matrix algebra notation, the two most popular input-output framework: the demand and supply driven models[15].

The demand driven input-output model was developed by Leontief (1951), and the supply driven model by Ghosh (1958), while the supply driven input-output model was subsequently reinterpreted by Dietzenbacher (1997)[16].

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[15] The other commonly discussed input-output model is the price model (see Miller & Blair (2009)).

[16] Appendix A discusses of the formulation of these and other common input-output systems based on symmetric input-output tables. These approaches generate input-output models

2.4.1 Demand driven input-output model

The intuition behind the demand driven input-output model is straightforward: production takes place to satisfy final demand. Exogenous final demands are in this sense 'driving' this production and this economic model. In addition, because the demand driven input-output model assumes an entirely passive supply side (no intermediate input, labour, capital etc constraints), it is often thought to be a model in keeping with the economic view of Keynes (Ferguson et al. 2005, p106). In this model, and the supply driven model we outline later, what is exogenous and what is endogenous is crucial.

It is worth stating at the outset that there are different formulations of both the demand and supply driven input-output models in terms of the transacting groups identified (sector or commodities). In this paper we focus on the industry by industry input-output system outlined in Miller & Blair (2009, p10-29). Appendix A contains an outline of the commodity based input-output systems as well as an overview of the construction of input-output models from the raw economic data using different technology assumptions. This information and these approaches have not been utilised to construct the models used in this paper, as we are fortunate to have officially produced symmetric industry-by-industry input-output tables for Scotland courtesy of the Scottish Government[17], however a detailed outline of the different approaches is included in Appendix A for completeness.

The basis of all input output models is a system of simultaneous equations (Miller & Blair 2009, Ten Raa 2005). These equations are the basis for the inputs to the matrix of technical coefficients that are needed to produce the workhorse of demand driven input-output analysis: the Leontief inverse. Using the raw economic data on sectoral purchases and sales as well as total sectoral

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from the raw supply and use tables by applying either the industry or commodity technology assumption. This covers the creation of symmetric input-output tables for the following specifications: industry by industry, industry by commodity, commodity by industry and commodity by commodity systems.

[17] Scottish input-output data are available from: `http://www.scotland.gov.uk/Topics/Statistics/Browse/Economy/Input-Output`

output, we can create the matrix of technical coefficients which are used to create the Leontief inverse.

We begin this section by showing how the basic input-output relationships (including ultimately the Leontief inverse) are derived from the series of simultaneous equations, we then discuss the assumptions of the input-output framework, and how they inform the interpretation of the model. Starting by examining a single equation characterising one sector of the economy (which follows directly from the identity in the schematic in Figure 2.1 above):

$$\mathrm{x_i = z_{i1} + ... + z_{ij} + Y_i = \sum_{j=1}^{n} z_{ij} + Y_i} \tag{2.1}$$

Here, x_i is the total output of sector i, z_{ij} is the total intermediate demand by sector j for the output of sector i, that is, the demand of sector j for the output of sector i as an input into their production process, and Y_i is the total final demand for the output of sector i. It is often the case that there are multiple categories of final demand, in which case we would have Y_{i1}, Y_{i2},..... Y_{ik} where there are k categories of final demand. It's worth making clear that final demand is the consumption of this sector's output, rather than the use of it which would be the intermediate demands.

In the single region case however, exports are considered to be final demands, although they may in fact be intermediate demands in the importing economy. In the interregional case where we can specify all imports and exports within the system by use, then these exports would be split between intermediate and final demand accordingly. Equation 2.1 states that the output of each sector x_i, is split in this set of accounts, between the demand for this output by each of the other n sectors (including their own intra-sectoral demands), and the demands by the final consumers (which normally include both public and private sector consumers).

There are both exogenous (i.e. outside the model) and endogenous (originating within the model) determinants of total sectoral output. Equation 2.1

recognises the endogenous determinant of total sectoral output in the demand driven model. Equation 2.1 shows that the output of a particular sector i depends upon the demand for its output from each of the other n sectors (again including any intra-sectoral demands), which is also related to the level of demand for the output of the other n sectors (Miller & Blair 2009, p11). This relationship is crucial to the understanding of the concept of intermediate demands in an input-output framework.

It is worth noting that in terms of the exogenous determinants of sectoral output, Miller & Blair (2009) describe how the level of final demand for the output of a particular sector is often related to changes out with the production process. In other words changes in the output of any of the sectors in the model economy can be exogenous to the system. This is something which is interesting, although not important for our modelling work here. For the interested reader, Miller & Blair (2009, p11) provide a couple of examples of these exogenous determinants.

It is worthwhile pausing at this stage to consider one of the assumptions that is implicit in the implementation of Equation 2.1- the assumption of homogeneous sectoral output. While this assumption is not required by Equation 2.1, it is invoked by the practical use of this equation since we must use aggregated sectoral level data for such a model to be tractable[18]. We discuss later the other assumptions that are involved in demand driven input-output systems, and restrict ourselves to outlining the homogeneous output assumption here.

The assumption that each sector produces one homogeneous good means, in effect, that we assume that each sector is homogeneous and thus that each firm is identical (or at least has an identical input structure), and that each firm has an identical composition of inputs and outputs. The realism of this assumption is open to question, and will depend upon the nature of the sector itself, and from the perspective of input-output methods, it will also depend upon the degree

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[18] Equation 2.1 requires that the output of industry i can be meaningfully and consistently measured, this implicitly requires that the output of every firm in that sector can be aggregated into a homogeneous measure. Thus we require consistent units (value, weight etc).

of sectoral aggregation in the database (the higher the level of aggregation the more difficult this assumption becomes to sustain). The assumption that each sector produces a single homogeneous product also provides some interpretive headaches when we consider the intra sectoral transactions- this is a point that we take up later in this paper.

Taking the single equation approach and replicating it for the whole economy.

The underlying intuition behind the demand driven monetary input-output system is straightforward. Each sector[19] within the economy produces output, but does so using inputs from other sectors in the economy. Similarly each sector's output will be used as an input by the other sectors in the economy including itself. Thus we have a simple economic supply chain framework. The usefulness of the input-output system that Leontief developed is that all of these flows can be easily shown within the framework and the interdependence of the economy and each individual sector, measured.

If we now replicate Equation 2.1 n times for each of the n sectors of the economy, we get:

$$\begin{bmatrix} x_1 & = & z_{11} & \dots & z_{1n} & + & y_1 \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots \\ x_n & = & z_{n1} & \dots & z_{nn} & + & y_n \end{bmatrix} = \sum_{\forall i,j} z_{ij} + Y_i \tag{2.2}$$

Or in matrix notation, where i is a vector of 1's, Z is an n x n matrix of intersectoral transactions, and x and y are n x 1 vectors representing total sectoral output and total sectoral final demand respectively, we get:

$$\mathrm{X} = \mathrm{Zi} + \mathrm{Y} \tag{2.3}$$

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[19] There is a standardised system for the classification of industries within the economy which is used in the construction of the input-output tables, see: `http://www.statistics.gov.uk/methods_quality/sic/downloads/SIC2007explanatorynotes.pdf` for more information on the United Kingdom Standard Industrial Classification of Economic Activities (SIC), which are consistent with EU and UN methodologies.

This can be represented as an accounting procedure. Defining the average coefficient as: $a_{ij} = \frac{z_{ij}}{X_j}$, the matrix of these coefficients, A, is:

$$A = \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{bmatrix} \tag{2.4}$$

This allows us to replace Zi in Equation 2.3 with A.X, producing Equation 2.5:

$$\mathrm{X} = \mathrm{A.X} + \mathrm{Y} \tag{2.5}$$

Subtracting A.X from both sides of Equation 2.5, it is thus easy to see how we can obtain:

$$(I - A).X = Y \tag{2.6}$$

Pre-multiplying both sides of Equation 2.6 by $(I - A)^{-1}$ we arrive at the standard demand driven input-output model relationships:

$$X = (I - A)^{-1}.Y$$

and

$$\Delta X = (I - A)^{-1}.\Delta Y \tag{2.7}$$

Note, that in order to derive the second identity in Equation 2.7 we must assume fixed production coefficients[20]. Therefore, total sectoral output of the economy **X**, can be (by matrix multiplication) attributed to the k categories of final demand, **Y**, assuming that **A** is fixed. This means that any change in sectoral output **X**, derived through a change in sectoral final demand **Y**, is assumed to occur using a fixed proportion or Leontief production function.

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[20] The distinction here between these two equations is that the first is an accounting identity, whereas the second is a modelling identity. In order to derive the modelling identity, and therefore consider economic changes, we have to assume that production is characterised by Leontief 'fixed proportion' production function.

Recall that the **A** matrix here is the input coefficient matrix based on the intersectoral transactions matrix **Z**. Each column of the **A** matrix represents each sector's supply chain (purchases from the other sectors) as a proportion of its total output. The assumption of a fixed proportion production function is an essential component of our application of the demand driven input-output system, later in this chapter, to generate the consumption driven pollution totals. While we need not assume anything about the structure of production in treating the input-output data as a set of accounts, for any kind of modelling work this assumption is crucial.

Earlier we examined the assumptions inherent in the single equation on which demand driven input-output models are based, we now discuss the assumptions that we are making in converting this series of equations into the demand driven input-output system. Gerking (1976) (echoing Chenery & Clark (1959, p33)) list three principle assumptions involved in using these input-output systems:

1. The economy can be meaningfully divided into a finite number of sectors, each of which produces a single homogeneous product
2. There are neither economies nor diseconomies of scale in production
3. The level of output in each sector uniquely determines the quantity of each input which is purchased

The first assumption here is that each sector 1, ..., n, produces one homogeneous good, or alternatively as we noted earlier, that it produces different goods using an identical input mix. Further to this, it is important to note that there is an implicit assumption here that each economic sector is essentially comprised of homogeneous firms, or at least that their production techniques are identical. Where this becomes important is when the input-output system is used for economic modelling analysis, particularly at the regional level.

Paradoxically perhaps, this assumption appears to be more reasonable where the subject economy is larger and more diverse. The reason being that, in a broader and larger economy, this assumption (of homogeneous firms within each sector) may be considered a weaker assumption owing to the reduced probability that industries are missing from any sector. A broader economy therefore lessens the chance that the average sectoral production and pollution technology assumptions (which are vital in many analyses) will be biased in impact studies- this is a point that we will pick up again later in this paper. Although we note here that it is trivially true that if we had a very small economy where each firm was itself represented as an industry in an input-output system that the conclusion that a broader economy made this assumption more realistic, would cease to be the case.

The second assumption, noted by Gerking (1976), is that the demand driven input-output model assumes that the subject economy is characterised by Leontief 'fixed proportion' production functions, (Ghosh (1958), (Miller & Blair 2009, p15-19)). In essence this allows for a homothetic transformation of the production function to satisfy any level of sectoral final demand. In other words the same fundamental production function is assumed to be used to satisfy any level of final demand. It is this assumption which underpins the use of demand driven input-output models for modelling exercises. This assumption rules out, for example, economies adapting their production functions in the face of a demand expansion to take advantage of economies of scale (although the Leontief production function itself may embody existing economies of scale)[21].

To consider why we must assume constant returns to scale technologies, consider that if (in an input-output model context) sectors were allowed to take advantage of economies of scale in the face of a demand expansion, this would imply that the input coefficients were changing. Given that we assume that the input coefficients are fixed in input-output models, we must assumes that the input-output production function is characterised by constant returns to scale technologies (Miller & Blair 2009, p16). Chenery & Clark (1959) produce

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[21] In other words, to the extent that the raw data is reflective of economies of scale operating within sectors in the economy, these will be reflected in the fixed proportion Leontief production relationships assumed by this model.

an elegant summary of the implications of this assumption which we cannot improve upon and therefore reproduce here. They argue that this assumption implies:

1. "...that all inputs are uniformly affected by a change in the scale of production, thus ignoring the...distinction between fixed and variable inputs and between short and long run..." (Chenery & Clark 1959, p157)
2. "...that industries can be classified sufficiently finely to eliminate multi-product industries whose input structures would be affected by changes in the product-mix of their outputs" (Chenery & Clark 1959, p158)
3. "...that economizing substitutions among inputs due to changes in relative prices or availabilities are of negligible importance" (Chenery & Clark 1959, p158)
4. "...that technological changes in input structures are sufficiently rare and slow that they can be either disregarded or adjusted for in simple fashion" (Chenery & Clark 1959, p158)

We are unable to improve upon this summary, except to say that for our purposes here, where we are engaged primarily in an accounting exercise, these assumptions and their implications are not critical. We discuss what we mean by an "accounting exercise" shortly. For modelling exercises within the input-output system these assumptions do come to the fore and have to be borne in mind in the analysis of the model results. The third assumption from Gerking (1976) follows from the second assumption and the structure of the input-output tables. This assumption is also known as the assumption of fixed input-coefficients, and means that we assume that the column elements of the A matrix (i.e. the purchases from each of the other sectors as a proportion of the column sectors total output) are fixed, an assumption of which Ghosh (1958, p58) was critical and which resulted in him formulating the supply driven input-output model.

As a consequence of assumptions two and three of Gerking (1976) is should be noted that the demand driven input-output model, in estimating the impact of changes in output, implicitly assumes that there are no supply side frictions, i.e. it assumes that there are no scarce inputs whether they be ‘produced inputs’ (i.e. the output of other sectors) or ‘non produced’ inputs like labour, at the prevailing price (Ghosh 1958, p58).

In practice, there are often a number of frictions or barriers to changes in supply which the demand driven input-output model assumes do not exist. Ghosh (1958) makes a similar point, arguing “that there are various alternative technical combinations (production functions) in any economy and under different market situations different combinations are actually taken up” (Ghosh 1958, p58). It is, in part, for this reason that demand driven input-output models are considered to provide a better long-run than short run perspective on economic change.

As a final note, we should also bear in mind that an input-output system is based on a snapshot of the subject economy for the year in question, and as such is not necessarily generalisable in the sense of representing any constant production function for the subject economy. The production relationships embodied in the demand driven input-output system could change markedly from one year to another as, for example, major producers relocate abroad, or as may be the case in Scotland if a major ship building contract either begins or ends.

There has been little recent work in this area, but there is some older relevant work including Chenery & Clark (1959). They examined the issue of coefficient stability from two directions; one approach being to examine the time series of input coefficients to determine their stability over time, and the other was to compare the results of modelling exercises undertaken with successive year’s input-output accounts. The former approach (despite incurring serious challenges on account of statistical and data difficulties (Chenery & Clark 1959, p159)) was used by Leontief (1953).

Chenery & Clark (1959, p159) report that while Leontief’s analysis lacked statistical objectivity (in the sense that it lacked a statistical test), it nonetheless resulted in the clear conclusion that the input-coefficients in the US tables for 1919, 1929 and 1939 demonstrated little stability. As Chenery & Clark (1959, p160) report a later study using Japanese data for 1951 and 1954 took the same approach as Leontief (1953) and provided some evidence of a degree of stability (again with no objective statistical measure to rely on) in the input coefficients. Chenery & Clark suggest that this conclusion may well be due to the narrow time lag between the years that are being compared. In the end Chenery & Clark (1959) cannot find conclusive evidence of stability in the input coefficients from studies which examined the coefficients directly.

Chenery & Clark (1959) also report on a series of studies which sought to compare the results of an input-output projection of sectoral output, calculated on the basis of given sectoral final demands, with previously known (or naively estimated) sectoral output totals. Again though, the authors ran into the difficulty of not having an objective test and standard against which to measure the coefficient (in)stability. Chenery & Clark (1959) report on one study which pursued this approach (by Hoffenberg), which found that input-output projections were more reliable than naive projections in estimating output for those sectors which sold mostly to intermediate rather than final demand, but that they became less reliable the further from the base year the projections were made (Chenery & Clark 1959, p167).

That this is so, suggests a degree of instability of the input coefficients over longer time periods, but perhaps (plausibly) less so over shorter horizons. Field (1986) reviews a number of studies looking at changes in the input coefficients and finds mixed results, some studies seem to suggest at least a degree of constancy while others reject it entirely.

Another study that addressed the issue of the stability of the input-output production function over time was McGilvray (1964) who examined this issue for the case of Ireland. According to McGilvray (1964) there are three principle sources of instability in the technical coefficients of the demand driven input-output model (as components of the Leontief production function):

1. Aggregation
2. Non-linearity in production functions[22]
3. Technical change in production methods[23]

Point 1 here is a reference to the assumption discussed earlier about homogeneous sectoral output, clearly the more varied the actual output (in other words what firms in each sector are actually producing) the less stable the underlying sectoral relationships. It is not hard to imagine that a sector that, in reality, is made up of many diverse producers and output would have an input mix that was considerably more volatile than would be the case where the output of the firms classed in the sector was in reality more homogeneous.

Thus the greater the degree of aggregation in the model the greater the chance that the composition of firms in each sector will be more varied in terms of its true output and thus varied in terms of its input mix- therefore more unstable (McGilvray 1964, p50). The counter-argument here is that larger sectors would perhaps be less affected by economic shocks than smaller sectors, and thus this would suggest a greater degree of stability in sectoral input and output patterns.

In using these models for modelling work, there are two things that are important. The first is the stability or otherwise of the input coefficients (in other words the stability of the supply chain of the focus sector). The second is whether the actual response to a change in demand can truly be characterised by the sectoral average technology that the demand driven input-output model claims.

The first issue is one that can be empirically tested, and conclusions drawn about the actual stability of these coefficients over time, as McGilvray (1964)

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[22] This could be as a result of substitution over time between inputs, following changes in input prices.

[23] Another candidate source of instability could be changes in prices, where changes in prices alter the relative value of inputs in total output. In this case, with no changes in the physical quantities of inputs, there would be changes in relative value of intermediate inputs in total output.

did. The second issue meanwhile, is left to the modeller, using this model to quantify the economy wide response to a demand stimulus, to consider and justify ex-post. Neither of these issues, the stability of the coefficients or whether average technology assumptions are important, raise concerns in the use of this model for the kind of single period analysis work that we undertake in this chapter.

McGilvray's (1964) second point above refers to the assumption in demand driven input-output models that relates inputs to outputs in a linear manner. This, as we already noted, rules out anything other than a constant returns to scale production function, and takes no account of "the law of diminishing returns" (McGilvray 1964, p50), which McGilvray suggests requires a marginal rather than average input coefficient approach.

If the true underlying production function is not characterised by linearity, and instead there are increasing returns to scale or diminishing returns, we would expect the input-coefficients to be unstable over time. In terms of marginal versus average change, this is an important issue. The assumption that average and marginal change are essentially the same in input-output impact analyses is a required, if perhaps not always plausible, assumption. However, again this is less of an issue in our work here since we are focused on accounting rather than modelling work using the demand driven input-output system.

McGilvray's (1964) third point here is that, since the input-coefficients represent the production technology in this model, any change in these coefficients (or instability) could be the result of actual technological change, which if observed or expected could be allowed for by way of an adjustment in the coefficient, but more generally it would urge against the use of input-output models for any longer term forecasting exercises (McGilvray 1964). One alternative which might get round this for long term forecasts would be to build changes in the coefficients into the analysis. However, this is well outside the scope of the work here. Nonetheless McGilvrey's three points are of interest in using this model. In summary, while there is little up-to-date work on the stability of input-coefficients anywhere, fresh work in this area would certainly be of interest, particularly as it relates to the underlying production function in the input-output model of Scotland[24].

Several references have been made in this section to the distinction between using the input-output system for an accounting rather than modelling analysis. The distinction lies in whether we are seeking to take the core model, calibrated using the base year data, and to ask that model a 'what if' type question. For instance if we were seeking to estimate the size of the economy wide expansion that would result from an increase in the final demand of the construction sector of £100m, we would require the input-output model to address this question. The way that the demand driven input-output system works means that we can also use it to find out the output that is directly and indirectly supported by the final demand of each sector- or in other words we can attribute domestic economic activity to the final demand that is supporting it.

Now, if we assume a linear relationship between sectoral output and sectoral pollution then we can also use this demand driven model to attribute this pollution to the final demand supporting it. Because this exercise simply uses the relationships of the input-output system to attribute pollution to final demand (and we do not alter the fundamental relationships which stem from the raw data) we call this exercise an accounting analysis as we are not transforming the underlying data.

2.4.2 Supply driven input-output model

The supply driven input-output framework began with the work of Ghosh (1958) who motivated the model with reference to the case of monopolistic suppliers of scarce output, and its potential implications for centrally planned economies[25].

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[24] As an aside, its worth noting that while there is little research on the stability of the input coefficients there has been considerable work on testing the joint stability of the demand driven input-output model (input coefficients) and its supply driven equivalent (output coefficients), see (Oosterhaven 1988, p205-208) for a fuller discussion of this issue.

[25] Park (2007) produces an alternative motivation for the Ghosh model in the context of a major terrorist attack or other major disaster. Park (2007) argues that the presence of imperfect information and market power act to prevent short run shocks from immediately

The idea is simple: the output relationships (i.e. the destination for sectoral output) are taken to be fixed. This contrasts with the demand driven model we discussed earlier where the input relationships (sectoral supply chains) were taken to be fixed. Value added (also referred to as non-produced inputs) are exogenous in the supply driven model, whereas it is final demand that is exogenous in the demand driven model.

In the supply driven model any changes in supply (as a result of an increase in factor supplies) are taken to generate proportionate sales of output to the n sectors of the economy. This means that each £million of primary factor inputs (represented by payments to factors in our system as 'value added') supports a particular level of output. Total sectoral output is taken to vary depending only on the level of value added and the distribution of sales of output. Since Ghosh (1958) a significant amount of work has gone into reinterpreting this model to address some notable criticisms of its original interpretation. Some concerns about the Ghosh motivation for the supply driven input-output system originated in the work of Frank Giarratani and also Jan Oosterhaven in the early 1980's (Miller & Blair 2009, p548).

The thrust of Giarratani's (1981) argument was that the motivation based on a centrally planned economy allocating supplies of productive factors across the sectors of the economy was unrealistic. Girrantani's alternative was based on firms, faced with a 'disruption' to the supply of some basic commodity, seeking to sustain their existing markets "by allocating available product on the basis of deliveries in more normal times" (Miller & Blair 2009, p549). This interpretation seems to be almost more unrealistic, based on a hypothetically chaotic scene where the economy is facing random, persistent and unexpected shocks to factor

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affecting producers output, argues that in the period immediately following a major disaster or terrorist attack, existing technical relationships and output levels would be maintained (Park 2007, p14). In such a circumstance he argues that the original Ghosh input-output model would be of use. This mimics in part the motivation of Giarratani (1981) who suggested that firms which experience a sudden disruption to their production activities may in the absence of fuller information, attempt to maintain their market share by allocating their output based on historical relationships. The motivation provided by Park (2007) is interesting if not convincing, and while his proposed motivation is imaginable, I am not convinced that it resurrects the original Ghosh model in any generally useful way.

supply unimaginable in most economies, in the developed world at least. Firms are suggested by this interpretation to be living in an anarchic economy, but in this context they are said to act with regularity and restraint and allocate their product on a previously established basis, rather than adapting in any way to the chaos around them.

Given the problems with the existing motivations for the supply driven model, there has been a significant effort in recent years to redefine the Ghosh model to give it an entirely different motivation, largely due to the work of Oosterhaven (1980, 1988, 1989, 1996) and Dietzenbacher (1989, 1997). The nub of the problem that these authors addressed was that in the supply driven model, increases in factor inputs in sector j (capital, labour etc) result in increases in output in all sectors which depend on the output of sector j- but without any increase in other inputs to those sectors (Miller & Blair 2009, p549). In other words, these sectors are now assumed to be delivering a higher output level with the same input level (with the exception of the increased amount of sector j's output that it uses).

Put simply this means that if there is an increase in factor inputs in the steel sector, this results in an increase in steel consumption in the car industry, and an increase in total output of the car industry with no corresponding increase in the other inputs to the car industry. Oosterhaven (1988) summarises the situation well: "this means [assuming] that local consumption or investment reacts perfectly to any change in supply and that purchases are made, e.g., of cars without gas and factories without machines" (Oosterhaven 1988, p207). This is an implausible situation, resting as it does on the abandonment of a constant production function, with the production function admitting of perfect substitutability in production[26].

We mentioned in passing earlier that various studies had attempted to test the joint stability of the Leontief and Ghoshian models, specifically the fixed input and fixed output coefficients. This is important because, as Miller & Blair

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[26] Perfect substitutability in production is more common (and reasonable) in other contexts, for example in growth accounting work.

(2009, p549) show, the assumption of fixed input-coefficients in the demand driven model necessitates that the Ghoshian inverse is non-constant through the impact. Known as the joint stability problem, it is almost universally the case that in using either the Leontief or Ghoshian inverses for an impact analysis, the inverse that is not used, is not constant through the analysis (Miller & Blair 2009, p551).

In summary, the problem here is that if we assume fixed input-coefficients in the A matrix, created from the transactions matrix Z_0 and then use this matrix to formulate a demand driven input-output system to carry out an impact analysis, then having carried out the impact analysis if we recreate the transactions matrix Z_1 and use this new transaction matrix to create the output coefficients matrix B_1, it will not be the same as the output coefficient matrix B_0 that we would have created using Z_0; in other words $B_0 \neq B_1$.

Miller & Blair (2009) outline the specific conditions under which they are constant during the modelling exercise, however they note that studies have concluded that this instability in and of itself, is not a major problem in empirical applications (Miller & Blair 2009, p551). This is because the decision about which model to use, and the results of whatever model are chosen, are not affected by the joint stability problem.

The joint stability problem was another inconsistency that led in part to the reinterpretation of the Ghosh model as a price input-output model- a move that blunted many of the previously laid criticisms of it. Before discussing the models reinterpretation, we will outline the model fully using traditional matrix notation. After the model has been outlined, we discuss the assumptions, interpretation and motivation (based on the reinterpretation) for this approach in more detail.

In broad terms the supply driven input-output system is based on a similar series of equations to the demand driven system, but some components are redefined. For example, in place of the production function in the demand driven model, in the Ghoshian supply-driven model there is an 'allocation' function.

Instead of final demand, the exogenous component in the demand driven model, driving the model, the supply driven model is driven by primary inputs or value added which are exogenous. However, Ghosh (1958) retains a number of key features of the demand driven modelling approach, for instance he uses the same database that is used in the demand driven case (no additional information is needed).

Further, we continue to make the assumption of linear relationships between key variables, and finally we again rely on the notion of a set of exogenous variables (here value added) driving a set of endogenous variables. In terms of the mechanics of this model, we begin by recognising that like the demand driven system, the supply driven model has its origins as a series of simultaneous equations, we begin with the corollary of Equation 2.1.

$$\mathrm{x_j{=}z_{j1}{+}\cdots{+}z_{ji}{+}\cdots{+}z_{jn}{+}v_j{=}\sum_{j=1}^{n}Z_{ji}{+}v_j} \tag{2.8}$$

Where **X** and **Z** are as defined previously and **V** here represents gross value added. Sectoral output here is the sum of the sector's purchases, as opposed to (as in the demand driven model) sectoral sales. The corollary of Equation 2.2 is:

$$\begin{bmatrix} x_1 & = & z_{11} & \dots & z_{n1} & + & v_1 \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots \\ x_n & = & z_{1n} & \dots & z_{nn} & + & v_n \end{bmatrix} = \sum_{\forall j,i=1}^{n} z_{ij} + V_j \tag{2.9}$$

The corollary of Equation 2.3 is:

$$X' = I'Z + V \tag{2.10}$$

In Equation 2.10 the prime after the summation vector (**I**) denotes a transposed vector. The inclusion of the transposed I vector here sums the multiplicand matrix Z down its columns rather than along their rows, making it consistent with Equations 2.8 and 2.9 above. Intuitively, what we are doing in the supply driven system is transposing the entire system so that we sum down the columns of the key matrices. This gives us an accounting framework where total output for each sector is the sum of the total intermediate purchases by that sector (as opposed to the total intermediate sales of that sector to each of the other sectors in the demand driven system) and the total value added in each sector. Similarly, in constituting the supply driven input-output system, we take Equation 2.10 and following (Miller & Blair 2009, p543-544) we define a new matrix **B**, where each element b_{ij}, referred to in the literature as an 'allocation coefficient' (Miller & Blair 2009, p543), is given by:

$$\mathrm{b_{ij}}=\frac{\mathrm{z_{ij}}}{\mathrm{X_i}}$$

b_{ij} is the sales of sector i's output to sector j, as a proportion of total sector i output. These are known as the output (or allocation) coefficients in the supply driven input-output model.

The matrix **B** is defined as:

$$B = \begin{bmatrix} b_{11} & \cdots & b_{1n} \\ \vdots & \ddots & \vdots \\ b_{n1} & \cdots & b_{nn} \end{bmatrix} \tag{2.11}$$

Substituting **X'B** for **I'Z** in Equation 2.10, we get $X' = X'B + V$ and therefore $X'.(I - B) = V$, and $X = (I - B)^{-1}.V'$. For notational convenience from this point on we drop the transposed notation and denote this accounting identity by:

$$\mathbf{X} = (\mathbf{I} - \mathbf{B})^{\mathbf{-1}}.\mathbf{V} \tag{2.12}$$

So in this case all output **X** can be shown to be attributable to each of the categories **V** of value added. From an accounting perspective these identities explain how we can relate total output generation to the value added that stimulates it. If we want to consider using this framework for a modelling exercise, we would denote it as:

$$\mathbf{\Delta X} = (\mathbf{I} - \mathbf{B}')^{\mathbf{-1}}.\mathbf{\Delta V} \tag{2.13}$$

Here we can look at the change in sectoral output that would result from a change in primary factor inputs. Thus in the supply driven input-output model, total output in the economy is essentially determined as a function of value added **V** assuming fixed output coefficients **B**. Each element g_{ij} of the Ghoshian inverse $G = (I - B)^{-1}$ is taken (using the classic interpretation of the model) to represent the impact on the output of sector j of a 1 unit increase in the availability of primary input factors to sector i (Miller & Blair 2009, p545). So a 1 unit increase in the supply of primary inputs to sector i will result in a g_{ij} increase in the output of sector j, as increases in factor inputs result in increased supply of sector i output which via fixed output coefficients results in an increase in the output of sector j.

According to the original interpretation this model allows you to examine, from a given level of 'national income' (taken to be the sum of payments to labour, capital and other factors), what the likely allocation pattern across the different sectors will be (Ghosh 1958, p61). This means that in the supply driven framework we have increases in sectoral output (driven by increases in sectoral value added) spread in fixed proportions across the sectors demanding the sectoral output of those sectors which have increased primary factor supplies. This contrast with the demand driven framework where any increase in demand for a particular sector's output, results in increased demand from that sector for the output of the other sector's in the economy to be used as an intermediate input, on a fixed proportion basis.

We noted earlier that there had been some convincing criticisms of this original interpretation of the supply driven Ghoshian model, and that it had been reinterpreted in a much more convincing manner as a price input-output model. This reinterpretation was based primarily on the work of Oosterhaven (1980, 1988, 1989, 1996) and Dietzenbacher (1989, 1997). An interesting review article on the supply driven model is De Mesnard (2009). Oosterhaven (1988) raised concerns about the use of the supply driven input-output system for economic modelling. While he did not dispute the use of the model for descriptive analysis using forward linkage techniques, he did strongly criticise the 'straightforward' use of the model for analysing economic impacts where scant regard is given to its "highly implausible economic implications" (Oosterhaven 1988, p204). Oosterhaven summarised the principal implausibilities as:

1. Perfectly elastic demand.
2. Input ratios vary arbitrarily, depending upon the supply of inputs- implying a rejection of the core idea of a production function.

The first response to Oosterhaven (1988) was by Gruver (1989) who showed that there is a production function consistent with input ratios varying in the manner that Oosterhaven described. Essentially Gruver (1989) derives a production function characterised by perfect substitutability of all inputs, as contrasts with the Leontief assumption of no substitutability between inputs, since all inputs are required in fixed proportions.

Gruver (1989) concedes that the assumption of perfect substitutability is not realistic when we are considering the economic impact of a large change, but importantly he suggests that his approach holds as an approximation of the effect of cost minimising behaviour when we are considering the impact of a very small economic change (Gruver 1989, p449). Rose & Allison (1989) also responded to Oosterhaven's critique of the supply driven input-output model, but as Oosterhaven (1989) notes they left the main thrust of his earlier attack intact.

The principal difference that remained was over whether the changes in the input-ratios as a result of the impact analysis were more reasonable at a smaller scale using the Gruver (1989) approach, as Rose & Allison (1989) argue, than at a larger scale. Oosterhaven (1989) concedes that Rose & Allison (1989) in employing the Gruver (1989) method have managed to create a version of the framework that 'mechanically' prevented the input coefficients from changing in the problematic way, but that they did so in such a way as to add to the 'theoretical ambiguity' Oosterhaven (1989, p459). This was as far as the debate had got until the important contributions of Oosterhaven (1996) who compared the price and quantity versions of the demand and supply driven models, and Dietzenbacher (1997) who reinterpreted the Ghoshian monetary model as a price input-output model, addressing most of the previous criticisms.

The basic idea behind this reinterpretation is that instead of changes in the quantity of primary inputs available to sector i, resulting in the increased output of sector i and the increased output of all sectors that use output from sector i as an input, we instead have changes in the price of primary inputs, driving changes in the value of sector i's output, which drives changes in the value of the output of the other sectors that use the output of sector i as an input into their production process (Dietzenbacher 1997, p630-634) . Further Dietzenbacher shows that the Leontief price model and Ghosh supply driven models are essentially identical.

The notation of the supply driven input-output model does not change under this re-interpretation; all that changes is the interpretation of the model. What (Dietzenbacher 1997) shows is that, using this new interpretation of the supply driven input-output model we can examine the effect of an exogenous cost-push. In addition he argues that in spite of this reinterpretation, the usefulness of the Ghosh model in constructing forward linkage measures is maintained, giving us a plausible interpretation of the row sums of the Ghoshian inverse (Dietzenbacher 1997). Dietzenbacher ends by concluding that we get little additional information from using the supply driven framework as a price model over the Leontief price model, except for gains in tractability and interpretability. However, the usefulness of this model for the construction of forward linkage measures is still intact, and indeed strengthened by this reinterpretation. This will be important in the next chapter. So what is the price reinterpretation of the supply driven input-output model?

Each element b_{ij} of the output coefficients matrix B could now be interpreted as expressing: "the dollar increase of the output value of sector j-as caused by simultaneous price increases-necessary for an increase of the value added in sector i by one dollar" (Dietzenbacher 1997, p637). While each row of the Ghoshian inverse $(I-B)^{-1}$ could now be interpreted as expressing: "the amount of dollars by which the output value of all sectors together is to be increased, due to a one dollar increase in the value added of sector i" (Dietzenbacher 1997, p638). This ease of interpretation perhaps suggest an advantage that the supply driven price model has over its demand driven counterpart, since they have been shown to be identical. In any case, the outline of the supply driven model here has been necessary to establish a reference point against which both the selection of the demand driven model for our attribution work in this chapter and the use of various linkage measures in the next chapter can be viewed.

For the remainder of this chapter we will only consider the case of the demand driven monetary input-output system and any references to input-output systems, except where explicitly stated, should be taken as references to this type of input-output framework. The use of the demand driven input-output model in this paper is motivated by the ability it gives us to examine the underlying pattern of sectoral final demand that drives sectoral emissions generation. Recall that the input mix (production function) is constant in the Leontief demand driven input-output model, whereas as we just saw the supply driven model is inconsistent with any production function other than one characterised by perfect substitutes.

Both of these embody extreme views about the production function, one with no substitutability (Leontief) and one with perfect substitutability (Ghoshian). If we are to apply sectoral output-pollution coefficients (or output-employment coefficients or output-energy coefficients) then we are assuming that there is a linear relationship between a sector's output and the pollution it generates. This is violated in the presence of a production function characterised by inputs being perfect substitutes, but is maintained in the presence of a production function characterised by fixed input ratios as is the case in the demand driven input-output model. The demand driven model is the only input-output model consistent with the use of fixed direct sectoral output intensities[27].

To see this, note that the accounting identity in Equation 2.12 shows that sectoral output **X** can be attributed to sectoral value added **V** using the Ghoshian inverse **G** (or $(I - B)^{-1}$). Using the Ghoshian inverse for accounting however maintains the integrity of the underlying data and is not subject to the criticism of assuming an allocation function with perfect substitutes, since in this special case we have an allocation function arising from the relationships given by the core data. **X**, **V** and **G** are all given by the raw data and algebraic identities.

When we use this system for modelling work using Equation 2.13, we are no longer able to rely on this particular view of the allocation function. So whereas in the accounting case we can relate sectoral factors like pollution to sectoral output **X**, and because we are only attributing this pollution using fixed quantities there is no difficulty in such an exercise, we cannot relate these factors to output in the modelling case, because to do so would require applying a fixed pollution intensity to a varying input mix which is clearly implausible. It should therefore be clear why we use the demand driven input-output model for the carbon accounting work in this thesis. Next we outline how the demand driven input-output system is extended to examine environmental issues.

2.5 Environmental extension of the demand driven model

The seminal paper on extending input-output models to environmental uses was Leontief (1970). For a brief review of the history of economic-environmental

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[27] It's worth noting that the supply driven model would be similarly consistent when used solely as an accounting framework, but would be unsuitable when used for modelling work. This is an important issue in the context of the attribution and modelling of the emissions driven by final demand, a crucial issue in carbon accounting.

models prior to Leontief (1970), beyond what we cover here, see Forssell & Polenske (1998) and the special issue on these models in Economic Systems Research which their paper introduces. In his paper Leontief presents a simple two sector and one final demand economy (denoted in physical units).

The key aim was to show how pollution could be introduced and how pollution generated to satisfy final demand could be calculated using the input-output system. Leontief argued that: "pollution and other undesirable or desirable-external effects of productive or consumptive activities should for all practical purposes be considered part of the economic system" (Leontief 1970, p264). In order to do this, he argued, the externality in question must be linked to an economic output or input, and included in the structural equations that describe the economic model.

Leontief begins his demonstration by writing an equation, explicitly including the quantity of the externality (e.g. pollution) produced per unit of output of each of his two sectors. The point of this is to create an 'externality' sector, and for the total amount of this externality that is generated to be calculated using this system. Pollution within this model is therefore able to be treated as another input to the production process. Taking a simple case with two production sectors (with sectors denoted 1 and 2) and continuing our earlier notation, we adopt the example from Leontief (1970) starting with a two sector version of Equation 2.6[28]:

$$\begin{bmatrix} 0.75 & -0.40 \\ -0.14 & 0.88 \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \end{bmatrix} = \begin{bmatrix} Y_1 \\ Y_2 \end{bmatrix} \tag{2.14}$$

This can be written out in equation form as:

$$0.75X_1 - 0.4X_2 = Y_1 \tag{2.15}$$

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[28] It should be clear that we have skipped some steps in moving directly to the consideration of this equation in this 2 sector example. The reason for this is purely, having familiarised the reader with the derivation of this equation in Section 2.4.1, to expedite the discussion in this section.

and

$$-0.14X_1 + 0.88X_2 = Y_2 \tag{2.16}$$

Given that in the Leontief demand driven input-output system the input mix is kept constant (i.e. we assume a constant input mix for sectoral production) we can introduce pollution, as Leontief argued, into his input-output model using pollution intensities (quantity of pollution per unit of output). Since we are assuming that the input mix is constant, and all output is homogeneous, if we know the volume of sectoral emissions and the volume of sectoral output we can calculate sectoral emission intensities ($\frac{emissions}{sectoraloutput}$). This means that the two equations above can be added to by writing out an equation for pollution (or other externality) generation tied to sectoral output as:

$$p_{x1}.X_1 + p_{x2}.X_2 - X_3 = 0$$

and

$$0.50X_1 + 0.2X_2 - X_3 = 0 \tag{2.17}$$

Here p_{xi} is the pollution intensity of Sector i's output. The final equation here reflects the fact that 0.5g of a pollutant is released per unit of sector 1's output, and 0.2g of a pollutant is released per unit of output of sector 2. X_3 here is the total of the pollutant (or any other externality) generated in the economic system. The creation of this new pollution sector results in the generation of a new version of Equation 2.14:

$$\begin{bmatrix} & Sector1 & Sector2 & Sector3 \\ Sector1 & 0.75 & -0.40 & 0 \\ Sector2 & 0.14 & 0.88 & 0 \\ Sector3 & 0.50 & 0.20 & -1 \end{bmatrix} \begin{bmatrix} Output \\ X_1 \\ X_2 \\ X_3 \end{bmatrix} = \begin{bmatrix} FinalDemand \\ Y_1 \\ Y_2 \\ Y_3 \end{bmatrix} \tag{2.18}$$

In Equation 2.18, the column entries for the new pollution sector (sector 3) are the pollution embodied in each sector's purchases per unit of the purchasing sectors output, and the row entry is the pollution embodied in that sector's purchases from the other sector, again per unit of the purchasing sectors output. Leontief however shows that altering the structural matrix in this way is not necessary, since there is an alternative way to calculate total pollution in this system.

The two step approach that Leontief (1970) proposed is to use the input-output system to establish the amount of each sectors output required (directly and indirectly) to satisfy the given level of final demand. Then, having established the sectoral output supported by sectoral final demand (using the demand driven input-output system) we can work out the total pollution generated by applying sectoral output-pollution intensities (i.e. pollution generation per unit of sectoral output).

When we say 'directly and indirectly' required to satisfy a unit of final demand its worth explaining further what we mean. Meeting household final demand for the output of the Electricity production and distribution sector requires inputs from other sectors; for instance Coal from the Coal extraction sector. The production of this coal generates pollution. The pollution directly and indirectly attributable to household final demand for electricity production includes the pollution embodied in the coal that the electricity sector uses to generate electricity, as well as the emissions generated to produce all the other inputs to the electricity sector.

Leontief (1970) extends his system to include a pollution abatement (or cleaning) sector; however since we are not pursuing this approach here we refer the interested reader to Leontief (1970) for full details. As Leontief notes, the inclusion of such a cleaning sector depends on the ability to separately identify it- an ability that we do not currently have. An input-output system, which includes a pollution abatement sector, would be an interesting analytical exercise if the data were available. Here we utilise Leontief's environmental extension to the input-output system to allow us to examine the relationship between pollution generation and the final demand that is driving this pollution generation.

There is an alternative way to generate these emissions estimates without the need for the two stage approach detailed above (i.e. without the calculation of the supported output then the application to these output totals of the output-CO_2 intensities). A simple extension of the demand driven model will allow a single stage calculation of the emissions generated to satisfy sectoral final demand. This has been done frequently in the literature (see Gale (1995), Peters & Hertwich (2006), Ipek Tunē et al. (2007), McGregor et al. (2008), Miller & Blair (2009), Jensen et al. (2011a), Turner et al. (2011b)).

By pre-multiplying both sides of Equation 2.7 above (i.e. $X = (I - A)^{-1}.Y$) by a vector of sectoral output-pollution coefficients (here we use output-CO_2 coefficients) p (this is the amount of CO_2 produced per unit of output, i.e. total sector pollution P_i divided by total sectoral output X_i), we can attribute total pollution P to the final demand that is driving this pollution generation. The demand driven input-output model in Equation 2.7, extended to the environmental version, is:

$$p.X + P_c.Y_c = p.(I - A)^{-1}.Y + P_c.Y_c$$

or

$$P = p.(I - A)^{-1}.Y + P_c.Y_c \tag{2.19}$$

The only alteration to the equation in going from Equation 2.7 to Equation 2.19 other than the multiplication of both sides by a vector of pollution intensities, is the addition of direct household pollution generation ($P_c.Y_c$) to both sides. Here P_c is the direct pollution intensity of each category of final demand, denoted Y_c. Equation 2.19 attributes the total pollution generated within the economy (i.e. territorially based pollution) to the n categories (for instance households, government, export etc) of final demand (in our application later in this chapter we have a maximum of 9 categories of final demand). This allows us to determine how much of the pollution generated in the economy is produced to meet each category of final demand.

This approach makes some assumptions, beyond those discussed earlier, and implied by the use of the demand driven input-output system. One of these is that, in addition to the assumption that each sector produces a single homogeneous good, we assume that each unit of sectoral output requires the same amount of pollution generation. In terms of the identity above, we assume that each unit of sector i's output embodies p_i units of pollution, so not only do we assume that the intermediate inputs are homogeneous, we also assume that the pollutants produced in the production of each unit of sectoral output are identical.

So while government final demand from sector i may, in reality, be for a very different type of good than household final demand from sector i, we assume that they are identical. In addition this means that we assume that each sectors sale of its output to the n sectors of the economy embody the same quantity of emissions per unit. Therefore all intersectoral sales from sector i are assumed, per unit of output, to embody the same amount of pollution. This allows us to utilise the demand driven input-output system to calculate the emissions embodied in each unit of final demand.

Assuming that all sectoral interactions involve market transactions over the single good or service that each sector is assumed to produce, it is worth considering how reasonable the homogeneous sectoral output/firm assumption proves in this kind of environment-economic situation. In some sectors (for example, cement) where the output seems more or less homogeneous in practice this assumption seems to be quite reasonable. However in the case of other sectors (for example, agriculture) this assumption, depending upon your purpose in utilising the input-output framework, may seem less reasonable.

To explain this point with reference to an environmental application of the input-output framework the assumption of a single homogeneous good would result in the following assumption: that each unit of that sector's output embodies the same average pollution (whether this is CO_2 or another pollutant). This also means that we assume that the intermediate demands by the other sector's for that sectors output embody the average level of pollution.

Taking a simple example:

- Sector A demands £30 million worth of the output of Sector 1 (agriculture) as an input to the production of the output of Sector A. We also assume for the sake of this example that the actual demand here (in the real world, not the model) is for a low polluting good X.
- Similarly Sector B demands £30 million worth of the output of Sector 1 (agriculture) as an input to the production of the output of Sector B. We assume here that the actual (real world) demand is for a high polluting good Y.

Following from our assumption that each sector produces a single homogeneous good, and in the case of the environmentally augmented input-output system that each unit of a sectors output embodies the same amount of pollution, the model regards these two flows to be identical. This example (although highly stylistic) suggests a scenario where the output-CO_2 multiplier in the case of Sector A would be too high, and that of Sector B too low (as compared to a micro evaluation of the pollution embodied in these flows). This needs to be recognised when using environmentally extended input-output models for simulation work.

2.5.1 Production and consumption based emissions measures

Before proceeding, and having outlined the extension of the input-output model to environmental applications, it is worth discussing in more detail what is meant by territorial and consumption based emissions measures. Territorial emission measures are the basis of all the official national emissions targets in the UK, for instance those in the UK Climate Change Act, the Scottish Climate Change Act and the Kyoto protocols. The basic idea is that countries or regions are responsible for the emissions that are generated within their territorial boundaries- these are known in the literature as territorial accounting principle (TAP) emissions.

There are two main approaches to calculating these TAP emission totals, one approach uses the direct sectoral intensities (emissions per unit of sectoral output) multiplied by the size of sectoral output to establish the TAP emissions total[29]. This is the first part of the left hand side of Equation 2.19, the second part is the addition of direct household emissions generation. An alternative approach is to use the environmentally extended input-output system, which was just outlined, using the standard 'Type I' approach discussed below. The basic idea is to use the input-output framework to establish the emissions required directly and indirectly to satisfy a unit of each sector's final demand. This is then combined with the emissions that are directly generated by households, to give the national emissions total.

Using this approach we can establish the production emissions generated to satisfy sectoral final demand. This give us two ways to think about TAP emissions totals, one using the input-output methodology to gain an insight into the final demand that drives the emissions generation through sectoral supply chains and the other which focuses only on direct sectoral pollution. These two approaches produce the same TAP emissions total estimate.

In the case of the consumption-based measures we construct the national emissions balance by considering the emissions embodied in satisfying domestic consumption demands, referred to here as the consumption accounting principle (CAP) approach. This has three components:

1. the emissions generated domestically by production activities to meet domestic demand.

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[29] In other words, there is no need to use an input-output model to derive a TAP measure, but doing so allows you to investigate the final demand that drives the TAP emissions generation.

2. the emissions embodied in the imports that are required as inputs to the domestic production process to satisfy our domestic consumption needs.
3. the emissions embodied in direct final demand consumption (this can be direct household emissions, or the emissions embodied in imports by households, government, etc.).

Taking account of the emissions embodied in our importing activities requires information on the pollution embodied in the exports of each country or region we trade with, at the sectoral level. This is why constructing CAP estimates is more challenging; the data requirements are significantly more onerous.

Given these data requirements, formulating a CAP measure that can actually be reasonably estimated requires some assumptions to be made later in this chapter. We present a range of different approaches to formulating CAP measures for Scotland using different assumptions about the production and pollution technology used to produce our estimates of the pollution content of imports. We explain these below, but to aid understanding of how the CAP measures that we outline later is constructed, we first outline a simple two region input-output model.

2.5.2 A simple two region input-output model: a reference

The simple two region schematic below[30] has 8 elements, numbered 1-8. Elements 1 and 2 are the domestic **Z** matrices for both regions (Scotland and RUK). These are exactly as described above in outlining the standard demand driven input-output system. Elements 3, 4, 7 and 8 are the final demands from each of the two regions, broken down by demand for domestically produced goods and goods produced in the other region and imported/exported. We ignore non-produced inputs in this example.

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[30] We have left out of this schematic value added/non-produced inputs to simplify the schematic and focus on the core elements required for the interregional input-output database. The reader is referred to Figure 2.1 to see where value added would enter the interregional database.

Elements 5 and 6 are the import matrices for each region. These detail the imports by that region from the other region broken down by the sector that these imports come from. So, element 5 below is the intermediate imports by each Scottish production sector from each of the RUK production sector. This means that each element of this matrix m_{ij} is the imports by sector j in Scotland from sector i in RUK. m_{ij} is therefore also the exports by sector i in RUK to sector j in Scotland.

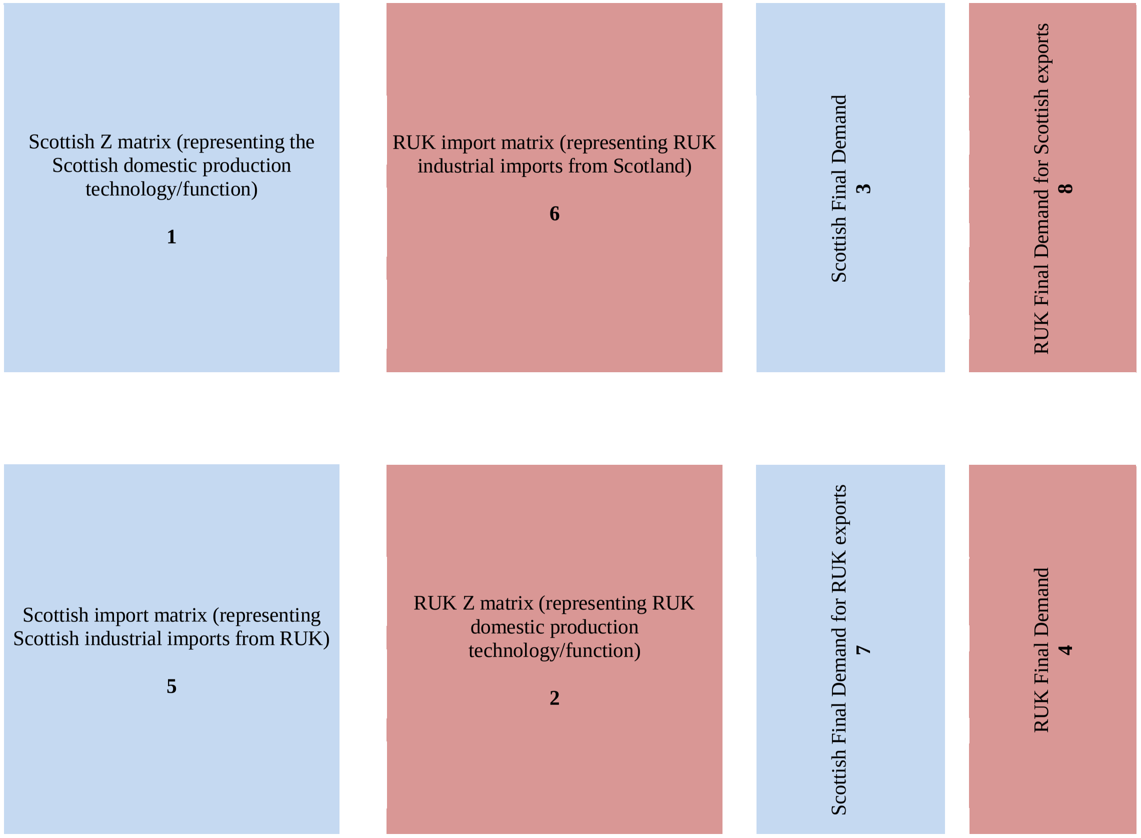
In the TELAS case outlined below, we do not need to have element 5 to endogenise trade and thus close off the single region model, all that is needed is sectoral import totals- in other words the total value of imports by each sector. This in combination with element 8 (Scottish exports to RUK) is enough to close the Scottish single region input-output model off to trade with RUK using TELAS. In the single region DTA case, both elements 1 and 5 are required to produce a combined use production technology/function for Scotland (or elements 2 and 6 to do the same for RUK). Elements 1 & 5 are used to produce the production technology/function that we use to estimate the pollution embodied in Scottish imports from RUK. This is distinct from what the 'true' RUK domestic production technology/function actually is (represented by element 2 above).

It is worth, before applying different closure mechanisms to the single region system, outlining what an interregional environmentally extended input-output system would look like. Taking the single region environmentally extended model from our earlier discussion (Equation 2.19):

$$P = p.(I - A)^{-1}.Y + P_c.Y_c \tag{2.20}$$

We can extend this single region system to the 2 region case (which could also easily be extended to more than the 2 region case), by redefining some of the elements in Equation 2.20. Firstly P here is total pollution in the system, not just in the region. p here must be extended from a 1 x n vector to a 1 x

Figure 2.2: 2 region schematic of an input-output database



2n vector reflecting the n sectors in region 1 and the n sectors in region 2. The A matrix here must be extended in two directions, going from being an n x n matrix to a 2n x 2n matrix. Y becomes a 2n x 2k matrix, and P_C and Y_C are also similarly redefined. This gives the following system in expanded notation:

$$P = \begin{bmatrix} p_{11} \\ \vdots \\ p_{1n} \\ p_{21} \\ \vdots \\ p_{2n} \end{bmatrix} \left(\begin{bmatrix} 1 & 0 & \cdots & \cdots & \cdots & 0 \\ 0 & \ddots & & & & \vdots \\ \vdots & & \ddots & & & \vdots \\ \vdots & & & \ddots & & \vdots \\ \vdots & & & & \ddots & \vdots \\ 0 & \cdots & \cdots & \cdots & \cdots & 1 \end{bmatrix} - \begin{bmatrix} a_{11,11} & a_{11,2n} \\ \vdots & \\ a_{1n,11} & a_{1n,2n} \\ a_{21,11} & a_{21,2n} \\ \vdots & \\ a_{2n,11} & a_{2n,2n} \end{bmatrix} \right)^{-1} \cdot \begin{bmatrix} y_{11,1k} & \cdots & y_{11,2k} \\ \vdots & \ddots & \vdots \\ y_{1n,1k} & \cdots & y_{1n,2k} \\ y_{21,1k} & \cdots & y_{21,2k} \\ \vdots & \ddots & \vdots \\ y_{2n,1k} & \cdots & y_{2n,2k} \end{bmatrix} + \begin{bmatrix} P_{C11} \\ \vdots \\ P_{C1n} \\ P_{C21} \\ \vdots \\ P_{C2n} \end{bmatrix} \cdot \begin{bmatrix} Y_{C11} \\ \vdots \\ Y_{C1n} \\ Y_{C21} \\ \vdots \\ Y_{C2n} \end{bmatrix} \tag{2.21}$$

In Equation 2.21 the labeling convention that is followed is that in the case of the A matrix each subscript describes the region then the sector e.g. $a_{11,2n}$, refers to the sales of region 1 sector 1 to region 2 sector n, per unit of region 2 sector n total output. In the case of the final demand matrix, the first part of the subscript refers to the region and the sector to which the final demand relates, while the second component refers to the region and type of final demand, e.g. $y_{11,2k}$ refers to the demand for region 1 sector 1 final demand by final demand category k in region 2.

From Equation 2.21 we can see that this interregional system allows the partitioning out of the emissions supported within this interregional system by each category, k, of final demand in each of the two regions. The separate identification of the interregional intermediate input flows in the A matrix, and the identification of final demand in each region for the output of each sector in each region in the Y matrix is what distinguishes the interregional system from the single region system, and from a single region system where the imports to that region are specified through a combined use matrix.

In addition, and for comparison with the DTA and DTA (OECD) closures to the single region environmentally extended input-output model considered later in this paper, the pollution vector p specifies the pollution intensity of each of the n sectors in each of the two regions. In these ways, the interregional system can be considered to be the 'fully specified' environmental accounting model. In this paper, because of data limitations, we have to consider only the single region system. As a result, this chapter is an attempt to understand what information on the emissions balances of a region can be obtained from a single region input-output model. We outline the data that we use in the next section before undertaking a range of analyses using the single region environmentally extended input-output model for Scotland.

2.6 Data

In the analysis that follows we use the Scottish input-output tables for 2004, available on the Scottish Government's website[31] and experimental imports matrices for Scotland's trade with the rest of the UK and the rest of the world that were also produced by the Scottish Government. Data on the CO_2/GHG intensities of industrial sectors are taken from the UK national air emissions accounts[32]. There are now data available on Scottish sectoral emissions[33], but these data have not been released under the terms of official statistics.

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[31] Input-output tables for Scotland are available for download from: `http://www.scotland.gov.uk/Topics/Statistics/Browse/Economy/Input-Output/Downloads`

[32] These UK environmental datasets are available from: `http://www.statistics.gov.uk/STATBASE/Expodata/Spreadsheets/D5695.xls`

[33] These datasets are also publicly available for download for Scotland, and can be accessed at: `http://www.scotland.gov.uk/Resource/Doc/933/0093993.xls`

These Scottish emissions data have been released as ‘experimental’ statistics, and some elements- at the sectoral level- show wide variation from the equivalent UK elements without any clear explanation of why this is the case. In addition the emissions ascribed to particular sectors are difficult to understand. The clearest example of this is the positive emissions attributed to the Tobacco sector which has zero output (meaning that there is no tobacco production) in Scotland in 2004. This remains unexplained.

For the purposes of this analysis we prefer the pollution data produced at the UK level for all sectors except sector 38 (electricity production and distribution) where we use the Scottish sectoral intensity. This is because of the confidence we have in the underlying data on the energy intensity of electricity production in Scotland. We have relatively good data on the electricity production sector in Scotland, partly because of its economic and political significance to Scotland, and partly because of the operation of the European Union Emissions Trading Scheme (EU-ETS). It is because there are more data available on the volume of energy generated and the emissions associated with it that we have greater confidence in the emissions intensity data for the electricity sector, derived on behalf of the Scottish Government and used here.

The example of the tobacco sector noted above, and the lack of explanation for some important differences between the Scottish and UK sectoral emissions intensities, make us cautious about the use of these Scottish specific intensities. Later we demonstrate the effect of using full UK pollution intensities versus what we call the ‘hybrid’ emissions intensities (where we use full UK intensities for all sectors except electricity production and distribution which we take from the Scottish emissions accounts).

Ferguson et al. (2005) outline the two main assumptions that using the UK sectoral emissions intensities as a proxy for the Scottish sectoral emissions intensities entails:

1. We must assume in adopting this approach that the sectoral pattern of fuel use in Scotland is the same as in the UK as a whole

2. We must also assume that the technology used to transform this fuel into energy is the same in Scotland and the UK as a whole.

Neither of these assumptions appears to us to be particularly difficult to sustain. The first simply requires that the fuel use to output ratio in Scotland is the same as in the UK as a whole. The second assumption, as Ferguson et al. (2005) note, is not an unreasonable assumption since fuel technology would be unlikely to exhibit large spatial variations (at least within a country like the UK).

In the case of applying UK household emissions intensity data to Scotland, Ferguson et al. (2005) note that this involves the additional and obvious assumption, that household consumption and fuel use patterns are identical in Scotland and the UK as a whole- in other words that the emissions intensity of Scottish and UK household consumption activity is identical. Again, this does not seem unreasonable.

To recap: in one case we apply UK pollution intensity data for all sectors, and in the other case adopt UK pollution intensity data for all sectors except sector 38 (Electricity production and distribution), where we adopt the Scottish intensity. This allows the reader to see the impact of this change, and thus the importance of the emissions intensity of electricity production on total emissions in Scotland.

2.7 Pollution accounting and attribution

In this section we outline each of the models used, including closure methods (i.e. how we 'close' the single region model off to trade) where these are adopted, followed in each case by the results of this exercise using the data outlined previously. The rest of this section is outlined as follows: firstly, we discuss the standard Type I input-output approach, which represents the 'open economy' case, and then we present the results from this analysis for Scotland in 2004. The 'open economy' distinction means that we do not consider the intermediate use of imported goods as endogenous to the system, and we treated exported goods as an exogenous category of final demand.

In order to 'close' this system off with respect to trade, we must consider further how we treat imports and exports, and in the case of environmentally extended systems, what this means for pollution analysis. Our starting point here comes from the work of McGregor et al (2004) who suggested an innovative approach to the treatment of trade that does not require any additional information beyond the domestic input-output database (e.g. imports matrices for each trading partner of the focus economy). This trade closure is particularly valuable where the absence of a full trade matrix for each trading partner or trading group rules out the use of the domestic technology assumption (DTA) method proposed below.

The TELAS closure method is outlined and discussed before we present the results of applying this closure method to Scotland. The TELAS case represents the first attempt in this paper to 'close' the single region Scottish input-output model off to trade with both the rest of the UK (RUK) and the rest of the World (ROW). Closing the single region model off with respect to trade allows us to calculate consumption based emissions measures. TELAS is a 'consumption based measure' in the sense that it attempts to estimate the emissions supported by total domestic consumption, but it is aligned with the territorial accounting principle.

In the TELAS case we reattribute the emissions generated within the region (including in the production of exports) to domestic consumption. In the closed economy model we are able to take account of the emissions embodied in our imports (or in the TELAS case 'proxy' for them) which otherwise 'leak' out in the Type I case, while not considering the emissions embodied in our exports to RUK or ROW.

In the TELAS case though, we constrain the estimate of the total emissions embodied in imports to equal the total emissions embodied in exports. In this way, what the TELAS approach does is not estimate these emissions, but reattribute them according to the sectoral propensity to import. While this measure is not really a 'consumption' measure, it does let us examine which categories of final demand are driving import demands. That is, TELAS allows us to take the emissions generated domestically to meet export demand, (which under CAP are the responsibility of the importing country/region) and reallocate them to domestic demands.

The rationale for this approach to closing off the single region model, is that the region needs to export in order to satisfy its import demands. In the case of sectoral output, in order to purchase the imports that the sector requires, we need to export some of our own output. In the case of emissions, the corollary would be that we need to generate emissions to produce exports, in order to be able to purchase imports, but we need to recognise from an emissions perspective that these imports require the generation of emissions elsewhere.

We also outline two domestic technology assumption (DTA) closure approaches here. The DTA closure estimates the output (emissions) required to satisfy domestic and import final demand using domestic (combined use) production (and pollution) technology. Essentially we estimate the output (emissions) that would be produced to satisfy a given level of final demand, if we employed domestic production (and pollution) technology. This means constructing a domestic 'combined use' matrix and using this as the basis for the construction of the environmentally extended input-output model.

This approach recognises that there are both domestic and an imported inputs to domestic production which need to be taken into account in closing the region off to trade. A Leontief inverse based on the combined use matrix is referred to as a domestic technology assumption production function. In the environmentally extended model, when we utilise domestic sectoral pollution intensities, we refer to this as the domestic technology assumption pollution technology.

In this chapter the TELAS and DTA closures are applied to the two trade flows identified in the Scottish input-output model (RUK and ROW) in combination: i.e. TELAS (RUK), DTA (ROW) and DTA (RUK), TELAS (ROW). This allows us to compare these results to the full DTA and TELAS cases, which permits a greater understanding of the emissions embodied in RUK (ROW) imports. For instance, since applying the TELAS closure will not change the emissions balance, applying TELAS to one trade flow and DTA to another allows us to isolate the impact of treating each of the two trade flows (RUK and ROW) using the DTA. From the emissions balance we will know whether the emissions embodied in exports to that trading partner are greater than those estimated as embodied in our imports from that trading partner.

In the second DTA approach, we apply the DTA closure to both RUK and ROW trade using weighted pollution intensities derived from Organisation for Economic Co-operation and Development (OECD) bilateral trade and pollution data (see Turner et al. (2011a) for more details on how this pollution vector was constructed). Essentially, we weight the domestic pollution intensity discussed earlier according to the domestic use of each sectors output, and add to this a weighted pollution intensity from each region we import from in proportion to our sectoral imports from each region.

If 50% of Scotland's use of cement is produced in Scotland, 25% is produced in France and 25% in India, the pollution intensity used for the cement sector in the DTA (OECD) closure is taken as 0.5 times the Scottish pollution intensity, plus 0.25 times the French pollution intensity, plus 0.25 times the Indian pollution intensity for the cement sector. We derive these trade proportions and pollution intensities from OECD data as well as our Scottish input-output and environmental data.

We do not follow others in the literature (for instance Hertwich & Peters (2009)) in using the GTAP database to derive estimates of the emissions embodied in trade for Scotland, since, as a regional economy that is part of the UK, Scottish data are not separately identified.

The DTA (OECD) closure is the final closure method applied here, and extends the earlier DTA closure only in utilising different pollution intensities based on data specific to UK trading partners. These data were derived from OECD bilateral trade data and country specific sectoral pollution intensity data using a number of constructed international regions (see Turner et al. (2011a)) for more details on the regions that were constructed and their sectoral composition). Table 2.1 summarises each of the measures applied in this chapter.

The result of each of these analyses is presented firstly in Table 2.5 where we use a hybrid pollution intensity assumption comprising pollution intensities for 66 sectors from the UK intensity data and a Scotland-specific intensity for the Electricity production and distribution sector. While in Table 2.6 we present the same range of analyses but this time using full UK sectoral emissions intensities. This allows us to compare each emissions balance estimate to each of the other approaches using the same emissions intensity assumption and to itself with the only change being the pollution intensity of the Electricity production and distribution sector.

A separate analysis is then outlined which allows for differences in both production and pollution technology between Scotland and its trading partners. This approach focuses only on the emissions embodied in exports and imports, and is known as the balance of emissions embodied in trade (BEET). This analysis focuses on the emissions embodied in trade rather than the national emissions balance. This can, however, be compared to the trade emission balances derived from the earlier national emissions balance analysis. This provides another way of thinking about Scottish sustainability with respect to its trading partners.

2.7.1 Type I

The Type I case is the application of the traditional demand driven input-output system where all the categories of final demand identified in the national input-output tables are exogenous. This is in contrast to the standard Type II case where households (however they are identified as a category of final demand in the national input-output tables) are made endogenous. The results from the Type I attribution exercise demonstrate firstly as a verification exercise that

Table 2.1: Summary of different measures applied.

Attribution method	**Production technology applied**	**Pollution technology applied**	**Description**
Type I	Domestic use	Hybrid UK/Scottish	Standard input-output attribution method.
TELAS	Domestic use	Hybrid UK/Scottish	An approach which attributes the emissions embodied in exports to each sector according to the propensity of each sector to import.
DTA	Combined use	Hybrid UK/Scottish	This approach calculates the emissions embodied in imports using a combined use domestic production function and a hybrid UK/Scottish pollution technology.
DTA (OECD)	Combined use	Hybrid UK/Scottish/OECD	This approach calculates the emissions embodied in imports using a combined use domestic production function and a pollution technology based on UK, Scottish and OECD pollution data.

the environmentally extended input-output system recreates the base pollution level for Scotland in 2004. Recall that, in the terminology of the literature, the total of a country or region's emissions (whether constructed on a production or consumption basis) is referred to as the national emissions balance.

The most noticeable finding from Table 2.5 below is that a large proportion of the emissions generated in Scotland in 2004 were generated to support external demands (i.e. RUK and ROW exports). This reiterates our earlier discussion about the fact that Scotland is a small open economy that is heavily dependent on external demand for its products. Looking at the results in Table 2.5 we can see that 49% of the emissions in Scotland in 2004 were emitted in the production of goods and services that were sold to consumers in other parts of the UK or the rest of the world.

The next largest supporter of Scottish emissions in 2004 was Scottish households which supported 42% of the emissions generated in Scotland in 2004. A number of other categories of final demand (gross fixed capital formation, local government, central government) are responsible for supporting around 9% of Scottish emissions in 2004. There has been some recent work in the literature attempting to divide the TAP emissions total between domestic producers and domestic consumers (see Lenzen et al. (2007) and Andrew & Forgie (2008)).

The central argument that these papers make is that we can view the domestic emissions balance as either the responsibility of domestic producers (i.e. industries or sectors generating the pollution) or as the responsibility of domestic consumers (whose final demands necessitates the underlying pollution-production processes). It was argued that in terms of attributing 'responsibility' for the national (domestic) emissions balance- whether constructed on a TAP or CAP basis- responsibility should be shared between domestic producers and domestic consumers in a non-arbitrary way based on the underlying economic data.

This may be useful for policymakers who are faced with decisions over where to focus effort in reducing emissions, between trying to affect industry behaviour and trying to affect consumer behaviour. Lenzen et al. (2007) argue that since producers "use [and determine the level to use, of] land and energy" (Lenzen et al. 2007, p32) and consumers "decide how to spend their money on... [these] products" (Lenzen et al. 2007, p32) a shared responsibility approach could be useful for policymakers.

Lenzen et al. (2007) outline the simple process by which they determine the split in responsibility between producers and consumers of goods. They define a weight which is the proportion of responsibility that the producers of sector i retain, with the balance remitted to the consumers. Lenzen et al. (2007) define this weight to be:

$$(1 - \Phi_i) = \frac{v_i}{x_i - z_{ii}} \tag{2.22}$$

Here v_i is the value added in sector i, x_i is total sectoral output of sector i, and z_{ii} is the total intra-sectoral transactions of sector i. This is the sales that a sector makes to itself (i.e. sales between firms operating in the same sector). Essentially the weight that they construct measures the size of value added in a particular sector as a proportion of sectoral output less any intrasectoral transactions. Here sectoral value added is defined as the sum of non-domestically produced inputs (imports) and non-produced inputs (labour, capital etc) in each sector.

The motivation for this weight lies in the argument by Lenzen et al. (2007) that a sector with a higher sectoral value added component has a higher degree of control over their product- in other words they transform the product more than a sector which acts as an intermediary between another sector and final demand. This, they argue, means that the producers in this sector should take more 'responsibility' for the emissions associated with their activities.

Interestingly, the inclusion of imported goods in the value added part of this calculation suggests that producers should be penalised more to the extent that they import more. Given that any emissions associated with imported goods will not be counted under a TAP emissions total (which is what Lenzen et al. (2007) is using), this suggests that the production sectors are being 'penalised' using this approach for not contributing to the domestic emissions balance. The reason being that the domestic emissions balance will be increasing in the volume of domestic economic activity, unlike the share of producer responsibility which will be declining in the volume of domestic economic activity.

In order to establish the producer and consumer shares of a nations TAP emissions total we have to calculate:

$$\sum_{\forall i} \Big[(I_i - \Phi_i).(p.(I-A)^{-1}.Y_i) \Big]$$

and

$$\sum_{\forall i} \Big[\Phi_i.(p.(I-A)^{-1}.Y_i) \Big] + P_c.Y_c \qquad (2.23)$$

In these equations I_i is a vector of 1's, Y_i is a vector of sectoral final demand. Using this approach, the directly generated household emissions are assigned to the consumer's emissions balance. Doing this for Scotland based on the TAP emissions total yields the results reported in Table 2.2.

Table 2.2: Shared responsibility emissions

	Producer Responsibility Emissions	Consumer Responsibility Emissions
Territorial production emissions	16,528,922	21,088,606
Direct household emissions		10,423,473
% share of total territorial emissions	34%	66%
	16,528,922	31,512,080

Under this allocation the total emissions balance is unchanged, but here total emissions are shared across producers and consumers at the sectoral level according to the weight defined above. This split allows us to look at another perspective on this issue, which could be valuable especially when we consider that any action that is taken to reduce our emissions balance will have to be focused on either reducing production emissions or on changing the behaviour of consumers.

While the data contained in the Table 2.2 is not extensive, it provides a clear basis on which to consider the relative share of responsibility for national emissions balances that domestic consumers have relative to domestic producers. This method is based on the fixed level of final demand (and hence emissions) defined for the Type I case. An alternative methodology which creates a new shared responsibility balance based on the emissions required to satisfy domestic final demand, plus a weighted portion of the emissions embodied in imports and exports, has been outlined in Peters (2008).

Peters (2008) reviews a range of 'shared responsibility' measures in the context of national emissions balances and concludes that there are two principle approaches. One, as we outlined above, looks at the sharing of the domestic emissions balance between domestic producers and consumers. The other (which Peters (2008) introduces) creates a shared national emissions balance based on a weighting of the territorial and consumption accounting principle emissions balances. This way of calculating a national emissions balance is a mix of 'for whom' and 'where' the emissions are generated.

The domestically produced emissions that are emitted to satisfy domestic consumption are taken to form the core of this emissions balance. What is shared is the emissions embodied in trade. The approach taken is to sum together a share of the emissions embodied in national exports and a share of the emissions embodied in national imports. The national emissions balance under this formulation becomes (from Peters (2008) Equation 28):

$$f_s^r = F_t^{rr} y^{rr} + \Phi F_t^r \sum_s e^{rs} + (1 - \Phi) F_t^s \sum_s e^{sr} \tag{2.24}$$

Where f_s^r is the shared responsibility emissions balance, $F_t^{rr}y^{rr}$ is the emissions domestically generated in region r to satisfy region r final demand, $\Phi F_t^r \sum\limits_s e^{rs}$ is a weighted share of emissions embodied in domestically produced exports in region r, and $(1-\Phi)F_t^s \sum\limits_s e^{sr}$ is the weighted share of emissions embodied in foreign produced imports to region r. F here are the emissions multiplier vectors, and e are the sectoral trade volume vectors[34].

To explain Equation 2.24, consider that if $\Phi = 1$ then we get the full TAP emissions total, and where $\Phi = 0$ we get the full CAP emissions total. Note the parallels in terms of calculating the emissions embodied in trade here with the BEET approach introduced later in this paper. Peters (2008) does not suggest what the weight here should be. He does however note the approach of Lenzen et al. (2007) and acknowledges that (similar to Lenzen et al. (2007)) the sectoral value added- in this case embodied in trading sectors- could form the basis for the construction of such a weighting vector.

This approach, while interesting, is not pursued here because while we generate all the data required for such a calculation, we are uncertain as to the value that would be added from establishing what, essentially, is just another emissions trade balance estimate. The calculation of a domestic shared responsibility measure as we did above, at least adds to the pool of knowledge that policy-makers have, and provides a non-arbitrary way of thinking about the domestic sharing of responsibility for the national emissions balance between producing and consuming agents in the economy.

2.7.2 TELAS

Outline of approach

The TELAS approach, as mentioned earlier, endogenises trade in the input-output model (and in this sense 'closes' the model off to trade with the RUK and

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[34] The emissions embodied in exports and imports, depending upon the method of calculation, may or may not include the emissions due to interregional feedback effects. If an interregional model is used, these emissions due to interregional feedback effects would be included, if stand alone single region EIO models are used, interregional feedback effects would not be included in the emissions estimates.

the ROW). This can be useful in allowing us to examine the pattern of sectoral imports. In the emissions case it also allows us to redistribute the emissions generated by each sector to satisfy export demand, in a non-arbitrary manner, while retaining domestic demand as the driver of domestic pollution generation. This approach, developed by McGregor et al (2004) and initially referred to as NCLAS (Neo-Classical Linear Attribution System) but subsequently renamed as TELAS, takes a neoclassical view of trade in the single region input-output system. TELAS is motivated by the neoclassical viewpoint that countries only export goods and services to other countries in order that they can buy goods and services from other countries. Put succinctly: you only export in order to import.

This has the interesting extension in the case of pollution analysis of implying that the pollution that you generate to produce those exports, is done to finance your imports, and thus is attributable to your imports. In terms of the demand driven input-output system, the modification is as follows: in the same way as creating a Type II Leontief (see Miller & Blair (2009, p34-41)), an extra row and column is added to the A matrix representing a trading sector. It should be noted that a new column can either be added for each trading partner, or in the alternative all trading partners can be treated together and only one additional sector is required.

The decision about which trade flows to separately identify in the TELAS closure approach depends on data availability and the purpose of the analysis. In our case later, we add two new trade sectors, one for trade with the rest of the UK and one for trade with the rest of the world. There is no difference in the results between applying TELAS with an aggregate trade sector and applying it with separately identified trade sectors. The only reason we separately identify trade with the RUK and ROW here is because we later apply the domestic technology assumption approach to one trading partner (RUK) and the TELAS approach to the other (ROW), and vice versa. Where import matrices are available for a trading partner this allows the application of the domestic technology assumption approach. Without these data the TELAS approach may be necessary to endogenise trade, to generate consumption based emissions balances.

In the TELAS **A** matrix the row elements of these new trade sectors are the imports by sector j=1...n from trading region r, as a proportion of total sectoral output, X_j. The column elements for each trade sector are the sectoral exports to region r as a proportion of total imports from region r. This procedure produces a new sector within the A matrix. In addition, where there are imports from these regions to satisfy final demand these are added to the appropriate category of final demand as final demand for the output of these trade sectors. In our case, reported below, we create two new sectors within our A matrix, and proceed to reproduce our demand driven input-output system as before. In this case we use our new final demand matrix which only includes the final demand for those categories that are still exogenous.

In the case of the environmentally extended demand driven input-output model, the direct output-CO_2 intensity of these trade sectors is zero. The output-CO_2 multipliers of these trade sectors are non-zero however, because of the pollution embodied in transactions with the other sectors of the economy (i.e. indirect emissions). When we attribute the emissions of the trade sector to final demand we are attributing to each sector the emissions embodied in the sectoral "export production required to finance [that sector's] imports" (McGregor et al. 2008, p5). In essence we reattribute the emissions embodied in exports according the sectoral import propensities.

It is worth noting at this stage the assumptions that TELAS makes, and the implications for TELAS of unbalanced trade. If we are assuming that we only export to finance our imports, this would require balanced trade (that is the values of your exports and imports would have to be equal). This was not the case for Scotland in 2004. In 2004 Scotland ran a trade deficit with the rest of the UK and with the rest of the world of over £1billion and over £2billion respectively. This means that the value of our exports would not have been sufficient to purchase all our imports. We are therefore assuming in applying this closure method that the region is able to borrow (or through a national transfer) cover this balance of payments deficit[35]. In practical terms the approach here recreates total sectoral output and pollution and so the two identities in Equation 2.19 still hold in this case, it is just that we have redefined the **A** matrix that is used.

What TELAS does is allow us to retain a TAP perspective but attribute these emissions across the local sources of final demand according to the sectoral pattern of imports. This means that local consumption decisions are still driving this attribution, even if they are not directly driving the generation of pollution. If trade were balanced, then the TELAS method applied to the traditional demand driven model would not require the assumption to cover this shortfall.

The unbalanced trade argument is a limitation of the TELAS approach, but the TELAS approach does give us a non-arbitrary way of endogenising trade within the model and reattributing the emissions embodied in exports to each of the remaining categories of final demand (which in this case are all domestic sources of final demand). This approach also gives us the means to re-attribute total domestic production emissions (including those generated to satisfy external demands) in line with the particular region's jurisdictional purview. In other words, this approach reattributes the emissions that are within the domestic regions jurisdictional responsibility for pollution abatement according to the pattern of local public and private consumption, in a sensible manner while respecting the underlying economic relationships.

Results of TELAS approach

It was noted above that in examining the TELAS results an obvious finding is that the total emissions attributed under TELAS are the same as those at-

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[35] This is the same type of assumption that must be made when we endogenise households in the traditional Type II input-output framework (see Miller & Blair (2009)). In endogenising households, payments to employees are generally less than the value of household consumption, because households have non-labour income, for example income from investments. In this case we must assume that the value of transfers covers this discrepancy.

tributed in the Type I analysis above. The purpose of TELAS is to take the estimated Type I emissions embodied in the support of Scottish export activities and to reattribute them across the economy in accordance with the propensity to import of each sector.

This means that the same total level of emissions is attributed as in the Type I case, but these emissions are assigned to final demand according to the purchases of each category of final demand from each trade sector. This reattribution is most starkly demonstrated by comparing the % composition of the final demand drivers of sectoral emissions in Table 2.5 below for the Type-I and TELAS attributions.

External demands are no longer assigned any emissions in the attribution to final demand, since trade has now been endogenised. This results in the percentage of emissions ascribed to domestic household final demand jumping from 42% to 75%. Similarly the % of emissions supported by central government, local government and gross fixed capital formation also jump to 8%, 4% and 11% from 4%, 2% and 2% respectively. This is entirely driven by the propensity of each of the sectors, whose output is being demanded by each category of final demand, to import goods from abroad.

2.7.3 Domestic Technology assumption

Outline of approach

The domestic technology assumption, whose first appearance in the literature is unknown, but which has been discussed and applied in a number of other papers (see Druckman et al. (2008), Druckman & Jackson (2009), Weber & Matthews (2008), Weinzettel & Kovanda (2008), Wiedmann (2009), Jensen et al. (2011a) and Turner et al. (2011b)), is premised on the simple idea that the imports to the subject economy (here Scotland) are produced using domestic technology, or technological processes.

In other words we assume that the country of origin of the imports shares the

Leontief production function that characterises the production process domestically. Within the input-output system this demands the involvement of what is called the combined use matrix. The combined use matrix is structurally identical to the A matrix we introduced earlier, except instead of showing only the domestic intersectoral sales as a proportion of total output, it shows the combined domestic and imported intersectoral sales as a proportion of total sectoral output.

Following our earlier notation, the DTA methodology can be stated as:

$$P = p.[I - (R + M)]^{-1}.(y^R + y^M) + p_c.y_c \tag{2.25}$$

R here is the same as the **A** matrix considered previously in this paper, we rename it here to distinguish its use in this DTA case. **M** here is a matrix constructed on a similar basis to the **A** matrix outlined earlier. In this case each element m_{ij} is the imports by sector j from sector i, per unit of sector j's output.

Equation 2.25 here indicates that total pollution (P) is obtained by multiplying a vector of output-pollution intensities as before, a new Leontief inverse $[I - (R + M)]^{-1}$ based on the combined use matrix (R+M) and a combined final demand matrix (although we exclude export final demand here) $(y^R + y^M)$, then adding directly generated final demand emissions $p_c.y_c$. This approach generates a different pollution total to that calculated in Equation 2.19, and attributes it to what is also a different level and composition of final demand.

In this case we attribute the total pollution that would (hypothetically) be generated in the subject economy, based on the combined use production technology and the sectoral output-pollution intensities, to total domestic and imported final demand. Using the combined use matrix creates a new production function and uses this to estimate the pollution embodied in sectoral final demand.

Another way to think about Equation 2.25 is that we attribute emissions to final demand using two technology assumptions; one relating to the production technology and another relating to the pollution technology. In the DTA case we use the same pollution technology as we use in the Type I analysis (by using the same output-pollution intensity vector- meaning that we assume the same relationship between pollution and output), however we use an assumed production technology represented by the combined use matrix instead of the domestic use matrix in the Type I case.

This assumption is not to say that we believe that imported final demand is produced using combined domestic technology, but only that using this assumption to close the single region input-output model allows us to consider the effect of our consumption decisions (including imports) based on these being produced by a domestic production processes. This can be useful, as Jensen et al. (2011a) and Turner et al. (2011b) demonstrate, in examining some of the jurisdictional issues that are involved in pollution reduction policy.

There are three motivations for using the DTA approach to generate consumption based emissions balances:

1. To overcome data gaps and problems, particularly useful is the ability that the DTA approach provides to utilise a single consistent database.
2. Because we believe that we trade mostly with countries like ourselves.
3. Because we believe, perhaps from a moral perspective, that we ought to be responsible for the emissions that would be emitted if we were to produce all these goods for ourselves. In other words, we believe that we should take responsibility for both our production and consumption decisions in calculating our national emissions total.

Results from DTA approach

The effect of the domestic technology assumption approach can be best understood through the following example. Consider a small regional economy being in autarky[36]- unable to trade with any other country in the world. In this situation, the small regional economy would have to produce all the goods and services that it needed by itself. This would require (from a base as an open economy) either an increase or a decrease in output depending on the current trade balance (i.e. whether there was a trade surplus or deficit). In the context of input-output systems this hypothetical move to 'autarky' changes the fundamental production function underpinning the economy as we discussed earlier.

We are not assuming or implying that the Scottish economy is, or ever will be, in autarky. We are merely considering this hypothetical case to give us another perspective on the emissions embodied in domestic consumption. This case could, of course, rest on any of the three motivations outlined at the end of the previous section for a justification.

We move from a known and measured series of relationships in the Type-I and TELAS environmental input-output models, to a situation where we are considering hypothetical relationships in the DTA model. The standard input-output assumption discussed earlier, that each sector produces a single homogeneous product, becomes somewhat more strained in the context of a DTA model (for example it would assume a single agricultural output).

In addition, the move to a DTA based consumption driven emissions balance breaks the accounting relationship between national emissions balances and global emissions. While it is true that the sum of the territorial production based emissions balances (assuming measurement accuracy!) and consumption driven emissions balances (constructed using perfect data) across all countries, will sum to global emissions, this is no longer guaranteed under a DTA derived

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[36] Autarky is an economic concept referring to a situation where there is an absence of trade. A country is said to be in autarky if it does not engage in any trade activities. In trade terms autarky is completely unrealistic for an open economy like Scotland, however in the context of international emissions reduction it is perhaps less so. It could be argued that the territorial production based emissions balance approach creates a 'pollution autarky' situation, since in this case we only consider the impact of the emissions we generate ourselves. By contrast, following this line of argument, a consumption based emissions total would reflect a version of 'pollution autarky' where we sought to take account of our consumption behaviour in terms of our chosen production decisions.

consumption based measure. So using a DTA approach to derive consumption based measures breaks the accounting relationship that currently holds using TAP based emissions totals, and that would hold using CAP based emissions balances if we had perfect data.

In extending the environmental input-output model to the DTA case we need to be conscious of the opportunities for the under/over estimation of pollution relationships by assuming domestic pollution intensities. This, to a certain extent, is addressed in the DTA (OECD) case below where we allow for a weighted average pollution intensity vector to be used, incorporating estimates of the emissions intensity of production in countries that the UK (and we assume Scotland) imports from, in our calculations. Picking up the agriculture point from earlier, assuming domestic pollution technology (as we do in the full DTA case) is perhaps unrealistic.

For instance, Scotland currently imports bananas and other tropical fruits. To produce these domestically would require a huge investment in the required production process; including extensive inputs of artificial heat and light. So moving to the DTA perspective, while useful and insightful in some senses, is constrained in its realism by the assumption that we can produce all the imported goods using Scottish sectoral average combined use production and pollution technology. This move to DTA therefore stretches the assumption of homogeneous sectoral output when we incorporate 'foreign' sectors[37].

The DTA approach is useful however in giving us a different (consumption) perspective on the pollution relationships in the Scottish economy. As Jensen et al. (2011a) argued, the adoption of the DTA measure allows us to examine from a jurisdictional perspective (i.e. from the viewpoint of jurisdictional responsibility to affect the production technologies employed to produce sectoral output), what a CAP emissions total would look like. That is, retaining the chosen domestic production and pollution technology as the drivers of sectoral emissions generation, what would the CAP emissions total be? Another way

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[37] If we could disaggregate these sectors fully into the actual product being produced, we may find that for some trade flows (for instance tropical fruit) this assumption is very unrealistic.

to think about this is; taking into consideration our production decisions (production and pollution technology) as well as our consumption decisions (how much to consume of sectoral output), what impact do these decisions have- in combination- on the national emissions total?

From Table 2.5 we see that the total emissions balance, estimated for Scotland in 2004, increases in the DTA case from 48 million tonnes of CO_2 to 51.3 million tonnes of CO_2. This is not a huge increase, but is nonetheless interesting. It suggests that the emissions embodied in Scottish imports (measured using Scottish production and hybrid-Scottish pollution technologies) are greater than the emissions embodied in Scottish exports. The emissions supported by household final demands increase under the DTA specification as compared to the TAP specification, this time to 78% of the new higher (hypothetical) emissions balance. Compared to the TAP based emissions total, central government, local government and gross fixed capital formation all have their respective shares of the national emissions balance increase under the DTA specification.

What this tells us, is that when we consider this hypothetical case where we assume that everything we consume is produced using domestic production and pollution technology, that in doing so we would be generating a higher emissions level than we are currently in order to satisfy our current level of consumption. This indicates that the emissions balance currently attributed to Scotland under a production accounting perspective is underestimating the emissions embodied in the current pattern of Scottish consumption behaviour.

The important caveat here is that we are assuming domestic pollution relationships in deriving these estimates. Therefore if the pollution intensity of sectoral production in the countries we actually import from are lower than the domestic pollution intensities used here, we may see this relationship be reversed. This is an issue that we will address later when we incorporate information on the actual sectoral pollution intensity of countries that the UK trades with using OECD data. The next stage is to see whether there are any interesting results from mixing the DTA and TELAS closure methods.

2.7.4 Results from applying a combination of TELAS and DTA closures

TELAS (RUK)-DTA (ROW)

In this case we keep the DTA closure from the previous case for trade with the rest of the world, but this time we adopt the TELAS closure for trade with the rest of the UK. Under one motivation, it is more likely that trade with the rest of the world would be disrupted than trade with the rest of the UK, so under this closure combination we are essentially assuming that we are closed to trade with the world and only export to the rest of the UK to finance our imports from the rest of the UK.

From Table 2.5 this specification increases the national emissions balance slightly relative to the full DTA approach. This means that the emissions embodied in exports to the rest of the UK must be (marginally) larger than the emissions estimated using the DTA approach to be embodied in our imports from the rest of the UK. Similarly by comparing this emissions balance to the full TELAS case we can see that the emissions embodied in our imports from the ROW must be greater than the emissions estimated to be embodied in our exports to the ROW. These results should be contrasted with our results from an analysis of the emissions embodied in trade, later in this chapter, where we use full UK production and pollution technology to estimate the emissions embodied in Scottish imports from RUK.

This measure is perhaps less useful than the full DTA approach in that it does not present a fully consumption-based measure, but the TELAS closure might be of considerable use in closing off single region models to trade with a trading partner for whom a full imports matrix to operationalise the DTA measure is not available (as was the case in McGregor et al. (2008)). Looking at Figure 2.1 this would be the case if we did not have the information required to construct element 5, and therefore could not disaggregate Scottish imports by source sector.

We can also look at the reverse of this case and consider trade with the rest of the UK to be closed off and trade with the rest of the world carried out under the neoclassical view outlined earlier. This approach is much harder to motivate and is only included for completeness and to allow a similar comparison of the emissions estimated to be embodied in imports from the rest of the world under DTA and TELAS.

DTA (RUK)-TELAS (ROW)

This particular combination of trade closures in the Scottish model case is perhaps, from a data perspective at least, more likely to be used. Remembering the outline of the DTA and TELAS approaches given earlier, we need intersectoral trade matrices to operationalise the DTA closure, but only sector import and export totals to apply the TELAS closure. It is more likely in the Scottish case at least, and perhaps more generally with regional input-output models, that we would have the trade matrices for the regions trade with the rest of the nation (here RUK). This being the case we can apply the DTA approach to these trade flows. Meanwhile it may be more difficult to obtain full trade matrices for trade with the rest of the world, in which case the TELAS approach can be utilised.

When we endogenise trade with the rest of the world, and treat trade with the rest of the UK under the DTA, we see from Table 2.5 that the national emissions balance drops from the full DTA case above at just over 51.3 million tonnes of CO_2 down to nearly 47 million tonnes of CO_2. The emissions estimated under this closure approach are in fact also lower than our Type-I TAP emissions. This means that the emissions embodied in our imports from the rest of the UK are less than the emissions embodied in our exports to the rest of the UK. Similarly comparing these results to the full DTA case allows us to confirm, as before, that the emissions embodied in our imports from the ROW are greater than our exports to the ROW. At least, that is, when we estimate these imported emissions using Scottish production and pollution technologies.

The extent of the drop in this case compared to the drop in the previous DTA/TELAS case tells us that there is a much bigger proportional difference in the emissions trade balance between Scotland and the rest of the world than there is between Scotland and the rest of the UK. This reinforces what we established in the previous section with the TELAS (RUK)-DTA (ROW) specification. In addition, what the inclusion of these measures demonstrates is that even without full information for all regions we can obtain national emissions balance estimates using the single region input-output model.

2.7.5 DTA (OECD)

Outline of approach

In outlining the Type I approach earlier we noted that the attribution of pollution to the final demand that it was emitted to satisfy, required the use of two technology assumptions. One assumption relates to the production technology applied, the other to the pollution technology used. In the DTA case we changed the production technology that we had used in the standard Type I case by replacing it with a combined domestic use technology. In the DTA (OECD) case we use the same production technology used in the full DTA case. In the DTA (OECD) case however, we use a different pollution technology than was used in the DTA case.

We replace the assumption of hybrid-UK average output-pollution intensities with weighted output-pollution intensities based on region specific sectoral import propensities. This is a similar approach to that of Druckman & Jackson (2009), who call their approach a QMRIO (Quasi multi regional input-output model). This means that we are replacing our estimates of the sectoral emissions intensity of each sector used in the earlier DTA case with estimates based on region- and sector- specific pollution intensity estimates derived using OECD data.

We will outline the calculation of these new weighted pollution intensities shortly, but intuitively, what we are doing is creating a pollution intensity for each sector which reflects the emissions embodied in the sectoral output used, regardless of source. We take the proportion of sectoral use that is satisfied both domestically and from each trading partner, and combine it with information on the sectoral emissions intensities both domestically and from each trading partner to arrive at a single weighted pollution intensity for each sector. In this way we can relax the pollution technology (or output-CO_2) assumption that we made in the DTA analysis, and utilise an output-pollution intensity that better reflects:

- the propensity to consume domestically produced versus imported sectoral output.
- the propensity to import from different regions of the world with different pollution intensities.
- the emissions embodied in an average unit of output use, i.e. regardless of source.

We do not have bilateral trade data for Scotland, so the bilateral trade weights that are used in this chapter are calculated at the UK level, and applied to Scottish trade totals. We therefore have to assume that these are identical for Scotland in the absence of Scottish bilateral trade data at the same level of disaggregation that we currently have for the UK from the OECD. While we do retain information on Scottish use in constructing the weight, we use UK bilateral trade data to disaggregate Scotland's trade with the ROW by source country (region).

One interesting issue that the DTA (OECD) approach raises, is the potential inconsistency between using a domestic production technology assumption with region specific pollution technologies- in essence exactly what we do in the DTA (OECD) case. Assuming that imports are produced using domestic production technology implies that the inputs necessary to produce those imports are produced using domestic production technologies, but generating the emissions that would be produced using the region specific production technology.

This means that, say we import electricity from France into the UK, in the DTA (OECD) case for the UK the emissions embodied in this trade would be measured as being produced using the supply chain of the electricity sector in the UK, but with the emissions intensity of these imports reflecting the emissions intensity prevailing with a different (French) supply chain. In the French-UK case, this would produce a stark result relative to the actual emissions intensity of these imports given the dominance of nuclear power in the French electricity sector.

The DTA (OECD) case is useful in highlighting differences in the emissions intensity of our imports from different regions of the world. It also allows us to compare the results, taking this into account, with the full DTA case earlier where we assumed domestic pollution intensities for sectoral imports. In order to construct the weighted pollution intensity vector we use bilateral trade data to establish the propensity of the UK to import from each sector in ROW (grouped into regions). We calculate the share of the total UK use of the output of each sector i in each of the other k regions, as well as the share of domestic (UK) produced output use. Intuitively, if 50% of the total UK use of sector i output is produced in the UK and 50% is produced in region 3, the weighted pollution intensity applied to sector i is 0.5 * the CO_2 intensity of the UK sector i and 0.5 * the CO_2 intensity of the region 3 sector i.

We group countries into 14 regions (one of which is the UK), and then using the sectoral propensities to import from each of them, along with the average sectoral output-pollution intensities (CO_2/£million of sectoral output) of each of these sectors in each of these regions, we calculate the aggregate sectoral output-pollution intensity of the UK's imports. Combining this with the domestic output-pollution intensity in line with the propensity to consume domestically produced versus imported sectoral output, we arrive at our weighted output-pollution intensity vector:

$$P_{RDTA} = \sum_{\mathrm{i\,=\,1,\ldots,n}} [(\mathrm{P_I}) \,.\, (\mathrm{S_M})] = \sum_{\mathrm{i\,=\,1,\ldots,n}} \mathrm{p_{RDTA}} \tag{2.26}$$

The vector P_{RDTA} is the row sums of the n x n matrix formed by the product of the pollution intensity matrix P_I (this is the total pollution generated/total output, of each sector in each region) for each of the k regions (in our case there are 14 regions including the UK). P_I is an k x n matrix (regions x sectors). The share matrix S_M is an nxk matrix which contains the share of Scotland's use of each sector's output that in produced in each region k.[38]. The weighted pollution intensity of sector j equals:

$$\overset{\mathrm{j}}{\mathrm{p_{RDTA}}} = \sum_{\mathrm{r\,=\,1}}^{\mathrm{k}} \mathrm{p_r^j . s_r^j} \tag{2.27}$$

Replacing the output-pollution intensity vector p in Equation 2.25 earlier with our new weighted output-pollution intensity, we arrive at a new pollution level. This time, our national emissions total is based on combined use domestic production technology and a weighted pollution technology. This allows us to relax one of the limitations of the original DTA method in imposing the pollution technology of a single region to all imports, and towards a fuller CAP measure. It allows us to better incorporate differences in foreign pollution technologies, while retaining domestic production technology, based on our single region economic database.

This means that the DTA (OECD) retains the jurisdictional advantages of the DTA measure in terms of production technology noted in Jensen et al. (2011a)[39], but with a more realistic treatment of pollution technology (only part of which aligns with domestic jurisdiction since the domestic pollution intensity is included in the calculation of the weighted pollution intensities). This measure uses a single weighted pollution vector to attribute emissions to

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[38] For further details on the construction of the weighted pollution intensity vectors used here, see (Turner et al. 2011a).

[39] In other words, the production technology used to create the emissions balance is a technology over which domestic policymakers have control.

final demand (both domestically produced and imported); a different approach involves the calculation of national emissions using three separate emissions intensity vectors, this is outlined below.

2.7.6 DTA (OECD) with multiple pollution vectors

The basic approach here is the same as that undertaken under the DTA (OECD) approach described above. The only difference is that, while retaining domestic production technology, we estimate the emissions generated in domestic and imported production using different pollution intensities i.e. different pollution intensity vectors are used. The simple approach is, similar to Equation 2.25, that the emissions attributable to domestically satisfied final demand are given by the Type I identity:

$$P_{Dom} = p_{Scot}.(I - R_{Scot})^{-1}.(Y_{Scot}) + P_C Y_{Scot} \tag{2.28}$$

Where Y_{Scot} here only includes domestic final demand (i.e. no imports and excluding export final demand), and p_{Scot} refers to the pollution intensity vector applied to Scotland. The emissions embodied in imports from the rest of the UK are estimated by subtracting the Type I emissions from the DTA emissions (where only trade with the RUK is endogenised). Thus the emissions attributable to Scottish imports from RUK are given by:

$$\begin{aligned} P_{RUK} = {} & [p_{RUK}.(I - (R_{Scot} + M_{RUK})).(Y_{Scot} + Y_{RUKimp})] - \\ & [p_{Scot}.(I - R_{Scot}).(Y_{Scot})] + P^c_{RUK}.Y_{RUK} \end{aligned} \tag{2.29}$$

Similarly we can estimate the emissions embodied in trade with the rest of the world by calculating:

$$\begin{aligned} P_{ROW} = {} & [p_{ROW}.(I - (R_{Scot} + M_{ROW})).(Y_{Scot} + Y_{ROWimp})] - \\ & [p_{Scot}.(I - R_{Scot}).(Y_{Scot})] + P^c_{ROW}.Y_{ROW} \end{aligned} \tag{2.30}$$

The P_{ROW} vector of pollution intensities is constructed using the approach in Equation 2.26 above. What this approach does that the DTA (OECD) approach in Section 2.7.5 does not do, is apply only Type I production technology to estimate the emissions embodied in domestic consumption. It is somewhat notationally messier than the DTA (OECD) approach, and involves three separate models to be estimated, but it does allow a more distinct estimate of each component to be obtained. In the previous case, the same pollution vector is applied to all final demand driven emissions generation activities, and separate pollution technology differences can only be picked up through the weighted pollution vector.

We should note here that there is an important distinction to be made between the calculation of the emissions embodied in final demand, using:

$$P^1_{RUK} = [p_{RUK}.(I-(R_{Scot}+M_{RUK})).(Y_{Scot}+Y_{RUKimp})]-[p_{Scot}.(I-R_{Scot}).(Y_{Scot})] \tag{2.31}$$

and

$$P^2_{RUK} = [p_{RUK}.(I-(R_{Scot}+M_{RUK})).(Y_{RUKimp})] \tag{2.32}$$

The difference is that in Equation 2.31 we calculate the difference between the emissions supported in the generation of the full level of domestic demand and RUK imports using the combined use technology, and the emissions supported by domestic final demand in the production based Type-I attribution. In Equation 2.32 we calculate the emissions embodied in producing imported final demand directly using the combined use technology.

The difference between these two measures of the emissions embodied in Scottish imports from RUK using the DTA, can be ascribed to the influence of the intermediate imports (and the embodied emissions) that are required to satisfy this hypothetical level of final demand. Only calculating the latter measure does not include these emissions. In order for the components to sum to the total of the DTA (OECD) emissions balance, we have to calculate the former measure, i.e. P^1_{RUK} .

2.7.7 Results from DTA (OECD) approach

When we relax the assumption we made in the earlier DTA analysis of domestic pollution technology, but retain the assumption of domestic combined use production technology, we get the DTA (OECD) measure. The most interesting result when we do this for Scotland is that the estimated emissions balance increases from just over 51.3 million tonnes of CO_2 in the full DTA case to over 60.2 million tonnes of CO_2. This large increase is due to the introduction of weighted pollution coefficients that take account of the sectoral pollution content of Scottish imports from different regions of the world. Although we add the caveat that, we are assuming here that the composition of UK and Scottish imports from the rest of the world is the same (since we adopt weighted pollution intensities based on UK trading patterns).

The composition of the emissions attribution across different categories of final demand remains fairly constant (in % terms) between the DTA measure and the DTA (OECD) measure. So despite there being an increase in the total emissions estimate, the attribution is fairly consistent across final demand. The fact that the estimated emissions balance increases, tells us that the domestic emissions intensity of production is lower than that of our trading partners based on these estimates. In the Scottish case, measures that do not allow for differences in the emissions intensities of imports from different countries are underestimating the emissions embodied in imports from these countries.

There are other solutions to this problem which utilise region specific production and pollution technologies to calculate the emissions embodied in trade between regions. The most common approach involves the use of a multi-region input-output model (MRIO). In this paper we do not extend to the multi region case, because of a lack of interregional data to allow us to construct such a model.

Another approach, demonstrated below, uses multiple, stand alone, single region EIO models to estimate what is known as the balance of emissions embodied in trade (BEET) (or alternatively the emissions embodied in bilateral trade (EEBT) Peters (2008)). We carry this out below for Scottish trade with the rest of the UK and the rest of the World using UK production and pollution technology. This approach, unlike the MRIO approach, does not take account of interregional feedback effects, but does provide a straightforward way of incorporating other EIO models without having all the data required for a full MRIO.

We turn now to examine the balance of emissions embodied in trade (BEET) case where we allow for both UK and Scottish production and pollution technology differences. In the Scottish case we again use our hybrid emissions intensity assumption (i.e. we use the full UK intensities except for the electricity sector) as well as Scottish production technologies, and in the RUK case we use full UK production and pollution technology assumptions.

2.7.8 Balance of emissions embodied in trade (BEET)

Outline of approach

Building on the relaxation of the pollution technology assumption in the DTA (OECD) case, we can also allow for differences in production technology in estimating the emissions embodied in imports. One of the simplest ways to incorporate production and pollution information from other regions into the estimation of the emissions embodied in imports, in the absence of an interregional input-output system, is to utilise region specific production and pollution data using region specific environmentally extended input-output models.

The first step in incorporating data from other economic systems is to examine what is known as the balance of emissions embodied in trade (BEET). This is also known as the emissions embodied in bilateral trade (EEBT) method of Peters (2008). Using stand-alone EIO models for each region that we import from we can estimate the pollution embodied in imports from each region (or country). This approach has the advantage of using region specific production and pollution technology, but unlike a full multi-region input-output this approach does not capture interregional feedback effects[40].

This, however, is not an issue where we are carrying out accounting work since this approach can be reduced to a comparison of the domestic emissions embodied in exports from region r to s and from region s to r. The exports are an element of the final demand used to establish the accounting balance using the Type I approach detailed earlier. Thus in a simple two region world the sum of the exports from region r to s and region s to r, combined with the emissions associated with domestic (r and s) final demand will sum to the accounting balances of region r and s combined.

Taking a three region case (Scotland, RUK, and ROW) to explain this point further, let us start with the first part of the aggregate Type I pollution identity from Equation 2.19 above: $P = p.(I - A)^{-1}.Y$ and note that this identity can be separated by each type of final demand, so for example we can decompose the first part of Equation 2.19 for Scotland into:

$$\begin{bmatrix} P^{Scot}_{Scot} & = & p_{Scot*} & (I - A_{Scot})^{-1} & * & Y^{Scot}_{Scot} \\ P^{Scot}_{RUK} & = & p_{Scot*} & (I - A_{Scot})^{-1} & * & Y^{Scot}_{RUK} \\ P^{Scot}_{ROW} & = & p_{Scot*} & (I - A_{Scot})^{-1} & * & Y^{Scot}_{ROW} \end{bmatrix} \tag{2.33}$$

Similarly we can decompose Equation 2.19 for RUK into:

$$\begin{bmatrix} P^{RUK}_{RUK} & = & p_{RUK*} & (I - A_{RUK})^{-1} & * & Y^{RUK}_{RUK} \\ P^{RUK}_{Scot} & = & p_{RUK*} & (I - A_{RUK})^{-1} & * & Y^{RUK}_{Scot} \\ P^{RUK}_{ROW} & = & p_{RUK*} & (I - A_{RUK})^{-1} & * & Y^{RUK}_{ROW} \end{bmatrix} \tag{2.34}$$

Here Y^{Scot}_{Scot} is Scottish domestic final demand, Y_{RUK} is RUK final demand, Y_{RUK} is final demand for exports to RUK, Y_{ROW} is final demand for export to ROW and Y_{Scot} is final demand for exports to Scotland. In summary for Scotland $Y^{Scot}_{Scot} + Y^{Scot}_{RUK} + Y^{Scot}_{ROW}$ sum to total (Scottish) final demand, and thus

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[40] Feedback effects here refer to the use by sectors in region 2 of imports from sectors in region 1, to make output that it sells back to region 1. In a full multi-region model with these feedback effects the final purchase by region 1 of region 2's output would be estimated to include the inputs (and in an environmental context the emissions) embodied in the output that region 1 initially sold to region two, who used it to make output to sell back to region 1.

P^{Scot}_{Scot}, P^{Scot}_{RUK} and P^{Scot}_{ROW} sum to total domestic (Scottish) pollution generation- the same principle applies to RUK final demand and pollution. As before, we proxy for the RUK pollution intensities with UK pollution intensities, and for Scotland with UK output-CO_2 intensities except for the electricity sector where we use an output-CO_2 based on Scottish specific data.

We can see from Equations 2.33 and 2.34 above that from an accounting perspective, re-attributing between the RUK emissions balance and the Scottish emissions balance does not affect the sum of Equation 2.33 and Equation 2.34. We are reattributing between regional emission balances, but it is an accounting exercise since the overall pollution estimate is the same.

The approach taken in the BEET analysis is to estimate region specific output-pollution multipliers for each region or country that the focus country imports from (these are the constant element in Equations 2.33 and 2.34 above- i.e. $p_{Scot*}.(I - A_{Scot})^{-1}$ and $p_{RUK*}.(I - A_{RUK})^{-1}$. Applying these region specific output-pollution multipliers to the volume of sectoral output that we import from each region, we can estimate the emissions embodied in our imports. This means that for imports to region s from each region r we calculate:

$$P^{rs}_I = p^r_I.(I - A)^{-1}.Y^{rs}_I \tag{2.35}$$

The pollution embodied in imports by region s from region r, P^{rs}_I , equals the Type I output-pollution multipliers $P^r_I.(I - A)^{-1}$ for region r multiplied by the total imports from region r by region s, Y^r_s. This information can be used in two ways; it can be used to calculate the balance of emissions embodied in trade (BEET), or we can use it in calculating a CAP emissions total. In calculating a BEET, say between Scotland and the rest of the UK, we simply apply the Scottish output-pollution multipliers to Scottish exports to the rest of the UK, and apply UK output-pollution multipliers to Scottish imports from the rest of the UK.

We calculate the BEET for region s between it and all other regions q:

$$BEET = \sum_{\forall q} P_q^s - \sum_{\forall q} P_s^q \tag{2.36}$$

where: $P_q^s = p^s(I - A_s)^{-1}.Y_q^s$ and $P_s^q = p^q(I - A_q)^{-1}.Y_s^q$, the first expression is the emissions directly and indirected generated in region s to satisfy region q demands, the second is the emissions directly and indirectly generated in region q to satisfy demands in region s.

If we were only interested in the emissions embodied in trade between Scotland, s, and the rest of the UK, r, then the BEET for region s is reduced to:

$$BEET = \sum P_r^s - \sum P_s^r \tag{2.37}$$

If we want to incorporate this approach to estimating the emissions embodied in imports into a CAP calculation for region s, we simply calculate the domestic Type I emissions using Equation 2.19 earlier, but amend the final demand matrix Y to remove export final demand (denoted below as Y^{-E}), while adding $\sum_{\forall q} P_s^q = p^q(I - A)^{-1}.Y_s^q$, giving:

$$CAP = \left[p^s.(I - A_s)^{-1}.Y^{-E} + P_c.Y_c^{-E}\right] + \left[\sum_{\forall q} P_s^q = p^q(I - A)^{-1}.Y_s^q\right] \tag{2.38}$$

The advantage of this approach over the DTA and DTA (OECD) approach in calculating a CAP emissions total is that it allows for region specific production and pollution technology (in the form of pollution-output multipliers for each trading partner or group) in the absence of a full MRIO. The problem is that it doesn't include the interregional feedback effects that are included in MRIO models. In addition, it is worth cautioning that this approach treats all imports (whether imported as intermediate or final demands) as final demand imports.

This is different to the treatment of trade in a multi region input-output model which would include such inter-regional feedback effects. The consequence of this, is that if imports from region 2 are made by region 1 solely to produce exports to region 2, then the emissions embodied in these imports in the interregional input-output system are attributed to region 2. In the BEET framework this feedback is ignored and the emissions are attributed to region 1.

Note also that if the emissions intensities of each of the BEET countries (say Scotland and the rest of the UK) were identical, then what would be driving differences in the output-CO_2 multipliers would be differences in the domestic supply chains of each sector in each region. This links back to the point made earlier in the context of the DTA (OECD) case where we discussed the impacts of different assumptions about the supply chain for each sector and its emissions intensity.

We discussed earlier, in the DTA (OECD) case, the difference between calculating the emissions embodied in imports using a direct approach similar to that in Equation 2.32 above, and noted that this would not include the emissions embodied in the intermediate demands as Equation 2.31 does. However this is not a problem in the BEET case, since we are not using a hypothetical production function (which is what the DTA production technology/function is) to estimate the emissions embodied in imported goods, but instead are using the actual UK production function (as a proxy for the RUK production function) along with the full UK output-pollution intensities (as a proxy for RUK intensities) to estimate the emissions embodied in imports from RUK, which would also be equal to the estimate (using the BEET approach) of the emissions embodied in RUK exports to Scotland[41].

Results from BEET approach

In summary, the approach taken here is to apply domestic production and pollution technology in the form of a domestic Type I output-CO_2 multiplier to

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[41] An interesting extension to the analysis presented here would be to use a UK model with trade with the rest of the world endogenised to estimate the emissions embodied in Scottish imports from the rest of the world.

Table 2.3: Balance of emissions embodied in trade

	(Tonnes of CO_2)
Scottish Exports to RUK	17,644,815
Scottish Exports to ROW	5,820,087
Scottish Imports from RUK	24,510,665
Scottish Imports from ROW	11,221,232
BEET (Exports - Imports)	-12,266,995

domestic exports, and apply the equivalent multipliers for each trading partner to imports by the domestic economy from that country. In our case we apply Scottish Type I CO_2-output multipliers to Scottish exports to the rest of the UK, and UK Type I CO_2-output multipliers to Scottish imports from RUK.

Ideally we would apply RUK multipliers, but data compatibility issues mean that we have opted instead to utilise UK sectoral average production and pollution technology. As before, we apply UK sectoral CO_2-output intensities to all Scottish sectors with the exception of sector 38 (Electricity production and distribution) where we apply the available Scottish sectoral intensity. We also apply the UK Type I output-CO_2 multipliers to imports from the ROW. This is an imperfect assumption, but we are constrained by a lack of data for the ROW at this time. When we calculate the above equations using our data we get the results shown in Table 2.3 below. This shows an estimate of the emissions trade balance between Scotland and the rest of the UK.

The emissions embodied in Scottish exports above are calculated using Scottish output-CO_2 multipliers while the emissions embodied in the imports from RUK and ROW are calculated using UK output-CO_2 multipliers. Ideally we would have world average output-CO_2 multipliers to apply to imports from ROW (or a standalone model for each- or a significant number- of our trading partner), but in the absence of the required data to construct such a measure, we have made the assumption that ROW imports are made using UK average production and pollution technology.

The result of this BEET analysis are interesting, as they show that the emissions embodied in Scottish imports from the rest of the UK are far larger than the emissions embodied in our imports from the rest of the world (13 million tonnes CO_2 larger in fact)[42]. In addition, our emissions trade balance is showing a deficit of over 12 million tonnes of CO_2. This tells us that according to this measure at least, Scotland is 'importing sustainability' and is consuming more emissions on a CAP basis than on a TAP basis. We briefly recap the implications of each measure on the implied emissions trade balance in Table 2.7 below.

The most interesting thing to note about the table below in relation to the BEET calculated here is that the BEET calculation estimates the trade deficit (in terms of emissions) lower than the DTA (OECD) estimate. This result makes sense in light of what we have already said about the higher pollution intensity of production that was derived using the OECD data. We could adapt the BEET procedure carried out in this paper to allow for weighted average pollution technology to apply to imports from ROW, while still retaining UK production technology assumptions. This would move towards a more realistic treatment of the emissions embodied in the production of Scottish imports from ROW, and would generate a new emissions balance estimate.

The emissions trade balance

Table 2.7 below illustrates, for comparison purposes, the implications of each of the national emissions balance measures that we discussed earlier, for the emissions trade balance. In other words it provides an answer to the question: are more emissions estimated to be embodied in our exports than in our imports? We can see from Table 2.7 that in almost all cases, irrespective of the approach

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[42] The emissions embodied in our imports from the RUK are 218% of the emissions embodied in our imports from ROW. It is worth remembering that Scottish imports from the RUK in 2004 were £37,024.8m and from the ROW were £18,700.7m making RUK imports some 198% of ROW imports. The different scale of trade with RUK and ROW probably explains part of the difference between the emissions embodied in Scottish imports from RUK and ROW. There will also be differences in the sectoral composition of trade.

taken to estimate the emissions embodied in imports, Scotland is estimated to run an emissions trade deficit- in other words the emissions embodied in our imports are greater under all these measures than the emissions embodied in our exports. This raises interesting questions for policymakers, such as: since we have emissions reduction targets based on reducing our TAP emissions total, should these be more stringent since we are augmenting our TAP emissions total by importing the product of pollution generating processes?

The only case where Scotland is estimated to run a trade surplus is in the DTA (RUK) TELAS (ROW) closure case. In this case the emissions embodied in imports from RUK are estimated using domestic combined use technology and domestic pollution intensities. Trade with the ROW has been endogenised in this measure and the emissions embodied in Scottish exports re-attributed across the Scottish production sectors. Therefore, relative to the full DTA case, this formulation (DTA (RUK) TELAS (ROW)) underestimates the emissions embodied in imports.

2.7.9 Comparing the UK and Scottish Pollution intensities of Electricity Production

We made clear earlier that because of data problems with the Scottish air emissions inventory, we had opted to utilise the UK CO_2 emissions intensities for all sectors except the Electricity production and distribution sector, for which we use the Scottish CO_2 intensity (reported by the Scottish Government as an experimental statistic). This was because we understood that the data on this sector within Scotland are good, and therefore we could have more confidence in this sector's emissions intensity estimate, than we had for other sectors.

In addition, we were keen to use the Scottish CO_2 intensity for the Electricity production and distribution sector because of the key role we know that the Electricity production and distribution sector plays in both emission generation and in Scottish trade. To illustrate the importance of the Electricity production and distribution sector in estimating Scotland's national emissions balance,

Table 2.6 below provides the same range of national emissions total estimates as we considered in Table 2.5 already, but in Table 2.6 we utilise the full UK emissions intensities.

Before discussing these results, recall our earlier discussion of the SEI/University of Leeds estimates of Scotland's consumption emissions. The results presented here, where we compare the impact of assuming a UK average pollution intensity for the Scottish electricity sector to adopting the Scottish specific emissions intensity for the electricity sector, are presented in the hope that they may allow us to better understand the SEI/University of Leeds estimates for Scotland. Note that we, ourselves, applied UK production and pollution technology in the preceding section (on the balance of emissions embodied in trade) to estimate the emissions embodied in Scottish imports from the RUK- believing it to be a reasonable approximation for the rest of the UK.

In this section we compare, on an identical basis, the emissions totals for Scotland which have been presented in Table 2.5, with the only difference being to assume a Scottish specific intensity for the largest emitting sector in Scotland (the Electricity production and distribution sector). The SEI/University of Leeds study goes further than we do in Table 2.6 by assuming UK production and pollution technology for all sectors. We offer this example as illustrative of the impact of using region specific data for the region rather than national average data.

At the bottom of Table 2.6 we examine the difference between the two emissions balances, the only difference being the use of either UK or Scottish electricity sector pollution intensities. We can see that the impact of this change is surprisingly large. This one change increases the Scottish TAP emissions total by nearly 18 million tonnes of CO_2; this is a 37% increase in the Table 2.5 emissions balance estimate.

The other emissions balances similarly increase following the change to a full UK emissions intensity assumption. The smallest % change occurs in the DTA (OECD) case, which makes sense, since the UK electricity sector pollution intensity enters the calculation of the overall emissions intensity vector in a weighted form in the DTA (OECD) case. The comparison between Tables 2.5 and 2.6 makes a couple of interesting points.

First of all, it shows the importance of the electricity sector to the national emissions balance estimates. Secondly it illustrates the impact of Scotland's lower emissions intensity of electricity production (compared to that of the UK) in terms of estimating Scotland's TAP emissions total and thirdly it demonstrates how important any reductions in individual sectoral emissions intensities can be. Specifically it illustrates for Scotland the importance of the electricity sector in affecting national emissions.

Fourthly, and perhaps most importantly, when we compare our results to the estimates produced by the University of Leeds[43] we can see that the University of Leeds estimate is similar to those obtained in the DTA (OECD) case in Table 2.6 here. The University of Leeds estimate consumption emissions in 2004 in Scotland to be 74,595 kT CO_2 compared to our estimate using full UK pollution technology, and incorporating OECD data on the pollution intensity of production in other regions, of 77,429kT CO_2. So, despite the University of Leeds estimates employing a seemingly more elaborate methodology to estimating the emissions embodied in imports from ROW, our DTA (OECD) estimates of Scottish consumption emissions from Table 2.6 are very similar to theirs.

When we use a Scottish-specific pollution intensity for the Electricity production and distribution sector (see Table 2.5), we can see that estimated consumption emissions drop by some 17,212kT of CO_2 or 29% (see Table 2.6). This suggests that if the University of Leeds researchers used region-specific emissions intensity data for Scotland instead of the UK- even if only for the Electricity production and distribution sector as we do here- they would derive a far lower estimate of consumption emissions in Scotland than they currently do. In other words, the methodology employed by the University of Leeds, and relied upon by the Scottish Government, may be producing estimates of Scot-

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[43] Available from: `http://www.scotland.gov.uk/Resource/0039/00392289.xls`.

tish consumption emissions that are far too high as a result of not using region specific environmental data.

2.8 Policy implications of each measure

The liberal economist's world view seems to reflect a belief that when a system of regulation (whether based on taxation or not) is constructed, it is generally the case that the people covered by that system -while (for the most part) meeting their obligations- also minimise the cost of their compliance. Put differently: they minimise its effect on them. It is this simple economic conclusion for example that drives the standard result in environmental economics that environmental taxes or tradable pollution permits are efficient instruments for reducing pollution. Firms are assumed to find the least cost way of complying (see Baumol & Oates (1988)) thus achieving the desired pollution reductions while minimising costs.

In the context of international climate change and emissions reduction schemes, there has (arguably) been a similar cost minimisation approach by signatory states. The original Kyoto Protocols required signatory countries to reduce their production emissions to a particular level, relative to the base year, by a certain point in time. The logical response to such a policy commitment for a lot of countries, given the costs involved in investing in pollution abatement technology, was to export the most polluting parts of their production processes abroad[44], beyond their territorial responsibility, creating so called 'pollution havens'[45]. Bergman (2005), for example, argues that the "international reloca-

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[44] Estimates of the magnitude of this kind of 'leakage' by Pezzey (1992), who examined the impact of the adoption of unilateral 20% emissions reductions relative to a base year by EU and OECD countries was 70%. Bergman (2005, p1293-1294) provide a useful review of estimate of this 'leakage' using environmental CGE models.

[45] The pollution haven hypothesis is well defined by Zeng & Zhao (2009, p141):"The so-called "pollution-haven" effect/hypothesis states that pollution-intensive industries will, in response to globalisation (e.g., freer trade or capital mobility), tend to move to countries with laxer environmental regulations". It is also well defined by Bommer (1999, p342): "Unilateral increases in environmental control have frequently been objected to on the grounds that domestic firms may lose their competitive edge to foreign competitors who are not subject to the same restrictions. According to this line of reasoning, domestic firms shift their production, and hence employment, to countries with less restrictive environmental standards. This is the so-called pollution-haven hypothesis."

tion of economic activity is a key potential response to unilateral environmental policy measures" (Bergman 2005, p1289).

The idea of importing sustainability by exporting the most polluting of our industries, as opposed to reducing the emissions that our behaviour supports, would seem to be what the UK did (see Druckman et al. (2008)). They show that while the UK met its Kyoto obligations, it did so while increasing the emissions embodied in UK consumption. In the terminology of carbon accounting, the UK's TAP emissions total may have been falling, but the CAP emissions total was rising. This result is, in part at least, driven by the fact that while certain technological changes (moving from coal to gas electricity production) led to 'absolute decoupling' of household consumption demand and CO_2 emissions, this decoupling was much weaker outside of this period of transition in the electricity market[46].

A less pessimistic interpretation might be that the UK did indeed reduce its production emissions, but by investing in emissions abatement and a more emissions efficient capital stock, rather than shipping its most polluting industries abroad. We suppose also, that it could be argued that the UK governments desire to reduce our domestic pollution generation through tighter regulation in order to meet their Kyoto target was what drove the polluting industries out. Regardless of what combination of domestic action or inaction led to the reduction in TAP emissions, UK TAP emissions did reduce to below the agreed Kyoto level. The UK was committed to a 12.5% reduction in territorial emissions by 2008-12 through the Kyoto agreements, the UK has in fact reduced its territorial emissions by 26.4% by 2011[47].

We offered the UK TAP emissions example above to demonstrate that when Kyoto was agreed, the treaty created certain strategic incentives that ran counter to the spirit if not the letter of the agreement, and that some countries

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[46] A recent report by the UK Parliament's Energy and Climate Change Select Committee, on the topic of consumption accounting, has a useful overview of the historic reasons which underpin the fall in UK territorial emissions. The report is available at: `http://www.publications.parliament.uk/pa/cm201213/cmselect/cmenergy/488/488.pdf`.

[47] See: `http://www.decc.gov.uk/assets/decc/11/stats/climate-change/6369-uk-greenhouse-gas-emissions-reductions-where-are-.pdf`.

have been accused of responding to them. Now, as we discussed earlier, it is true that a global system of TAP based targets would achieve the desired result in terms of emissions abatement, provided every country reduced the emissions they produced in line with the targets.

The difficulty with the Kyoto protocol was that, in order to get agreement from developing countries on the need for emissions reduction efforts, it exempted a series of developing countries from having to make any emissions abatement effort at all (referred to under the UNFCC as transition or non-annex I countries, which notably includes Brazil, India and China). The treaty thereby created a situation where countries who were covered by the treaty could export their polluting industries to the those countries not covered by the treaty, without penalty. Which is what has been argued, did indeed happen.

This meant that the countries which were not covered by the Kyoto protocol received additional economic activity in the form of additional foreign direct investment. As a consequence, those countries which were covered by the treaty were provided with an easy means of complying with their obligation. Or in the case of firms, an easy means of avoiding additional environmental levies; which were introduced in those countries covered by the treaty as a mechanism for meeting their Kyoto obligations.

The incentives that each country had to agree to the Kyoto protocols are important in understanding the outcome of that series of negotiations. For instance, in the developed world it could be argued that heavy (pollution intensive) industry was already in decline in many developed countries by the time that the Kyoto protocols were agreed and thus a reduction in TAP emissions was already underway and would continue.

This kind of argument, generalised to all developed economies, suggests that richer countries could sign up to these targets, while understanding that in doing so the effect would be partly (or largely in some cases) offset by the changing composition of industries in the economy. One indicator of this decline would be an assessment of whether or not there was a decoupling of overall economic growth and growth in highly pollution intensive industries. In other words, whether the growth in the economy outpaced the growth in pollution generation, this would be the decoupling of economic growth from its environmental impacts.

Jänicke et al. (1997) examining the period since 1970 for a number of major economies indeed found such a decoupling in the case of: Australia, Austria, Belgium, Canada, Denmark, France, Germany, Ireland, Italy, Japan, Luxembourg, Norway, the UK and the USA (Jänicke et al. 1997, p477). Less developed countries, which were largely exempt from obligations under Kyoto, were able to accept-without penalty under Kyoto- the inward investment to fund the creation or expansion of dirty industries[48]. We have not demonstrated here that they did in fact do this, and the evidence is not settled, but it could be argued that doing this is both logical and (from an economic perspective) rational.

The point that we're making is that developing countries could do this if they wanted, and in so doing could perhaps spur on the industrialisation process. However, a range of studies suggest that the overall effect of this industrialisation in developing countries has not created the anticipated pollution havens (see for example, Birdsall & Wheeler (1993), Jaffe et al. (1995), Jänicke et al. (1997), Mani & Wheeler (1998) and Dietzenbacher & Velázquez (2007)). This is perhaps to be understood, as Mani & Wheeler (1998) argue, as stemming from the fact that 'economic growth brings countervailing pressure to bear on polluters through increased regulation, technical expertise, and clean-sector production' thus perhaps explaining the lack of evidence in these studies to support the pollution haven hypothesis.

On the other hand, there have been studies which have found evidence of pollution haven effects. Cole (2004) for example, who nonetheless finds that the

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[48] This implies that the UK was pushing up the TAP emissions totals of other countries in the world. In the case of developing nations, one of the difficulties in assessing the impact on their emissions total of the shift towards reducing TAP emissions in the developed world, is that the reason developing countries were exempt from the Kyoto obligations was that their TAP emissions were anticipated to rise with industrialisation. The difficulty then arises as to how to disentangle the increase due to domestic industrialisation from the increase due to a 'pollution haven' type effect.

effect is small, Levinson & Taylor (2008) who find evidence of a pollution haven effect by examining trade flows between the United States and its two nearest neighbours; Canada and Mexico, Wagner & Timmins (2009) who find evidence using German trade data and Kellenberg (2009) who argues that the pollution haven effect affects more 'footloose' industries than heavy industries. It should also be noted that Wagner & Timmins (2009) and Levinson & Taylor (2008) both note the impact that incorrect econometric estimation methods can have in biasing against a finding of a pollution haven, which they both argue may have led to some erroneous conclusions in previous studies.

A final study that is worth drawing the readers attention to is Cole & Fredriksson (2009). They examine the pollution haven hypothesis in terms of whether foreign direct investment (FDI) affects environmental regulation. Essentially they want to know whether environmental regulation decreases with increasing FDI (in terms of both stocks and flows)- so far a fairly standard version of the pollution haven hypothesis. Where their approach is notably different though is that they control here for the nature of the domestic governance. In other words, they control for the institutional structures in place in the country in question (unicameral/bicameral legislature etc) and the number of different political parties in the Government.

In addition, they make environmental stringency endogenous to test whether the level of environmental stringency affects the FDI flows. This is in contrast to the traditional 'pollution haven hypothesis' view that the level of FDI flows affects the level of environmental regulation. They conclude that environmental stringency is an important determinant of FDI. Further, they conclude that FDI has a greater impact on environmental stringency when the number of 'legislative units' is lower. The pollution haven hypothesis literature has been briefly reviewed here to give some context to the policy discussion in this section. As we have seen, there are studies that suggest both that there is, and that there is not, a pollution haven effect in international trade- depending on the trade relationships examined and the methodology employed.

TAP measures may create an incentive to outsource heavy polluting industries, and there is some evidence to suggest that this has happened, largely stemming from a divergence in growth of pollution intensive sectors and the overall economy and the pollution haven. However, while this may give rise to growth in these industries in developing economies, it could be argued (and has been documented) that the countervailing economic forces from the industrialisation process may offset the incentives for environmental degradation in developing countries. The purpose of this Chapter is not to evaluate these studies of the 'pollution haven' hypothesis in detail, but this short review is offered by way of a narrative against which the debate on TAP versus CAP measures is being held.

It is worth noting two simple facts here. Firstly, as we stated earlier the difference between TAP and CAP essentially reduces to an analysis of the emissions embodied in trade. Secondly, assuming perfect compliance, monitoring and reporting, then both the CAP and TAP emissions measures should (globally) sum to the same total. Of course, measurement issues perhaps prevent the CAP measures from summing to the same global total as the TAP emissions in practice. In principle though, these two emissions balances at the global level are the same.

Regardless of whether there is a TAP or a CAP system in place, there will be loopholes and in the absence of a comprehensive international agreement these loopholes will be important. The range of closure mechanisms discussed in this paper all have appealing attributes, some much more than others, as the basis for CAP measures. It has been acknowledged already (see McGregor et al. (2008) and Jensen et al. (2011a)) that there is a jurisdictional issue here that cannot (in the absence of a full international agreement with enforcement powers) be ignored. One example of this arises from the fact that while the UK has some ability to influence the production and pollution technology employed in Scotland, it has no such ability in China. This immediately creates a problem and gives rise to a potential loophole.

If a country cannot be held responsible for the behaviour of their trading partners, what incentive do they have to try to affect it? They can't change it, so why should they be concerned about it[49]? Under a TAP framework China's emissions are China's problem. Under a CAP framework, a country may be penalised for buying goods from China which embody pollution, but they can't affect China's choice of production technology- so what can they do? Impose tariffs on Chinese goods[50]? In fact, in the absence of a global CAP based emissions reduction agreement being in place, the impact on a small open economy of it unilaterally adopting a full CAP measure based on foreign production and pollution technology, would surely be negative in economic terms.

Essentially it would mean accepting much higher prices for imported good in the domestic economy (assuming the adoption of some form of penalty being imposed on imported goods to raise the price of pollution intensive imports) in the pursuit of unilateral emissions reductions. Further, this emissions reduction may only be hypothetical if there is excess demand elsewhere in the global economy that will replace this drop in demand, i.e. the emissions may be released regardless, but the goods sold to a different buyer, leading to no improvement in environmental quality, but increased prices in the country that acts unilaterally[51].

There has been some work already (see Steckel et al. (2010)) which has looked at the effects of different global TAP and CAP agreements, and they demonstrate that where the system is a global agreement supported by a competitive carbon market, switching from TAP to CAP measures has "neither efficiency nor distributive effects" (Steckel et al. 2010, p781) with distribution

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[49] It may also be the case that one country or region is concerned about the emissions being generated by their trading partners. The difficulty then becomes how that country or region can address another countries impacts on their wellbeing, and the standard public good arguments arise.

[50] Interestingly, Fischer & Fox (2011) note a recent (failed) attempt in the United States to legislate for a tax based on the emissions content of imports. Interestingly Bernard et al. (2007) demonstrate that in cases where the polluting firms are outside the jurisdiction of a country, the second-best outcome is a form of import-taxation based on the emissions content of imports.

[51] There is also the issue of the political feasibility of such trade measures that would, it can only be conjectured, penalise cheap imports of clothing and food- the effect of which would surely be regressive.

effects contingent on the allocation of targets (and thus pollution permits) between countries, which in the presence of a competitive carbon market will ensure efficiency.

They conclude that regardless of the global emissions agreement framework that is adopted, with a global cap and trade scheme, the carbon costs under both TAP and CAP will ultimately be borne by the consumer. Steckel et al. (2010) also examine the preferences of carbon exporting economies between CAP and TAP measures, concluding that they are “not obvious” (Steckel et al. 2010, p780). This result Steckel et al. (2010) argue depends in their analysis on the allocation of permits. In this way, the market deals with the efficiency dimension, while the initial endowment deals with the equity issue.

Part of the reason for this result lies in the fact that both TAP and CAP schemes supported by a permit system provide compelling incentives to signatory countries to meet their obligations in the lowest cost manner. A permit scheme would ensure that those with abatement costs less than the permit price would abate these emissions, while those with abatement costs greater than the permit price would purchase a permit to cover these emissions, the permit scheme thus limits the volume of emissions that can be released in the lowest cost manner. We presented a range of results earlier that offer different ways of calculating CAP emissions totals while dealing with the issue of jurisdiction, but each of these measures still retain their own strategic incentives.

Taking them each in turn, we firstly look at the TELAS approach. Under this approach, we are simply closing the model by reattributing the TAP emissions embodied in exports across the sectoral imports. This approach is therefore still vulnerable to the strategy of exporting our polluting industries in order to minimise our territorial pollution levels and thus our emissions embodied in exports. The use of TELAS itself is entirely consistent with TAP emissions totals, but using TELAS still exposes it to the policy critiques of the TAP measures.

In defence of TAP based measures, if there were an international organisation which policed the agreed and binding global TAP measures, there is no obvious reason why it would not be as effective as a CAP measures. The lack of international coverage and the absence of enforcement mean that the incentive to export polluting industries might dominate (and arguably in some cases this has already happened). Next we introduced the Domestic Technology Assumption (DTA) approach. The DTA approach creates an incentive for the focus country to specialise in producing goods and services which it does not consume.

Under the DTA based CAP total, a country specialising in the production of goods that it does not consume, or at least doesn't consume much of, and not producing goods that it does consume, could minimise its emissions total. This would mean that where the sectoral output-CO_2 multipliers were high, final demand was low and vice versa. This is because the output-CO_2 multipliers are based on sectoral pollution intensities and the volume of domestic economic activity required to produce sectoral final demand. If you have higher output-CO_2 intensities in sectors where you don't consume much of the output, this does not affect your CAP total, since you are producing for export[52].

With a CAP based emissions total calculated using a full multi-region input-output model with each country separately identified in terms of both production and pollution technologies used, you would want to reduce your output-CO_2 multipliers in sectors where you do consume as well as being conscious of the emissions embodied in your imports from abroad (and perhaps there is room for a substitution effect here).

Now, returning to the DTA based CAP measure, the extent to which any economy could feasibly operate by producing in heavy polluting sectors largely for export is an open question[53], but that under a DTA CAP measure such

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[52] There is a broader point here, which is that under the CAP approach (regardless of how this is calculated in principle) where the emissions embodied in an imported item are greater than those embodied in an equivalent domestically produced item the CAP total will be increasing in the imports of this good. Similarly, all CAP measures provide no disincentive to generate domestic pollution in support of export demand.

[53] But as Turner et al. (2011b) demonstrate in the case of Wales this type of relationship does currently exist. Wales produces a significant volume of CO_2 emissions in the production of export, very little of which are used by domestic (Welsh) firms and consumers.

an incentive exists is indisputable. A similar if not as strong incentive exists under the DTA (OECD) approach for similar reasons, although the presence of weighted pollution coefficients offsets some of the advantage.

We noted earlier that there had been a discussion in the literature on the issue of jurisdiction in pollution abatement between a nation and its regions. In the case of Jensen et al. (2011a) the particular issues faced was the devolution of responsibility in Wales, contrasted with the overall responsibility of the UK. One of the most obviously outstanding issues from the implementation of both national and regional emission reduction targets is the effect that one region having unilateral territorial targets has on the ability of the overall national unit (in this case the UK) to achieve its national targets, and to do so in the most efficient manner.

The creation of region specific emission targets, like those in the Scottish Climate Change Act, could prevent the full realisation of regional specialisation in lower carbon goods and services. A simple example to explain this point relates to the electricity sector in Scotland. Before discussing this example, we should add the caveat that this example is offered to illustrate a particular point about UK regional economic and environmental interdependence. The electricity sector in Scotland as in the rest of the UK is covered by the European Union Emissions Trading Scheme (EU-ETS). This is a tradable emissions permit scheme.

As a result of the EU-ETS any reduction in the direct emissions of the 'covered' sectors (i.e. sectors 'covered' by the EU-ETS), of which electricity is an important one, are taken as given. Permits are only issued to the value of the EU wide emissions target level and thus countries 'automatically' meet their targets in the covered sectors. This means that the example we are about to outline is not strictly applicable because it is complicated by the operation of the EU-ETS. If a country or a region opted for greater electricity sector emissions reductions than under the EU-ETS however, this example is still useful given the clarity of the impact.

We noted earlier that in the domestic (Scottish) results presented above we had used the full UK sectoral emissions intensities with the exception of the electricity sector. This was because we knew that the underlying data for the electricity sector was more robust, and thus we had less of a concern over the accuracy of the data on the emissions intensity of the electricity sector than we had for the other sectors. One of the other reasons we did this, was because the difference in the Scottish and UK electricity sector emissions intensity is very large.

The UK 2004 electricity sector emissions intensity was 5,429 tonnes of CO_2 per £1m of output, as compared to only 2,615 tonnes of CO_2 per £1m of output in Scotland. See Table 2.6 to see the effect of this difference in the output-CO_2 intensity of the electricity sector in Scotland compared to the UK, on the Scottish national emissions total.

We already know that Scotland exports a large amount of electricity to the rest of the UK. Clearly, if this was to stop, then the emissions generated by the requirement for the rest of the UK to make this electricity themselves[54] would be higher than that which is currently generated in Scotland to meet this demand. So, through inter-regional trade, overall UK emissions are reduced by Scotland producing electricity for export to the rest of the UK.

If we follow this to its conclusion we can see that an argument could be made for Scotland to specialise in producing electricity to supply to the rest of the UK, since for every unit of electricity generated in Scotland to replace a reduction in generation in the rest of the UK, total emissions generation is lowered. However, if this was done, Scotland could not hope to meet its Climate Change (Scotland) Act targets, since the production of electricity in Scotland is less CO_2 intensive but certainly still has an important CO_2 impact.

This would mean that despite the fact that we would be achieving an overall reduction in UK emissions, we would still not be making any contribution

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[54] It is also possible that the RUK would substitute by importing electricity from, for example, France, which depending upon the emissions intensity of French electricity production may have a positive or negative impact on the RUK .

towards meeting the Scottish Climate Change targets. Of course, this is only one sector we are considering, but it is offered as an example of the issues raised by having both national and regional binding climate change targets that focus only on total emissions generation.

Needless to say that in the electricity sector in Scotland there may be supply constraints which would prevent the Scottish electricity sector from being able to meet increased levels of demand for its output from the rest of the UK in the short run, and in the medium run it may not be able to do it in a way that also delivers on the low emissions intensity that it currently has. Similarly, we have not commented here on whether the rest of the UK could achieve a similar reduction in the emissions intensity of electricity production more cheaply in other ways.

Put differently, we have not said anything about whether the same emissions reduction could be achieved more cheaply by reducing the emissions intensity of electricity production in the rest of the UK, as opposed to through other means while continuing to buy Scottish electricity. The route which would be more efficient for the rest of the UK to reduce their emissions is unclear. For these reasons there may be an argument for policy coordination in the setting of emissions targets[55].

One approach to dealing with the issue of regional versus national targets in the presence of both economic and environmental interdependence would be to parallel the current arrangement that operates under the Kyoto protocols for the EU-15. Under what is known as a 'bubble' arrangement in Article 4 of the Kyoto protocols, groups of signatory countries can pool their commitments together and "differentiate targets internally" (Michaelowa & Betz 2001). Essentially a group of countries can agree that in total they will meet the sum of their individual Kyoto emissions reduction targets, but that they need not all meet their own individual Kyoto targets.

A similar system could be put into operation in the UK, and would permit

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[55] This is not just a problem for environmental policy. There is a strong argument for policy coordination across devolved regional governments in a range of policy areas.

the flexibility that would allow for interregional production changes to realise the lowest cost or most efficient emissions reduction solution. We can only speculate on the motives of the Scottish Government in adopting their own targets (perhaps in an attempt to demonstrate global leadership on this issue or to fulfill the political objectives of the politicians in office at that point), but given that the Scottish Government do not have the full range of policy levers available to them (energy policy for example is reserved to the UK Government) might such a bubble arrangement assist in reducing global emissions more efficiently than overlapping territorial emissions targets?

Now, we have not established here that the presence of both regional and national targets has restricted the attainment of the most efficient emissions reductions strategy, but it should be clear that the presence of multiple targets could (at least in theory) prevent regional specialisation that decreased national emissions at the cost of increased emissions in that particular region. At the very least, this is an issue which should be explicitly considered in the design of emissions abatement policies.

The issue of regional versus national emissions regulations was raised recently by Goulder & Stavins (2011). They discussed the operation of national (federal) versus regional (state) level climate change policy instruments and illustrated the conflicts and 'problematic' interaction effects that can and have occurred. One example relates to the operation of federal and state fuel efficiency standards. In essence, the federal government set car manufacturers an average fuel efficiency standard for the cars they produce, and some states have also adopted their own standards through average emissions per mile standards (which effectively mandate higher fuel efficiency standards).

This overlap has meant that car manufacturers have met the tougher standards that are set at the state level in those states that operate such a standard. One side effect of car makers meeting these state level standards, is that the US federal average fuel efficiency standard is being exceeded by these same car makers in those states that do not have average emissions per mile standards.

The federal (national) constraint, as Goulder & Stavins (2011) argue, no longer binds car manufacturers.

Car makers can exceed the federal standard in some states, because they are more than meeting the federal standard in states with a stricter state level fuel efficiency standard. Estimates place this ‘carbon leakage’ at around 65% (Goulder & Stavins 2011) - meaning that 65% of the emissions reduction achieved by states adopting their own standard are being lost to increases in emissions in the states without their own emissions per mile standard. This reinforces the need for these interdependencies to be explicitly considered in the design of regional climate change policy instruments.

Another question that arises is the extent to which opportunities for emissions reduction are matched with policy responsibility. For instance, energy policy in the UK is reserved to the UK Government, but sustainability and planning policy is devolved to Scotland. This hasn’t hindered the Scottish Government from pursuing the development and construction of large renewable energy sites, but perhaps would be an issue if the UK government was against nuclear power and the Scottish Government wanted to build a new nuclear power plant. This is the reverse of the policy positions of the current UK and Scottish Governments.

We note this here to illustrate that there are more issues involved here than simply the coordination of emission reduction policy, there is also a coordination of government action in other areas which feeds into emissions abatement policy, and this involves coordinated government action consistent with the devolution of powers to the regions. In the next chapter we begin to look at sectoral level impacts and relationships using the tools and techniques of key sector analysis, and this discussion will reappear. For now, we return to discuss a final outstanding issue with the DTA measures discussed in this paper.

The DTA approach outlined in this paper is of more use in the context of some pollutants than others. It is questionable how much use a DTA approach would be where the pollutant is more geographically limited in its impact. A good example would be water pollution. While for air pollution (like CO_2 emissions) we can consider that each country is contributing to the 'global pool' of emissions, the same cannot always be said for all water pollution. This is worth noting, and it would obviously have big implications for the use of this measure in assessing performance against a CAP target for pollutants that do not have the same global scope for their impacts as air pollution does.

This is one case where the TELAS approach may be particularly useful, i.e. where we have a locally contained pollutant. The TELAS closure which is consumption demand driven but territorially limited, implies that the 'cost' of this pollution is locally imposed, unlike the case of GHG emissions which contribute to a global public 'bad' and global 'costs'. In the TELAS case for a locally contained pollutant, we would be attributing all of the generation of this local pollutant to local demands.

In particular, we would be attributing the pollution generated to meet external demands to the imports by local final demands. This means that the pollution, and by extension the cost of this pollution, is thought to be the responsibility of domestic consumers (public and private), and that the pollution generated to produce exports is the 'cost' incurred for demanding imported goods and services.

There are other issues that these measures do not address, for instance the attribution of international transportation emissions and the impacts of carbon offsetting activities. In the case of international aviation and maritime emissions, a system to divide these emissions up across nations in a manner that is considered fair by all is needed. As it stands, only the airport and dock emissions (and emissions embodied in airport and seaport purchases) are included in the domestic emissions total calculation.

In the case of carbon offsetting, these activities take two principle forms: 1. action taken by domestic companies and consumers to support offsetting activities, and 2. the relative ability of the domestic ecosystem to absorb our CO_2 emissions. Trees absorb CO_2 from the atmosphere as they grow, so in simple terms the more trees a country plants and has growing the greater its contribution towards the absorption of CO_2, and is tree cultivation not something that we want to reward? Now one of the issues here, and it is highly relevant to Scotland, is that CO_2 emissions absorbed by trees or contained in peat bogs can be substantial.

In Scotland, according to a report commissioned by the Scottish Government Nayak et al. (2008) some 11, 000 million tonnes of CO_2 is contained within Scotland's peat bogs. If we allow the peat bogs to dry out, or we allow deforestation to take place, these emissions will be released. So the rewetting of the peat bogs, and the planting of additional trees to absorb CO_2 from the atmosphere are important environmental mitigation measures. These are issues beyond the scope of this paper, but they are issues that need to be addressed. We cannot hope to fully capture domestic emissions generation under either a TAP or CAP measure until we fully account for all sources, but also reward offsetting activities that reduce the stock of CO_2 in the atmosphere[56].

2.9 Conclusions

This paper has presented a series of carbon accounting measures for Scotland. In addition this paper serves as the basis for the use of the input-output methodology in subsequent parts of this thesis and as such devoted a significant amount of space to a detailed explanation of the underlying input-output system. Our purpose here was to examine what the environmentally extended input-output system could tell us about the underlying environmental-economic relationships (particularly relating to trade) within the Scottish economy through the prism of what has become known as 'carbon accounting' methods.

In this paper we outlined a range of both TAP and CAP measures that can be constructed using the single region Scottish input-output system. Having

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[56] There is a version of the environmentally extended input-output model developed by Leontief (1970) that includes a cleaning sector, which makes the removal of pollution endogenous to the model.

done so we proceeded to discuss what these measures told us, and importantly what these told us about the underlying economic and environmental relationships. We saw the impact of endogenising trade and the emissions embodied within them, and the impact of assuming domestic production and/or polluting technology- in the estimation of the emissions embodied in imports- on the national emissions total.

We also extended the single region case to include information from other input-output systems in the BEET analysis that we carried out by incorporating into our calculation, production and pollution information from the UK input-output system. This allowed us to compare the various emissions estimates of imports that each measure derived, allowing us to compare the effects of different assumptions on this total. Having done so, we tried to set these measures into a policy context. As we argued, in the absence of complete international agreement it is easy to see how each measure that we propose can be manipulated to minimise the actual global emissions reduction activities of each signatory country.

This paper has presented a macro level overview of the emissions-economy relationship in Scotland. It has done this in part to set the scene for what follows in this thesis. In order to better understand these macro-level results, it is necessary to examine the sectoral level interactions that characterise these relationships. We need to know, for example, which sectors have pollution intensive supply chains, which sectors drive emissions growth the most if there was a uniform growth in export demand- one of the Scottish Government's stated routes to economic growth in Scotland- what are the 'key' sectors in Scotland (in terms of the environment and the economy) and other similar questions.

These and other questions are the subject of the next chapter on key sector analysis where we will disaggregate the national emissions total to better understand the sectoral relationships that underpin it. We will see that while there are a number of methodological issues that arise in the use of environmental key sector measures, it is a useful approach to helping us to understand these sectoral level relationships. The next chapter again begins to move away from the accounting perspective adopted in Chapters 3 and 4, and moves towards a more flexible modelling framework known as a computable general equilibrium (CGE) model.

Moving to a CGE approach allows us to begin to assess the impact of economic changes on environmental totals. For many of the reasons we outlined earlier when we discussed the limiting assumptions of demand driven-input-output models, input-output systems are not the most appropriate framework for assessing the impact of economic changes. Moving to a CGE framework allows us to build on the earlier accounting work in this paper, while examining a different aspect of Scotland's CO_2 impacts. The relationship between the economy and the environment is not a static one, it is subject to all manner of changes from sector to sector and year to year, and adopting a more flexible framework is key to fully understanding these relationships.

2.10 Tables

Table 2.4: Sectoral aggregation scheme and names

Sector name	New 67 sector code	Environmental account code	Input-output SIC sector code
Agriculture	1	1	1
Forestry	2	2	2
Fishing	3	3	3
Coal extraction	4	4	4
Oil and gas extraction	5	5	5
Metal ores extraction, Other mining and quarrying	6	6&7	6&7
Food and drink	7	8	8-19
Tobacco	8	9	20
Textiles	9	10	21-27
Wearing apparel	10	11	28
Leather products	11	12	29-30
Wood products	12	13	31
Pulp and paper; printing and publishing	13	14-15	32-33
Coke, refined petroleum & nuclear fuel	14	16-18	35
Industrial gases and dyes	15	19	36
Inorganic chemicals, Organic chemicals	16	20-21	37 & 38
Fertilisers, Plastics & Synthetic resins etc, Pesticides	17	22-24	39 - 41
Paints, varnishes, etc	18	25	42
Pharmaceuticals	19	26	43
Soap and detergents	20	27	44
Other Chemical products, Man-made fibres	21	28-29	45 & 46
Rubber products	22	30	47
Plastic products	23	31	48
Glass, glass products	24	32	49
Ceramic goods	25	33	50
Structural clay products, Cement, lime and plaster	26	34-35	51 & 52
Articles of concrete, stone etc	27	36	53
Iron and steel, Non-ferrous metals, Metal castings	28	37-40	54 - 56
Metal products	29	41	57-61
Machinery and equipment	30	42	62-68
Office machinery	31	43	69
Electrical machinery	32	44	70-72
Radio, television, comms	33	45	73-75
Medical and precision instruments	34	46	76
Motor vehicles	35	47	77
Other transport equipment	36	48	78-80
Other manufacturing and recycling	37	49-50	81-84
Electricity production & distribution	38	51-55	85
Gas distribution	39	56	86
Water supply	40	57	87
Construction	41	58	88
Motor vehicle sales, repair & fuel	42	59	89
Wholesale distribution	43	60	90
Retail distribution	44	61	91
Hotels, catering, pubs etc	45	62	92
Railway transport	46	63	93
Other land transport	47	64-68	94
Water transport	48	69	95
Air transport	49	70	96
Ancillary transport services	50	71	97
Post and telecommunications	51	72	98-99
Banking and finance	52	73	100
Insurance & pension funds	53	74	101
Auxiliary financial services	54	75	102
Real estate activities	55	76	103-105
Renting of machinery	56	77	106
Computer services	57	78	107
Research and development	58	79	108
Other business activities	59	80	109-114
Public administration and defence	60	81-82	115
Education	61	83	116
Health & social work	62	84	117-118
Sewage & refuse services	63	85-87	119
Membership organisations	64	88	120
Recreational services	65	89	121
Other service activities	66	90	122
Private Households with employed persons	67	91	123

Table 2.5: CO_2 Attribution Results (UK-Scot Hybrid Intensities)

Final Demand Category	Type I total emissions attribution to FD		TELAS total emissions attribution to FD		DTA total emissions attribution to FD		TELAS (RUK) DTA (ROW) total emissions attribution to FD		TELAS (ROW) DTA (RUK) total emissions attribution to FD		DTA (OECD) total emissions attribution to FD	
	Tonnes	%	Tonnes	%	Tonnes	%	Tonnes	%	Tonnes	%	Tonnes	%
Households	20,237,169	42%	35,839,812	75%	39,872,644	78%	38,591,667	75%	36,375,024	77%	47,210,761	78%
NPISHs	215,334	0%	423,422	1%	396,598	1%	444,897	1%	376,476	1%	466,924	1%
Central Government	1,803,233	4%	3,933,480	8%	3,628,719	7%	4,096,749	8%	3,459,092	7%	4,112,390	7%
Local Government	1,071,952	2%	2,149,969	4%	2,009,735	4%	2,241,859	4%	1,919,991	4%	2,299,883	4%
GFCF	1,177,744	2%	5,443,730	11%	5,172,856	10%	5,830,032	11%	4,577,822	10%	5,796,111	10%
Valuables	4,106	0%	-10,190	0%	-15,107	0%	-12,160	0%	-10,962	0%	-15,031	0%
Change in Inventories	66,561	0%	260,780	1%	312,742	1%	292,698	1%	262,593	1%	346,007	1%
RUK	17,644,815	37%		0%		0%		0%		0%		0%
ROW	5,820,087	12%		0%		0%		0%		0%		0%
Total	48,041,002	100%	48,041,002	100%	51,378,187	100%	51,485,742	100%	46,960,036	100%	60,217,044	100%

Table 2.6: CO_2 Attribution Results (Full UK Intensities)

Final Demand Category	Type I total emissions attribution to FD		TELAS total emissions attribution to FD		DTA total emissions attribution to FD		TELAS (RUK) DTA (ROW) total emissions attribution to FD		TELAS (ROW) DTA (RUK) total emissions attribution to FD		DTA (OECD) total emissions attribution to FD	
	Tonnes	%	Tonnes	%	Tonnes	%	Tonnes	%	Tonnes	%	Tonnes	%
Households	25,430,968	39%	48,696,117	74%	52,640,670	77%	51,879,028	74%	48,394,069	77%	60,272,176	78%
NPISHs	281,133	0%	592,462	1%	540,608	1%	618,249	1%	514,656	1%	611,379	1%
Central Government	2,269,930	3%	5,432,065	8%	4,915,619	7%	5,667,630	8%	4,643,697	7%	5,427,005	7%
Local Government	1,360,600	2%	2,964,753	5%	2,705,804	4%	3,084,843	4%	2,578,923	4%	3,008,034	4%
GFCF	1,391,304	2%	7,760,038	12%	6,915,180	10%	8,264,031	12%	6,125,254	10%	7,662,150	10%
Valuables	5,555	0%	-14,978	0%	-22,748	0%	-18,899	0%	-15,730	0%	-23,155	0%
Change in Inventories	82,175	0%	374,659	1%	420,801	1%	415,188	1%	354,807	1%	471,681	1%
RUK	27,584,391	42%		0%		0%		0%		0%		0%
ROW	7,399,060	11%		0%		0%		0%		0%		0%
Total	65,805,116	100%	65,805,116	100%	68,115,934	100%	69,910,071	100%	62,595,676	100%	77,429,271	100%
Impact of Electricity Sector Change	17,764,114	37%	17,764,114	37%	16,737,748	33%	18,424,329	36%	15,635,640	33%	17,212,226	29%

Table 2.7: Production and Consumption Emission Total Estimates for Scotland

	TAP Total	CAP Total			
Scottish domestic demand		DTA (RUK) - TELAS (ROW)	DTA (ROW) - TELAS (RUK)	Full DTA	DTA OECD
Household	20,452,503	20,452,503	20,452,503	20,452,503	20,452,503
Government	2,875,185	2,875,185	2,875,185	2,875,185	2,875,185
Capital	1,248,411	1,248,411	1,248,411	1,248,411	1,248,411
Total	24,576,099	24,576,099	24,576,099	24,576,099	24,576,099
Scottish import demand					
Household		16,298,996	18,584,060	19,816,738	27,225,182
Government		2,503,898	3,463,423	2,763,269	3,537,088
Capital		3,581,042	4,862,159	4,222,080	4,878,675
Total		22,383,936	26,909,642	26,802,087	35,640,945
Scottish export demand					
RUK	17,644,815				
ROW	5,820,087				
Total	23,464,902				
Emissions total:	48,041,002	46,960,036	51,485,741	51,378,186	60,217,044
Implied trade balance		1,080,966	-3,444,740	-3,337,184	-12,176,042

2.11 Appendix A

Commodity-by-Commodity input-output system

Here we outline the derivation of the commodity-by-commodity (CxC) input-output system. This section follows Miller & Blair (1985, p166). We begin by outlining the commodity balance Equation 2.39 below, which states that gross commodity output equals the sum of commodities used in production (and detailed in the use matrix) plus the sum of commodities delivered to final demand. The vector i is a summation vector.

$$Q = Ui + E \tag{2.39}$$

Next, we standardise the use matrix by total industry output X to create B.

$$B = U.(X)^{-1}$$

and by manipulation

$$BX = U \tag{2.40}$$

We note here that each element of B is composed as $b_{ij} = \frac{u_{ij}}{X_i}$

Thus each element bij denotes the amount of commodity i required by industry j to make one unit of industry j's output.

Substituting the manipulation of Equation 2.40 into Equation 2.39 we get:

$$Q = BXi + E$$

which is the same as

$$Q = BX + E \tag{2.41}$$

The manipulated version of Equation 2.41 is the commodity-by-commodity corollary to the identity $X = AX + Y$ in the industry-by-industry input-output system, where here the matrix B is the commodity by industry direct requirements matrix. Having outlined the commodity based input-output system here, and having outlined the industry based system in a previous section, we now outline the two technology assumptions that can be applied in constructing SIOTs from make and use tables. Thereafter we show how these two assumptions develop in the construction of the IxC, CxI, CxC and IxI input-output systems.

Practical formulation of different input-output systems from raw data

We are not always lucky enough to have symmetric input-output tables (SIOT's) produced by the national statistics agency of the country we are studying. In Scotland's the Scottish Government produces SIOT's on an annual basis; this is not the case for all countries and region[57]. Sometimes these national statistics agencies do produce SIOT's but the release of these is often intermittent. Bohlin & Widell (2006) highlight the Swedish case where make and use tables are produced annually, but SIOT's have only been produced at 5 year intervals (Bohlin & Widell 2006, p206).

In light of this, different approaches have been developed to compile SIOT's from the annual supply and use tables that are released. Despite our focus in this chapter being the analysis of the Scottish case, it is still illustrative to consider how we can compile SIOT's from their constituent parts. The purpose of this section is to do just that. Using the standard Make (Supply) and Use matrices, we can generate SIOT's under two different technology assumptions.

We begin by outlining the commodity based input-output system and the derivation of the corollary to the total requirements matrix in the industry-by-industry (IxI) SIOT $(I - A)^{-1}$ discussed above. Adopting the industry-technology assumption, we outline the commodity by industry (CxI) and industry by commodity (IxC) total requirements matrix and show how this can be used to derive the industry-by-industry SIOT again. Turning to the alternative technology assumption, the commodity technology assumption, we show how we

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[57] SIOT's from 1998-2004 are currently (as at July 2010) available from the Scottish Government's website at: `http://www.scotland.gov.uk/Topics/Statistics/Browse/Economy/Input-Output/Downloads`

can re-derive the commodity-by-commodity, commodity by industry, industry by commodity and industry-by-industry total requirements matrix under this alternative technology specification.

Notation

Defining some terms that will become important in the following sections:

- U - Use matrix
- E - Commodities delivered to final demand
- Q - Commodity gross output
- X = Total industry output
- EC - Employee compensation
- PI - Proprietors income
- OPTI - Other property Type Income
- IBT - Indirect business taxes
- HHC - Household consumption
- e - Employment by industry
- g - total industry output
- U^t - Total use matrix
- g^{hh} - total household output
- g^h - total industry output including household output
- B - Standardised use matrix
- V - Make matrix
- V^z - Domestic make with institutions

- V^t - Total make with institutions and imports
- q - Domestic commodity output
- M - Commodity imports
- Z - Institutions
- D - Standardised domestic make
- D^t - Standardised total make

Commodity technology assumption (CTA)

This section follows Miller & Blair (1985, p166). Starting with the make matrix V we note that the matrix is in the format of IxC, that is, the industries are on the rows and the commodities are on the columns. Summing across each row gives the total output of that industry regardless of the commodity that they have produced. You can therefore determine in matrix form what fraction of their total output is composed of each commodity that they produce. This procedure is known as row-standardising, and produces a matrix C:

$$C = V'(\hat{X})^{-1} \tag{2.42}$$

Where the individual elements are comprised as: $c_{ij} = \frac{v_{ij}}{\hat{X}_i}$, where v_{ij} is an element in the make matrix V, X_i is the total output of industry i, and the ' denotes a transposed matrix. This row standardisation assumes (and this assumption is the basis of the CTA) that industries produce commodities in fixed proportions, this is known therefore as the commodity technology assumption.

Industry technology assumption (ITA)

Bohlin & Widell (2006) sum the ITA up well: describing it as assuming "the same industry uses the same mix of inputs for all its output" (Bohlin & Widell 2006, p207). In other words we assume that all the firms operating in sector i use the same combination of commodities to produce its output.

This section also follows Miller & Blair (1985, p166).We start again in this case with the make matrix V. In the same way as was done above for the CTA, we can standardise the make matrix, but this time we standardise it by dividing each element v_{ij} by total commodity production X_j. This gives us a new matrix D, where each element d_{ij} is comprised as: $d_{ij} = \frac{v_{ij}}{\hat{X}_j}$, that is, each element d_{ij} is the amount that industry i produces of commodity j, as a proportion of the total output of commodity j.

$$D = V.(\hat{Q})^{-1}$$

and by manipulation

$$V = D\hat{Q} \tag{2.43}$$

Since we are assuming in the construction of the matrix D that the total output of commodity j is produced by industries in a fixed proportion this approach is referred to as making the industry technology assumption (ITA).

Applying the CTA and ITA to the construction of total requirement matrices

It is worth noting at the outset that there are different reasons to select to use each of the technology assumptions just discussed. Miller & Blair (1985, p166) discuss these in full and the reader is referred there for a fuller discussion. Miller & Blair (1985, p166) also note the main purpose of the CxI and IxC input-output systems is the examination of secondary production issues (Miller & Blair 1985, p166). We start this section by demonstrating how, using the CTA we can construct each of the following input-output systems: the commodity-by-commodity, commodity-by-industry, industry-by-commodity, and finally the industry-by-industry input-output systems. Having done this, we repeat the construction of each of these systems using the CTA approach.

Industry Technology Assumption

Commodity by Commodity

Recalling Equation 2.43 and noting that X = Vi, that is, the row sums (bearing in mind that i here is a row summation vector) of the make matrix equal the total output of each industry irrespective of its commodity composition, we can see that:

$$X = D\hat{Q}i = DQ \tag{2.44}$$

Substituting this into the manipulation of Equation 2.41:

$$Q = BDQ + E \tag{2.45}$$

rearranging gives:

$$Q - BDQ = E$$

and

$$Q.(I - BD) = E \tag{2.46}$$

and finally:

$$Q = (I - BD)^{-1}.E \tag{2.47}$$

which is the CxC total requirements matrix, where each element ij in $(I - BD)^{-1}$ denotes the amount of commodity i required to produce one unit of commodity j for final demand.

Commodity by Industry

Miller & Blair (1985, p167-168) demonstrate how, through a simple redefinition of the final demand vector, we can obtain a CxI input-output system. Our point of departure is to redefine the final demand vector E in the CxC system in terms not of commodity final demand, but industry final demand. Taking the standardised make matrix D formulated above in Equation 2.43:

$D = V.(\hat{Q})^{-1}$ it is possible to reformulate commodity final demand E in terms of industry final demand Y, by noting that $Y_i = d_{ij}E_j$. In matrix form:

$$Y = DE \tag{2.48}$$

This follows since the element d_{ij} is the proportion of output of commodity j produced by industry i, and Ej is the final demand for commodity j. Thus their product is equal to industry final demand, Yi since the final demand of each industry must equal the value of the final demand for each of the individual commodities that industry produces.

Rearranging Equation 2.48 we find that:

$$E = D^{-1}.Y \tag{2.49}$$

Thus we have translated commodity final demand E to be in terms of industry final demand Y. In this way, we can substitute Equation 2.49 into Equation 2.47 and obtain[58]:

$$Q = (I - BD)^{-1}.E = [(I - BD)^{-1}D^{-}1].Y \tag{2.50}$$

Industry by Commodity

Since from Equation 2.44 we have X = DQ and from Equation 2.47 we have $Q = (I - BD)^{-1}.E$ combining the two we obtain:

$$X = [D.(I - BD)^{-1}].E \tag{2.51}$$

Thus we have constructed an IxC total requirements matrix using a ITA assumption. Developing this further we can easy extend this approach to give

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[58] As Miller & Blair (1985, p168) show, the element in square brackets here is equal to the CxI total requirements matrix. They also show that obtaining the IxC total requirements matrix based on the ITA is straightforward.

us an IxI total requirements matrix.

Industry by Industry

Taking as our starting point Equation 2.51 and substituting from Equation 2.49 for E:

- Equation 2.57 $X = [D.(I - BD)^{-1}].E$
- Equation 2.51 $D^{-1}X = (I - BD)^{-1}.E$ [Dividing both sides by D]
- $(I - BD).D^{-1}X = E$ [Multiplying both sides by (I-BD)]
- $(D^{-1} - B)X = E$ [Collecting the D terms]
- $D.(D^{-1} - B).X = D.E$ [Multiplying both sides by D]
- $(I - DB).X = DE$ [Tidying up the left-hand-side]
- $X = (I - DB)^{-1}.DE$ [Dividing both sides by (I-DB)]
- $X = [(I - DB)^{-1}].Y$ [Substituting from Equation 2.49]

Again here the object in brackets in the final line is the industry-by-industry total requirements matrix.

Commodity Technology Assumption

Commodity by Commodity

Recalling Equation 2.39 and noting that Q = Ui + E which by Equation 2.41 also equals BX + E = Q. So the Commodity output Q is equal to the sum of the rows of the use matrix plus the total commodity final demand. Similar to above, this means that the row sums (bearing in mind that i here is a row summation vector) of the use matrix, plus commodity final demand, equal the total output of each commodity irrespective of its industry that produces the commodity. This in turn is equal (by Equation 2.41) to the sum of, the product of the standardised use matrix B and total industry output X, and total commodity final demand E.

Here we reintroduce the C matrix, and recall that it was the column standardised make matrix, from Equation 2.42: $C = V'(\hat{X})^{-1}$. We transform this in Equation 2.52 below:

$$C = V‘(\hat{X})^{-1}\hat{X}.C = V‘.\hat{X}.(\hat{X})^{-1}V‘ = \hat{X}.C$$

or

$$\hat{X} = C^{-1}.V'X = \hat{X}i = C^{-1}.V‘i \tag{2.52}$$

Noting that V'i is simply the sum of the rows (if dealing with V') or otherwise the columns of V, the make matrix, and therefore equals total commodity output, we can replace it with Q.

$X = C^{-1}.Q$

The continuation of Equation 2.52 here shows that C^{-1} acts as a translator taking total commodity output and translating it into total industrial output. Returning to Equation 2.41 from above and substituting from Equation 2.52 for X, we get:

$$Q = BC^{-1}.Q + EQ - BC^{-1}.Q = E$$

[Subtracting BC^{-1} .Q from both sides]

$$Q(I - BC^{-1}) = E$$

[Collecting terms]

$$Q = (I - BC^{-1})^{-1}.E$$

[Multiplying both sides by $(I - BC^{-1})^{-1}$]

(2.53)

This gives us a term almost identical to Equation 2.47 from above, except that it is based on the matrix C the column standardised use matrix rather than D the row standardised use matrix. This gives us a CxC input-output model based on the CTA. While the two CxC systems total to the same commodity output, Miller & Blair (1985, p170) note that the actual CxC inverses calculated in Equation 2.47 and Equation 2.53 will not be equivalent; that is $(I-BC^{-1})^{-1}$ will not, element by element, be identical to $(I-BD)^{-1}$.

Commodity by Industry

Again in the case of CxI, this time under the CTA, Miller & Blair (1985, p167-168) demonstrate how, by again redefining the final demand for commodities, we can obtain a CxI input-output system. Our point of departure is to redefine the final demand vector E in the CxC system in terms not of commodity output, but industry output.

Taking the standardised make matrix C formulated above in Equation 2.42: $C = V'(\hat{X})^{-1}$ it is possible to reformulate commodity final demand E in terms of industry final demand Y, by noting that $E_k = c_{kj}Y_j$. In matrix form:

$$E = CY \tag{2.54}$$

This follows since the element c_{kj} is the proportion of k's total output that is attributable to the production of commodity j and Y_j is the final demand for industry j. Thus their product is equal to industry final demand, Yk since the final demand of each commodity j must equal the value of the final demand for each of the individual industries' production of that commodity. Thus we have translated commodity final demand E to be in terms of industry output. In this way, we can substitute Equation 2.54 into Equation 2.53 and obtain:

$$Q = [(I - BC^{-1})^{-1}.C].Y \tag{2.55}$$

Following Miller & Blair (1985, p168) again here, they demonstrate that the element in square brackets here is equal to the CxI total requirements matrix in the CTA case. They also show that obtaining the IxC total requirements matrix based on the CTA is straightforward.

Industry by Commodity

Since from Equation 2.52 we have X = C-1 .Q and from Equation 2.53 we have Q = (I - BC-1)-1 .E then multiplying both sides of Equation 2.52 by C and then combining the two we obtain:

$$CX = C.C^{-1}.Q = CX = Q$$

[Taking Equation 2.52 and multiplying b.s. by C]

$$CX = (I - BC - 1)^{-1}.E$$

[Substituting the first term into Equation 2.53]

$$(I - BC - 1)^{-1}.CX = E$$

[Dividing b.s. by $(I - BC^{-1})^{-1}$]

$$(CB).X = E$$

[Tidying and collecting terms]

$$C^{-1}(CB).X = C^{-1}.E$$

[Multiplying b.s. by C^{-1}]

$$(I - C^{-1}.B).X = C^{-1}.E$$

[Tidying and collecting terms]

$$X = [(I - C^{-1}B)^{-1}C^{-1}].E$$

[Dividing b.s. by $(I - C^{-1}.B)$]

$$(2.56)$$

Thus we have constructed an IxC total requirements matrix using a CTA assumption. Developing this further we can easy extend this approach to give us an IxI total requirements matrix.

Industry by Industry

Taking as our starting point Equation 2.56 and substituting from Equation 2.54 with Equation 2.54 having been solved for Y:

$$X = [(I - C^{-1}B)^{-1}C^{-1}].E$$

[Equation Equation 2.56]

$$X = [(I - C^{-1}B)^{-1}].Y$$

[Substituting for $C^{-1}.E$ from Equation 2.54 solved for Y]

$$(2.57)$$

Again here the object in brackets $[(I - C^{-1}B)^{-1}]$ is the industry-by-industry total requirements matrix using ITA. Having outlined in full the derivation of each of these versions of the Inverse, under both technology assumptions, we turn now to discuss the implications and relative merits of each of the technology assumptions

Chapter 3

Output and pollution key sector analysis of Scotland

3.1 Introduction

The idea that the actions of one agent can have impacts on other agents in the economy is not in itself a remarkable observation. However, what those who first formulated the concept and the empirical measures of key sector analysis sought to establish was that there were particular sectors in the economy which had much larger impacts on the total economy (represented by all the sectors in the economy) than others. It was thought that this was something that could then, potentially, be exploited to achieve policy goals.

According to this school of thought, a change in one sector of the economy (whether a demand change, a technological change or some other change) spilled forward or backward to the other sectors of the economy to a greater or lesser degree depending upon the strength of the linkages between these sectors and the sector which experienced the initial change. This made measuring the strength of these linkages important.

We discuss the different methods that were initially proposed for measuring sectoral linkage strength later in this paper. The underlying motivation for calculating these measures is simple; if we can identify sectors which have strong linkages to other sectors of the economy then this is something that we can perhaps use to target policy changes.

The contribution of this chapter lies in three main areas. Firstly in extending the understanding of the economy-environment relationship in Scotland to the sectoral level. Secondly in examining explicitly the impact of the 'own sector' effects, which we will define shortly, something which has not yet happened in the literature. Thirdly, in carrying out a thorough and methodical examination of the different linkage measures that are available, and their interpretation in the environmental context. This is something that has not been done effectively in the literature to date.

This paper begins by discussing what is meant by a 'key' sector. In section 3.3 we introduce the concept of output key sector analysis, discussing in detail the history, motivation, calculation and application of different linkage measures to the Scottish economy. In section 3.3.3 we introduce, discuss and apply different weighting schemes to the linkage measures that are developed in sections 3.3.1 and 3.3.2. In section 3.4 we follow this same pattern in presenting our analysis of pollution linkages in Scotland focusing on CO_2 emissions. In section 3.5 we bring the results from the examination of the backward and forward linkage measures together.

In section 3.6 we outline the examination of key sectors using the hypothetical extraction method. This approach, in addition to examining key sectors, extends our analysis to include a key group analysis. The penultimate section offers an interpretation and analysis of the results obtained in the earlier sections of this chapter with an emphasis on how the information presented is useful in the context of environmental policy. This chapter concludes with a review of the analysis that is carried out here, and suggestions for future work in this area.

The path of output key sector analysis is a well worn one, but environmental key sector analysis remains an underdeveloped tool. Using output key sector analysis as the foundation for the discussion in this chapter, we attempt to develop and expand on key sector methods as an environmental analysis tool.

3.2 What is meant by a key sector?

Defining which sectors are 'key' is something that often proves controversial, especially when it is linked to additional government support or regulation. The literature has converged to the view that perhaps the most straightforward way of identifying 'key' sectors is by looking at the backward and forward linkages (Sonis et al. 2000). A sector which has above average backward and forward linkage strength is usually thought of as being 'key'(Dietzenbacher (1992, p423), Sonis et al. (2000, p403) and Sonis & Hewings (2009, p88)).

Backward linkages are the 'supply chain' linkages of a sector. In other words they embody the purchases that the sector in question makes of the output of the other sectors as an input to its production process. These inputs are referred to in the input-output literature as intermediate inputs. Forward linkages refer to the sales of that sectors' output to the other sectors of the economy as an intermediate input to their production processes[1].

In recent years, alternative applications of the tools of key sector analyses have been found in the literature. These measures focus on other 'factors' such as water use, pollution generation, waste generation etc, instead of sectoral output. In looking at some of these alternative key sector applications the approach taken is very similar to the original formulation. These alternative key sector applications have become popular in recent years because there has been increased attention among policymakers in determining how best to achieve particular environmental policy aims, for instance reduced pollution or reduced water use.

The traditional output based linkage measures used in key sector analysis

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[1] There are issues surrounding the interpretation of some of the forward linkage measures that have been proposed. We pick this issue up again later in this chapter.

seek to find sectors which are crucial supply chain purchasers and/or suppliers in the economy. In the same way, pollution key sector analysis seeks to examine the pollution linkages in the economy to determine, in the backward linkage case, the sectors whose production demands the greatest generation of pollution elsewhere in the economy. In the forward linkage case, the aim is to identify those sectors which are key suppliers of pollution, i.e. embodied in that sector's sales to the other sectors of the economy.

In addition, a policymaker may want to increase economic activity (output) but do so in a way which either maximises or minimises another factor (like employment or pollution). In this chapter we seek to determine what the key sectors in the Scottish economy are based on both economic output and aggregate pollution[2].

For the purposes of the early part of this chapter most of the discussion on extending the tools and techniques of traditional key sector analysis to an environmental context, is framed in terms of key pollution sectors. Later when we look at a particular application, we refer specifically to key carbon sectors, denoting that the analysis at this point focuses on CO_2 generation within the Scottish economy.

3.2.1 History of, and intuition for, key sector analysis

The concept of 'key sectors' within the economy was first raised and outlined by Hirschman (1958) in the context of economic development. Perhaps the clearest explanation of what Hirschman meant by the description 'key sector' is given by Cella (1984). He explains that the reason that sectors with the largest linkages were thought of as being 'key' is because "by concentrating resources in them it should be possible to stimulate a more rapid growth of production, income and employment than with an alternative allocation of resources" (Cella 1984, p73).

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[2] In this paper, while the methods are generalisable to any factor available as a sectoral factor/output intensity including employment, we only consider CO_2 generation within the economic system.

The original formulation of key sector analysis was designed for an examination of output patterns in developing countries with a view to spurring economic development through intensive investment in those sectors determined to be ‘key’. In other words, the initial use of this type of analysis was to determine which sectors within a particular national/regional economy, a government looking to support economic growth should focus their investment in to maximise the return on their investment.

There was also interest in applying these key sector methods to developed countries to assist governments in supporting the development of their own economies. Drejer (2002) points out that this interest in key sectors in the developed world needs to be viewed in light of the interest in post World War II Keynesian demand stimulating policies (Drejer 2002, p2) (see also, for example, Goodwin (1949)). The connection here being that the backward linkage measure that Hirschman (1958) suggested is similar to the output multiplier which Keynes theorised.

The argument about supporting key sectors in developed countries was that, since governments had limited funds for economic development, they wanted to focus their funds into developing/growing those sectors of the economy, where their investment would result in the greatest overall economic improvement. It has been argued that the use of these key sector measures in established economies was inconsistent with the original economic development motivation (Drejer 2002). In an established economy the presence of a sector with high economic linkages need not mean that it was one of the sectors that spurred the development of the economy. To the contrary it could have been the last sector to have been established (Drejer 2002, p7). In this way, the utilisation of key sector analysis techniques in an established economy has to be reassessed.

Hirschman (1986) responded to this criticism, arguing that using input-output methods to determine key sectors in established economies is still the best approach, since their expansion is more likely to lead to the growth of established industries- following the Keynesian demand multiplier motivation-rather than spurring the development of new industries (Hirschman 1986, p58).

An alternative perspective on which sectors offered the best opportunities for economic development, and hence the means of determining which sectors were key, was proposed by Ghosh (1958). He argued that key sector analysis based on a sectors forward linkage strength, which until then had mostly focused on demand driven measures, provided a good means of identifying bottlenecks in the supply chain. He argued that in the context of economic development, the most important hindrance to economic development is not a lack of demand *per se*, but rather lumpiness and bottlenecks in the supply of intermediate inputs in the domestic economy. In his view, using forward linkage measures to determine key sectors, allowed the government to assess those sectors which were crucial suppliers of intermediates. The result of this analysis could then be used to target investment into those sectors, the expansion of which would free up capacity for the other sectors of the economy to develop.

In this sense Ghosh's (1958) view of the developing world was of one consisting of supply constrained economies. When we introduced the Ghosh (1958) supply driven model in Section 2.4.2 of the previous chapter we saw that there were difficulties in its original motivation and interpretation, but that the reinterpretation of this model by Dietzenbacher (1997) had addressed a number of these issues. This reinterpretation can be carried through to the interpretation of the forward linkage measures that Ghosh (1958) had first suggested.

Ghosh (1958) was concerned with identifying those sectors which, if they increased their supply of primary inputs, would result in the greatest increase in capacity in the economy. Under the Dietzenbacher (1997) reinterpretation we're thinking instead about either, as Dietzenbacher (1997) himself suggests, a 'cost-push' effect or an efficiency improvement. In the 'cost-push' view, sectors ranked highly according to the forward linkage measure are sectors which, if there is a change in the price of primary inputs (for example labour or capital), would result in the greatest change in cost in the economy.

In other words, this sector's has such strong linkages to the other sectors of the economy, through the use of its output as an input to the other production sectors, that an increase in the price of primary inputs in this sector will increase aggregate cost in the economy the most. A good way of thinking about this intuitively is that if the price of primary inputs in the electricity sector increased, pushing up the price of electricity, this would increase the costs of all the other sectors which (assuming perfectly passive demand in the economy[3]) would increase the value of the output of all sectors which used electricity as an input to production.

This interpretation therefore addresses the difficulty with the original Ghosh (1958) supply driven input-output model, and hence forward linkage measures based on this model. Under the reinterpretation, as we just saw, increases in the price of primary inputs in sector i increases the value of output in all the other sectors j that buy output from sector i. In Ghosh's (1958) case, increases in the quantity of primary inputs would have led to increases in the output of all sectors that used the output of that sector as an input, but without increases in their other inputs. The Dietzenbacher (1997) reinterpretation of the supply driven input-output model addresses this point.

The alternative way of thinking about these forward linkage measures, also consistent with Dietzenbacher (1997), is to think of efficiency changes instead of changes in the price of primary inputs. Dietzenbacher's (1997) interpretation only required that the supply driven model be interpreted through the prism of changes in the value of primary inputs, rather than in the quantity of primary inputs as in the original interpretation. An interpretation of changes in the value of primary inputs as stemming from an improvement in the efficiency with which primary inputs are used is therefore consistent with Dietzenbacher (1997).

In this view, sectors with strong forward linkages are those where an increase in the efficiency with which primary inputs are used, which would reduce the cost of primary inputs (cost being price x quantity), would lead to the greatest overall

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[3] Recall from Section 2.4.2 that this is a key assumption of the supply driven input-output model.

reduction in cost in the economy. In the Dietzenbacher (1997) interpretation quantity remains fixed and prices change to affect the value of primary inputs. In the alternative efficiency improvement interpretation, price is fixed while quantity of primary inputs adjusts to change the value of primary inputs.

The purpose of this short section was to give some intuition and motivation for the measures that will be outlined in the next section. We will draw on the interpretation and intuition given in this section in discussing the key sector measures in the rest of this paper. In the next section we introduce and outline the tools of key sector analysis using backward and forward linkage measures. These include the Leontief backward and forward linkage measures and the Ghosh (1958) forward linkage measure.

3.3 Output key sector analysis

Two different approaches to determining what sectors within the economy are 'key' are used in this chapter. One approach utilises different calculations based on elements of either the supply or demand driven input-output system outlined in the previous chapter. This approach builds on the discussion in the previous section on backward and forward linkage measures. Another approach used to determine the 'key sectors' in the Scottish economy is known as the hypothetical extraction method. This approach amends the database used to construct the demand driven input-output system by extracting the sector (or sectors) of interest, before examining aggregate output or the total of another aggregate variable of interest (for example total pollution generation) in this 'new' system.

By extracting the focus sector's purchases from, and sales to, the other sectors in the database we can construct a new demand driven input-output system and measure aggregate output and emissions with the sector of interest 'extracted'. This approach leaves the system itself intact but allows us to measure the impact of the sector or sectors that have been extracted on total output, pollution, etc. The key group approach (Temurshoev 2010) determines the impact on aggregate output and pollution of extracting every combination of 2, 3 and 4 sectors in the economy[4]. Table 3.1 summarises the individual (backward and forward) linkage measures applied in this chapter. The hypothetical extraction method is outlined in more detail in Section 3.6 later.

In section 3.3.1 we outline the Leontief backward linkage index (LBLI) measure, discuss the intuition and motivation behind its use, and apply it to Scotland. Following this, we examine the issue of intra-sectoral linkages, a concept we will shortly define, and their impact on the determination of backward linkage strength using the LBLI. Section 3.3.2 introduces and outlines the Leontief and Ghoshian forward linkage measures, before applying them to Scotland. We then examine intra-sectoral impacts in the context of these forward linkage measures. In section 3.3.3 we introduce and apply weighting measures to the linkage indices that were calculated in the previous two sections.

Introducing weightings to the linkage measures, outlined in section 3.3.1 - 3.3.2, allows us to incorporate additional sectoral level data into the process of ranking sectoral importance. More details will be given in section 3.3.3, but a simple example will help to illustrate the usefulness of introducing weighted index measures. It is possible for a sector to be ranked highly according to one or more of the linkage measures that we outline in section 3.3.1 - 3.3.2 below, but for the sector to be a small sector in the economy. Such a sector is unlikely to be able to generate the economy-wide impacts that a policymaker wants to achieve.

One useful way of determining sectors which are both large and have strong linkages in the rest of the economy, is by weighting the sectoral linkage index using output or final demand. Introducing this information allows us to combine two different but related effects into one sectoral ranking. We discuss in section 3.3.3 the specifics of constructing weighted indexes, and the particular issues that this raises. We begin the next section by outlining the Leontief backward linkage measure.

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[4] It is possible to extract combinations of groups of sectors ranking in size from 2 through to n-1 sectors. For practical reasons we focus here on groups of size 2, 3 and 4.

3.3.1 Leontief backward linkage measure

We noted earlier that Hirschman (1958) first raised the question of how to identify the 'key' sectors within a particular economy. In arguing the importance of key sectors Hirschman focused on economic development justifications. The basic idea was to identify sectors of the economy which would, if targeted for government assistance, increase growth in the economy the most. There are generally considered to be two aspects to the determination of which sectors are 'key', only one of which we focus on in this section.

These two aspects are, on the one hand, the ability of a sector if it expanded to support the greatest amount of additional domestic activity (backward linkage or supply chain effects) and on the other hand, sectors which if expanded would help reduce bottle necks in the supply chain (forward linkages or cost push effects). We discuss forward linkages in section 3.3.2, for now we focus on backward linkages, and specifically how we can measure them.

The first approach introduced in the literature is based on the summation of the column elements of the input-output system to provide a measure of the backward linkage strength of each sector. It was Chenery & Watanabe (1958) who first devised an empirical measure to determine the 'key sectors' in the economy, using the column sums of the A (or input-output coefficient) matrix in the demand driven input-output system.

To recap from the previous chapter, each element of the A matrix is the purchases (z) by sector j from each sector i, z_{ij}, per unit (£million) of sector j output X_j, therefore each element of A is calculated as $\frac{z_{ij}}{X_j} = a_{ij}$. This A matrix is the basis of the demand driven input-output system from which we will derive all the backward linkage measures in this chapter, as well as one forward linkage measure in Section 2.3.

Chenery & Watanabe (1958) argued that a good backwards linkage measure could be constructed by summing the column element of the A matrix for each sector Chenery & Watanabe (1958), however this was shown to be unsatisfactory because it only measured the *direct* effect. Recall that the direct effect in input-output models refers to, taking the case of an increase in sector 1's final demand, the immediate (or partial equilibrium) effect of that increase in sector 1's final demand on the other sectors of the economy.

In other words, an increase in final demand for the output of sector 1, increases sector 1's demands for the output of the other sectors of the economy as an input to sector 1's production process. The direct effect here only captures the economy-wide increase in output caused by the expansion in input demand from sector 1. The *direct* effect ignores the wider impacts on total output of the expansion in the input demand of the other sectors which are facing increased demand for their output from sector 1 (hence the reference to a 'partial equilibrium' effect).

In reality, increased demands for sector 1's output, which *directly* increases the demand for the output of as many of the n sectors in the economy as are needed in sector 1's supply chain, also increases the demand for inputs from these other sectors that are now faced with increased demand for their output. The *indirect* effect of sector 1's demand captures the output (we focus here in this example on output, but this could equally refer to pollution, jobs etc) supported in the production of the inputs to sector 1. This output again requires inputs, and thus output from other sectors and so forth.

In a simple two sector economy, adopting the notation used in Section 2.4.1, a unit of final demand of sector 1 *directly* requires a_{11} units of sector 1 output and a_{21} units of sector 2 output. In the same way, a unit of final demand for sector 1 requires *directly and indirectly* l_{11} units of sector 1 output and l_{21} units of sector 2 output. L here refers to the Leontief inverse and l_{ij} to elements of the Leontief inverse. The difference between l_{11} and a_{11} is the amount of sector 1 f *indirectly* required to produce a unit of sector 1 final demand. The same is true of the difference between l_{21} and a_{21} representing the amount of sector 2 output *indirectly* required to produce a unit of sector 1 final demand.

In order to capture both the *direct* and *indirect* effects the Chenery & Watanabe (1958, p) approach had to be modified and instead of summing the column elements of the A matrix, it was suggested by Hirschman (1958) that we should sum the column elements of the Leontief inverse $(I - A)^{-1}$ or L. This is equivalent to the traditional Type-I output multiplier. This allows us to think of this measure as the economy wide response (in terms of supported intermediate output) of a unit increase in the final demand of that sector. Thus the backward linkage strength (BL) of each sector j is measured as:

$$BL_j = \sum_{i=1}^{n} L_{ij} \tag{3.1}$$

As Sonis et al. (2000) show, Rasmussen (1956) developed these measures into a 'power of dispersion' index (in the case of backwards linkages) and a 'sensitivity of dispersion' index (in the case of forward linkages) with a simple normalisation. To do this, Rasmussen (1956) first defined a 'global intensity' using the Leontief inverse L. This measure is calculated as:

$$K_L = \sum_{i=1}^{n} \sum_{j=1}^{n} L_{ij} = \sum_{j=1}^{n} M_j = \sum_{i=1,j=1}^{n} L_{ij} \tag{3.2}$$

In Equation 3.2 here M is a vector of Type-I output multipliers. Using this 'global intensity' construct, Sonis et al (2000) show that the Rasmussen (1956) normalised index of backwards linkages (which he calls the backward linkage power of dispersion (BLPD)) can be derived as follows:

$$\mathrm{BLPD_j} = \left[\frac{\frac{1}{\mathrm{n}} \sum\limits_{\mathrm{i=1}}^{\mathrm{n}} \mathrm{L_{ij}}}{\frac{1}{\mathrm{n^2}} \sum\limits_{\mathrm{i,j=1}}^{\mathrm{n}} \mathrm{L_{ij}}} \right] = \left[\frac{\frac{1}{\mathrm{n}} \mathrm{BL_j}}{\frac{1}{\mathrm{n^2}} \mathrm{K}_L} \right] = \left[\frac{\mathrm{BL_j}}{\frac{1}{\mathrm{n}} \mathrm{K}_L} \right] \tag{3.3}$$

This approach results in the formation of the BLPD index for all n sectors. In the BLPD a sectoral score >1 indicates that the sector has above average backwards linkage strength, or put differently that each unit of that sectors' final demand supports an above average quantity of output in the rest of the economy. Backward linkage effects refer to the direct and indirect dependence of one sector on the output of the other sectors of the economy, as input to its production process. Another way to think about this is that sectors with strong backwards linkages are those which have large and above average supply chain purchases from the production sectors of the domestic economy.

Conversely, this means that sectors where more of the inputs to production are in the form of imported goods or value added 'non-produced inputs' (such as labour or capital) will have lower backwards linkage index strength. In examining the results that follow it is necessary to keep this definition in mind. In the rest of this chapter we refer to the BLPD measure as the 'Leontief backwards linkage index' (LBLI).

It is worth noting here that sectoral aggregation may have an important role to play in determining the sectors which have above average impacts. Aggregating a sufficient number of, individually, less important sectors together would likely result in a finding that this 'new' sector had above average impacts, but clearly this is not what we are trying to find. This is a potential issue in the application of all of the measures presented in this chapter.

In our analysis we operate at the highest level of aggregation that we can for consistency between the output and carbon key sector analyses. In practice this means operating at the 67 sector level for compatibility with the 126 sector input-output accounts and 93 sector environmental accounts[5]. Table 2.4 from Chapter 2 contains the mapping from 126 and 93 sectors to the 67 sectors used here.

We apply the Leontief backward linkage index measure outlined above to Scotland using input-output and economic data for 2004. The ranking of the 67 sectors according to the LBLI are contained in the second column of Table 3.3. Sectoral scores >1 indicate that the sector has above average LBLI strength. Sectoral scores which are underlined indicate that the sector is ranked in the top 5 according to that measure. The 5 sectors with the largest LBLI score in the Scottish economy (in descending order of linkage strength) are: 38 (Electricity

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[5] UK Air Emissions data are available from `http://www.ons.gov.uk/ons/rel/environmental/uk-environmental-accounts/2012/rft-greenhouse-gas-emissions.xls`, while the Scottish Air Emissions Inventory is available at: `http://www.scotland.gov.uk/Resource/Doc/933/0093995.xls`.

production & distribution), 46 (Railway Transport), 14 (Coke, refined petroleum & nuclear fuel), 2 (Forestry), and 50 (Ancillary transport services).

Bear in mind that this measure tells us the sectors whose final demand supports the greatest amount of output in the economy, per £1m of final demand. This needs to be qualified by noting that we are focusing here only on the domestic production required by each sector, i.e. net of imported inputs. Nonetheless we can see from the results of this measure, which sectors would be expected to support the greatest amount of additional output in the domestic economy if they expanded. However, again we must bear in mind that this measure does not assess the relative size of the sector in the domestic economy. We will look at this issue again later when we construct weighted LBLI measures.

Intra-sectoral impacts in the Leontief backwards linkage measure

One of the issues touched on earlier was whether the linkage measures that are of most interest are those which focus on the total linkage strength, such as the LBLI measure discussed above, or exclusively on the strength of the linkages to other sectors. We noted in the previous chapter that within the input-output system the own sector coefficient in the Leontief or Ghoshian inverse has a peculiar dual role.

In the Leontief inverse the own sector coefficient, by which we mean l_{ij} where $i = j$, represents the direct and indirect demand for the sectors own output to generate a unit of that sectors final demand. In this sense the sector is acting in two roles, as a demander of its own output and as a supplier of its own output. This is made slightly stranger when we recall the necessary assumption that firms in a sector are homogeneous and produce the same good (or different goods with the same input mix). This dual interpretation is one reason why excluding its effects may be desirable in the context of a backwards linkage measure.

The most compelling reason to exclude the impact of these intra-sectoral effects, would be where the researcher is trying to identify a sector or sectors whose impacts are on the other sectors of the economy, as opposed to on all sectors of the economy (which would include itself). This could manifest itself in the context of development policy with the scenario of a policymaker wanting to identify a sector or sectors which if they received a stimuli would result in the greatest increase in output in the other sectors of the economy.

This could happen where a policymaker was keen to broaden the economy by trying to expand output in a number of other sectors. An industry with a supply chain concentrated in its own sector may increase aggregate economic activity the most if it receives the stimuli, and if this is the only criteria that matters then own sector effects should be left in. If however, the aim is to grow those sectors which have greater links to the other sectors of the economy, as oppose to within the one sector, a better measure of backward linkage strength may be one which omits these own sector effects.

Following Sánchez-Chóliz & Duarte (2003), the calculation of this measure is straightforward, we simply deduct from the measure outlined above (LBLI), the value of the own sector element of the Leontief inverse for each sector(i.e. L_{ij} where $i = j$). To see the effect of this on Equation 3.3 we derive the corollary to Equation 3.1 above and then we carry this forward to produce the equivalent of Equation 3.3 for the case where we omit these own sector effects. We refer to measures that omit these 'own sector' effects as *pure*[6] measures, so for instance the LBLI measure with the intrasectoral effects removed becomes the PLBLI (*pure* Leontief backward linkage index).

$$BL_j{}^* = \sum_{i=1, i \neq j}^{n} L_{ij} \tag{3.4}$$

$$\mathrm{LBLI^*{}_j}{=} \left[\frac{\frac{1}{\mathrm{n}} \sum\limits_{\mathrm{i=1,i \neq j}}^{\mathrm{n}} \mathrm{L_{ij}}}{\frac{1}{\mathrm{n^2}} \sum\limits_{\mathrm{i,j=1,i \neq j}}^{\mathrm{n}} \mathrm{L_{ij}}} \right] = \left[\frac{\frac{1}{\mathrm{n}} \mathrm{BL_{j*}}}{\frac{1}{\mathrm{n^2}} \mathrm{K}_{L*}} \right] = \left[\frac{\mathrm{BL_{j*}}}{\frac{1}{\mathrm{n}} \mathrm{K}_{L*}} \right] \tag{3.5}$$

Removing these intrasectoral transactions from the analysis carried out in

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[6] The use of the term *pure* here is admittedly unsatisfactory, but it does help us to convey the central ideal of focusing in this measure on the *purely* intersectoral impacts of each sector.

Equation 3.1 above results in a new set of backwards linkage rankings. These are in Table 3.3. Comparing the top 5 sectors according to the LBLI (with intrasectoral transactions included) and PLBLI (without intrasectoral transactions) we can see that two sectors are common to both lists: 46 (Railway transport) and 14 (Coke, refined petroleum & nuclear fuel).

The other 3 sectors from the LBLI ranking are 50 (Ancillary transport services), 38 (Electricity production & distribution), and 2 (Forestry). The inclusion of a sector on the LBLI top 5 list that is not on the equivalent PLBLI list means that the sector in question must have large intrasectoral (direct and indirect) effects. From the original economic development rationale for key sectors, the desire to establish a broader and more diverse economy would suggest that the PLBLI ranking would be more useful since it highlights sectors with the strongest intersectoral effects rather than combined inter and intrasectoral effects as in the LBLI case.

Clearly if the only aim is to increase total economic activity it is irrelevant whether the stimuli proposed will increase the combined intra and intersectoral output (LBLI) as opposed to intersectoral activity more (PLBLI). In this case we would only be interested in which sectors, if stimulated, would generate the greatest increase in total economic output. However, if we are interested in broadening the economy through stimulating some sectors to help to develop other sectors of the economy we may be more interested in stimulating those sectors which support more inter as opposed to total (inter and intra) sectoral activity.

It should be clear that there is an extent to which this comparison is sensitive to both the extent of sectoral vertical integration within sectors and the aggregation of the input-output data. More highly aggregated sectors might be expected to have greater intrasectoral transactions (since sectors are aggregated into similar industries). In addition this measure does not rule out prominence in its ranking being given to sectors which have very large intersectoral impacts focused into fewer sectors. In this sense the measure is not the best measure of the dispersion of economic impacts. That said, it does at least provide a means of thinking more clearly about, and measuring the impact of, the purely intersectoral impact of a sector as distinct from its total impact.

3.3.2 Leontief and Ghoshian forward linkage measures

In addition to formulating a backward linkage measure based on the A matrix, Chenery & Watanabe (1958) also developed a forward linkage measure in a similar way, this time as the row sums of the A matrix. This suffered from the same difficulties as the backward linkage measure based on the A matrix, namely that it only accounted for the direct impacts of each sector: in this case the direct intermediate sales of sector i to each of the other sectors j in the Scottish economy as a proportion of the total output of each sector j.

Rasmussen (1956) again suggested the Leontief inverse as an alternative basis for a measure of the forward linkage strength of a sector; specifically he suggested using the row sums of the Leontief inverse to measure forward linkage strength. The forward linkage strength (FL) of each sector i was therefore defined as:

$$\mathrm{FL_i}=\sum_{\mathrm{j=1}}^{\mathrm{n}}\mathrm{L_{ij}} \tag{3.6}$$

Sonis et al. (2000), as in the backward linkage case examined in Section 3.3.1, demonstrate that Rasmussen developed this measure into a 'sensitivity of dispersion' index with a simple normalisation. Again it begins by defining a 'global intensity', using the Leontief inverse L, as:

$$\mathrm{KL}=\sum_{\mathrm{i=1}}^{\mathrm{n}}\sum_{\mathrm{j=1}}^{\mathrm{n}}\mathrm{L_{ij}}=\sum_{\mathrm{j=1}}^{\mathrm{n}}\mathrm{M_j}=\sum_{\mathrm{i,j=1}}^{\mathrm{n}}\mathrm{L_{ij}} \tag{3.7}$$

In Equation 3.7 here M is a vector of Type-I output multipliers. Using this 'global intensity' construct, Sonis et al (2000) show that the forward linkage normalised index (which he calls the forward linkage 'sensitivity of dispersion'

(FLSD)) can be calculated as:

$$\mathrm{FLSD_i} = \left[\frac{\frac{1}{n}\sum\limits_{j=1}^{n} \mathrm{L_{ij}}}{\frac{1}{n^2}\sum\limits_{i,j=1}^{n} \mathrm{L_{ij}}}\right] = \left[\frac{\frac{1}{n}\mathrm{FL_i}}{\frac{1}{n^2}\mathrm{K_L}}\right] = \left[\frac{\mathrm{FL_i}}{\frac{1}{n}\mathrm{K_L}}\right] \tag{3.8}$$

Rasmussen defined a FLSD score >1 as indicating that the sector had above average forward linkage strength. Expressed differently, this means that this sector is supported, in the form of above average purchases of its output, by the final demand of all n sectors of the economy. In other words, the output of this sector is relied on more heavily than average as an input to the production of the n sectors of the economy. Hereafter, we refer to the FLSD as the Leontief forward linkage index (LFLI). We note, as before, that the extent of sectoral aggregation may have an effect on sectoral rankings based on this measure.

This measure, while at first quite attractive as a measure of forward linkage strength (at least as compared to the original Chenery & Watanabe (1958) formulation), does not have a straightforward interpretation. The reason is that this index is calculated on the basis of the response of the Leontief demand driven input-output model to a somewhat peculiar stimulus (see Miller & Lahr (2001), Miller & Blair (2009)) which is lacking in a plausible economic rationale. Specifically, this Leontief forward linkage measure is based on the response of each sector to a unit increase in the final demand of all sectors of the economy.

This contrasts with the backwards linkage measure discussed earlier which was calculated as the total output supported in the economy by each unit of a given sectors' final demand. Miller & Blair (2009) argue that nonetheless this Leontief forward linkage measure can be useful for policymakers looking to establish the impact of a general (in other words equal) expansion in final demand. However, a unit increase in final demand is not equal for each sector (i.e. an increase in final demand by one unit for each sector represents a different % increase in sectoral final demand across sectors).

This LFLI measure, the results of which are presented later in this chapter, while we acknowledge that it is based on a peculiar stimulus, is included here because we consider it to be useful in providing an alternative perspective on sectoral impacts. We think that this is a useful measure as it allows us, when we consider it alongside the standard deviation of the elements of the LFLI, to examine the dispersion of sectoral impacts in a way that the other forward linkage measures we discuss below do not.

Each individual element j of the LFLI measure for a sector i, from Equation 3.6 (i.e. l_{ij}) is the direct and indirect output supported in sector i by a unit increase in the final demand of sector j. So the closer in size each of the elements j of the LFLI are for each sector i, the lower the standard deviation of the elements that comprise its LFLI score. This means that a sector with a low standard deviation of its LFLI elements, is supported more equally by the demand of the other n sectors of the economy. The standard deviation of the elements of the LFLI for each sector i, where x is each element of the LBLI and $\bar{x}$ is the average of the elements of the LBLI, is calculated as:

$$\mathrm{SD} = \sqrt{\frac{\sum (\mathrm{x} - \bar{\mathrm{x}})^2}{\mathrm{n}}} \tag{3.9}$$

If the standard deviation of the elements of the LFLI is high, it means that there is a larger difference between the size of these elements of the LFLI for that sector. In simple terms, this means that the sector has greater dependence on fewer sectors as a source of intermediate demands for its output than a sector with a lower standard deviation of the elements of its LFLI. This gives us additional information on sectoral impacts that is not provided by any of the other forward linkage measures that we will discuss below.

As a last comment on the LFLI we note that various methods have been proposed to take account of differences between the sectors which might be masked by a measure based on a unit increase in the final demand of all sectors (since as we just argued, a unit represents a different % of sectoral final demand across sectors). This issue was first raised by Laumas (1976). A common response to this problem is to combine the Leontief forward linkage index with a weighting scheme based on each sectors share of total final demand (Drejer 2002, Miller & Blair 2009). This is an issue which we will return to when we outline and implement the weighting of our backward and forward linkage measures in Section 3.3.3 later in this chapter.

The results of applying the LFLI methodology to Scotland are presented in Table 3.4 below, alongside a measure of the sectoral standard deviation- see Table 3.7. 18 sectors according to the LFLI have above average forward linkage strength. The sectors ranked in the top five in descending order of linkage strength are: 59 (Professional Services), 38 (Electricity production and distribution), 50 (Ancillary transport services), 41 (Construction) and 52 (Banking & finance). All of these sectors have between 1.7 and 3.3 times the average forward linkage strength according to the LFLI.

This means that these sectors are the ones which, faced with a uniform growth in final demand (for example an increase of £1 million in the final demand of all sectors), would expand the most as a result of the increased demand for their output from the other sectors of the economy. The stimulus that this measure is the response to is crucial to understanding and interpreting its results. The uniform growth in final demand need be equal in absolute rather than proportional terms (% increase say). In addition, it is a demand driven measure constructed using a demand driven model. We therefore need to think about the demand ultimately supporting each sectors output.

This means that a policymaker looking to stimulate demand in this way may want to consider the ability of this sector to satisfy this increased demand. If there was an equal expansion in final demand in the economy, then it is the sectors ranked highest according to this measure that we would expect to see the greatest expansion in. In the absence of increased capacity in the face of such a demand stimuli, there could be wider economic impacts such as price inflation.

When we examine the standard deviation results for the LFLI measure, we see that only one of the top ranked sectors according to the LFLI measure has an above average standard deviation score; the Banking & finance sector (Sector 52). None of the other 4 sectors has an above average standard deviation score, while the Electricity production and distribution sector (Sector 38) has the lowest standard deviation score of any of the 67 sectors.

Next, we examine another approach to measuring 'forward' linkage strength, this time using the supply driven input-output model. This forward linkage measure is based on the Ghoshian or supply driven input-output system, specifically the Ghoshian inverse, denoted in the previous chapter as G or $(\mathrm{I}-\mathrm{B})^{-1}$. Recall that B here is the allocation matrix where each element b_{ij} is the sales of sector i's output to sector j, as a proportion of total sector i output.

It was Beyers (1976) and Jones (1976) who first suggested that the supply driven input-output system (or parts thereof) would provide a better basis for assessing forward linkages (Miller & Lahr 2001, p410). The actual calculation for each sector i is identical to the FLSD measure outlined in Equation 3.8 above, but in this case it is based on the summation of elements of the Ghoshian inverse G:

$$\mathrm{FL_i} = \sum_{\mathrm{j=1}}^{\mathrm{n}} \mathrm{G_{ij}} \tag{3.10}$$

This is then transformed into an index, referred to here as the Ghoshian forward linkage index (GFLI) measure, as follows:

$$GFLI = \left[\frac{\frac{1}{\mathrm{n}}\sum\limits_{\mathrm{j=1}}^{\mathrm{n}} \mathrm{G_{ij}}}{\frac{1}{\mathrm{n^2}}\sum\limits_{\mathrm{i,j=1}}^{\mathrm{n}} \mathrm{G_{ij}}}\right] = \left[\frac{\frac{1}{\mathrm{n}}\mathrm{FL_i}}{\frac{1}{\mathrm{n^2}}\mathrm{K}_G}\right] = \left[\frac{\mathrm{FL_i}}{\frac{1}{\mathrm{n}}\mathrm{K}_G}\right] \tag{3.11}$$

Where we redefine K (and note that $K_G \neq K_L$) as:

$$K_G = \sum_{\mathrm{i=1}}^{\mathrm{n}} \sum_{\mathrm{j=1}}^{\mathrm{n}} \mathrm{G_{ij}} \tag{3.12}$$

This particular forward linkage measure does not suffer from the peculiar assumption of the LFLI measure we discussed earlier, but it has a different issue associated with its use. The interpretation of the supply driven model, and its implications for the forward linkage measures that utilise it, is the main difficulty in the application of these measures. We discussed this issue earlier in this chapter, and considered it at length in the previous chapter, but we briefly recap the discussion of this issue in Section 2.4.2 here.

We noted in Section 2.4.2 that the supply driven input-output model has been the subject of significant debate in the literature regarding its interpretation and motivation (for example Oosterhaven (1988, 1989) & Dietzenbacher (1997)). To see this, we will outline the differing interpretations of the Ghoshian forward linkage (GFLI) measure here. Under the original (i.e. Ghosh (1958)) interpretation each element of the Ghoshian inverse represents the impact on the output of sector j of a 1 unit increase in the availability of primary input factors to sector i (Miller & Blair 2009, p545). The difficulty with this interpretation is that the allocation function on which it is based is one characterised by perfect substitutes.

This means that increases in the availability of primary inputs in sector 1 lead to increases in the output of other sectors which purchase output from sector 1, but without any other increases in the inputs of these other sectors, other than those from sector 1. This means that an increase in the availability of primary inputs in the steel sector, which increases the output of the steel sector, also leads for example to the output of the car manufacturing sector increasing while it maintains the same level of inputs from all sectors other than the steel sector.

This interpretation is unrealistic and difficult to justify in the context that we are using this model[7]. We discussed in the previous chapter that the original Ghosh (1958) model had been reinterpreted by Dietzenbacher (1997) who interpreted the Ghosh supply driven model as a price input-output model.

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[7] There are papers, (see Park (2008), Park et al. (2008)) which seek to resurrect the original Ghosh (1958) model and interpretation in the context of modelling the economic impacts of natural or terrorist disasters. These are not applicable in our context.

According to this price interpretation, each row of the Ghoshian inverse $(\mathrm{I}-\mathrm{B})^{-1}$ expresses: “the amount... by which the output value of all sectors together is to be increased, due to a [unit]... increase in the value added of sector i” (Dietzenbacher 1997, p638). This opens up an interesting interpretation for the supply driven forward linkage measures.

Each sector, according to the Dietzenbacher (1997) reinterpretation, is ranked according to its ability to impact the value of the output of the other sectors. This is termed the ‘cost-push’ effect. Changes in the cost of primary inputs in one sector push a cost change onto the other sectors of the economy. Sectors ranked highly by the GFLI are sectors which push the greatest cost change onto the other sectors of the economy for a given change in the price of primary inputs in that sector. In this chapter we will focus and rely largely on the price reinterpretation of the Ghoshian supply driven model in using the forward linkage measure.

The price reinterpretation of the GFLI can also be thought about in another way. We can consider sectors ranked highly by this measure to be sectors where a change in the value of primary inputs would change the value of sectoral output the most. This opens up the possibility of thinking, instead of changes in the price of primary inputs leading to changes in the price of sectoral output, about improvements in the efficiency with which primary inputs are used.

In this view, changes in the value of primary inputs could be driven by changes in primary input efficiency. Such a change, which would alter the value of that sector’s primary inputs, would also alter the price of that sectors output. This would affect the value of the output of each sector that relies on inputs from the sector with the change in primary input efficiency.

According to this view, sectors with strong forward linkage scores according to the GFLI are sectors where an improvement in the efficiency of primary input use, defined broadly as doing more with less so as to incur a reduction in the effective unit price, will result in the greatest decrease in the value of sectoral output. In this chapter we rely on this type of price reinterpretation of the GFLI measure. Other approaches have been proposed to rescue the GFLI measure from the difficulties that the supply driven input-output model raises.

One such approach is to defend the original Ghoshian interpretation on the basis that the supply driven input-output system can be formulated in terms of the demand driven Leontief input-output system- thereby avoiding the debate over the motivation and interpretation of the supply driven framework. The difficulty here is how we interpret and motivate forward linkage measures in this new system- which is why we do not adopt this approach.[8]

An alternative forward linkage measure could be formulated from the direct forward impacts of each sector, in other words the summation of the row elements of the B matrix. Recall from the previous chapter that $B = Z\hat{x}^{-1}$ and each element b_{ij}, known as 'allocation coefficients' (Miller & Blair 2009, p543) where b_{ij} is the sales of sector i's output to sector j, as a proportion of total sector i output and is given by: $b_{ij} = \frac{z_{ij}}{X_i}$.

This would an accounting exercise, so would not incur the problems of using the Ghoshian inverse. It would simply represent a comparison for each sector i of the proportion of each sectors i's total output that was comprised of sales to each of the other sectors j; in other words: $\frac{z_{ij}}{X_i}$. Thus the score for each sector would be the % of output sold to intermediates as opposed to final demand.

A direct forward linkage measure may provide an alternative to using the Ghoshian inverse, although it ignores the impact of indirect effects and therefore is not a particularly insightful measure. It is for this reason we do not present this measure in discussing the results presented below. We focus instead on interpreting our results from applying the GFLI measure in the context of a price input-output system (following Dietzenbacher (1997)) as discussed previously.

Particularly useful here will be the interpretation, discussed earlier, that sectors with high forward linkage strength can be thought of as sectors where

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[8] Miller & Lahr (2001) show that the supply driven framework's main workhorse the Ghoshian inverse G can be calculated as $G = (I - B)^{-1} = \hat{x}^{-1}.(I - A)^{-1}.\hat{x} = \hat{x}^{-1}.L.\hat{x}$ (Miller & Lahr 2001, p410). They do note thought that while it is possible to reformulate the Ghoshian supply driven input-output system and hence forward linkage measure in this way, it does lack a convincing interpretation in this context (Miller & Lahr 2001, p411).

an efficiency improvements would have the biggest impact on competitiveness. Next we report the results of calculating the Leontief forward linkage index measure (LFLI) and the Ghoshian forward linkage index (GFLI) to Scotland in 2004.

Turning to Table 3.4 we can see the results of calculating the GFLI measure. As before, we focus our discussion only on the top 5 'key' sectors according to each measure. These are: 4 (Coal extraction), 27 (Concrete), 50 (Ancillary transport services), 56 (Machinery Rental) and 26 (Cement & Clay). In all, 28 sectors have above average forward linkage strength according to this measure.

Remembering that forward linkages reflect the importance of a sector in terms of the strength of its sales to other sectors in the economy (although in different ways according to the different interpretations of the supply driven model), all 5 of these sectors are clearly sectors that are obvious inputs to production. It is worth noting that of these top 5 sectors, sector 50 is also a top 5 sector according to the LBLI, sectors 4 & 27 have above average LBLI scores, and sectors 56 & 26 have below average LBLI scores.

Intra-sectoral impacts in the Leontief and Ghoshian forward linkage measures

In Section 3.3.1 we discussed the motivation and methodology for removing the intrasectoral effects from linkage measures to focus on the *purely* intersectoral effects. We similarly adopt this approach with the GFLI measures presented in the previous section. The pure Ghoshian forward linkage index measure (PGFLI) presented in this section differs from the Ghoshian forward linkage index measures outlined in Section 3.3.2, only in that they omit the 'own sector' effect. This is the same approach taken in the LBLI case in section 3.3.1 above.

To recap, this means that the cell on the principle diagonal of the inverse being used for the linkage calculation (in this case the Ghoshian inverse) relating to the sector being investigated is not included in the forward linkage calculation. This has the effect of focusing the analysis solely on the impact of sector i on the other n-1 sectors rather than focusing on the effect on all n sectors of the economy. As we noted earlier, it is perhaps preferable to utilise this measure when we are interested in isolating the effect that one sector has on the other sectors of the economy, as distinct from its impact on the whole economy.

Next, we outline and discuss the key results from the PGFLI measures contained in Table 3.4. Firstly, the top 5 sectors according to the PGFLI measure (in descending order) are: 4 (Coal extraction), 27 (Concrete), 56 (Machinery Rental), 26 (Cement & Clay) and 39 (Gas distribution). The only changes between the top 5 sectors ranked by the PGFLI compared to the GFLI is sector 39 (Gas distribution) enters the top 5, replacing sector 50 (Ancillary transport services).

Sector 39 (Gas distribution) is considered to have above average GFLI strength and is ranked 7th according to this measure, so its promotion in the PGFLI case is perhaps not that surprising. The effect of excluding the 'own sector' coefficient from the GFLI measure is to increase the forward linkage strength of sector 39 measured using the PGFLI measure, but it also increases the forward linkage strength of sector 50 (Ancillary transport services), just not by as much.

3.3.3 Weighting linkage measures

Having outlined and applied both backward and forward linkage measures to Scotland in the preceding sections, we build upon these measures in this section. The LBLI measure examines the strength of a sectors supply chain linkages with the other sectors of the economy. The greater a sector's purchases from the sectors of the domestic economy (which recall includes itself in the input-output framework) to satisfy a unit of its final demand, the greater its backward linkage strength.

One problem with this approach to ranking sectoral backward linkage importance is that it fails to take account of other relevant factors, for example the size of the sector. A particular sector of the economy may be both small and have a strong backward linkage strength (recall that the LBLI is identical to the Type I output multiplier commonly used in input-output analyses).

Taking as an illustrative example the case of a policymaker wanting to expand output in the economy through increased demand in a particular sector, it is clear that sectoral scale is important, particularly in developed economies. In order to assess the potential for a sector to effect the given level of change in the overall economy, both its supply chain (or backward linkage) strength in the domestic economy and a measure of the size of the sector are important. One assesses the impact of its expansion in terms of its own supply chain, the other whether it can significantly impact aggregate output in the economy.

1% of final demand for the largest sector represents more output in £million (the unit of our monetary input-output system) than 1% of the final demand for the smallest sector. Combining information on the size of a sector and its backward linkage strength allows us to consider both linkage strength and the scope of the potential impact of the sector. Assuming that aggregate output is the ultimate barometer of the success of a sectoral policy, this approach is a better way of measuring sectoral importance because it considers the scope that the sector has to affect aggregate output, as represented by the size of the sector in the domestic economy.

There is, in principle, no limit to the number of different sectoral level weighting schemes that can be constructed, and it is the job of the investigator to choose the most appropriate weight to use. Provided that the weight used is available at the sectoral level and is sensible in the context, it can be applied to the LBLI, LFLI and GFLI measures outlined above. Weighting by sectoral output is a generally useful measure because it is the most obvious measure of sectoral scale. For specific applications a different weighting may be more appropriate, for instance in the identification of export important sectors a weighting by the share of export final demand would be more useful.

There is one other critical decision to be made about the weighting of linkage measures. The researcher using these weighted measures must decide on the weight that has to be attached to the weighting scheme that is used versus the linkage measure being used. Laumas (1976) noted the arbitrary nature of many of the proposed weighting schemes, a point which was amplified by Sonis et al. (2000). By arbitrary, Laumas (1976) meant that the weighting scheme did not necessarily correspond particularly well to the purpose of the study. A simple weighting by household final demand for instance is unlikely to properly represent household preferences, complex as they are. This is a legitimate criticism, and it makes it all the more important that the researcher selects both weights based on their particular application.

It may be the case, for example, that the researcher wants to give sectoral linkage strength and sectoral size the same weighting in the weighted ranking of sectors. In this case sectoral rankings can be constructed using a similar approach to Laumas (1976). Taking as our example the LBLI, although this approach is generalisable to the other linkage measures considered, we can combine the LBLI ranking alongside a weighting based on sectoral output to create the Leontief backward linkage measure weighted by sectoral output (LBLIwx) as follows:

$$LBLIwx = LBLI_i * \left(\frac{x_i}{\sum\limits_{\forall i} xi} \right) \tag{3.13}$$

Here x_i is sector i's total output. This combines the weight $\frac{x_i}{\sum\limits_{\forall i} xi}$ alongside the LBLI ranking in equal proportion creating a new ranking (LBLIwx) of sectoral importance. It may be the case however that the researcher does not want to apply a 1:1 relationship, in the ranking of sectors, between linkage strength and the chosen sectoral weight. In this case, the researcher would want to calculate:

$$LBLIwx^* = [(1 - U_i) * LBLI_i] * \left[U_i * \left(\frac{x_i}{\sum\limits_{\forall i} xi} \right) \right] \tag{3.14}$$

Here U_i is the weighting given to the output weight and $(1 - U_i)$ is the weighting given to sectoral linkage strength, in the ranking of sectors according to the $LBLIwx^*$ measure. If we want to obtain an equal ranking of sectoral linkage strength and (in this example) the total output weight, we can set U_i to equal 0.5 which will produce a ranking of sectors using Equation 3.14 that is identical to the ranking produced using Equation 3.13. The subscript on U_i here reflect the possibility that the researcher wants to weight sectoral linkage strength and an exogenous weighting measure (such as total sectoral output) differently across sectors.

Having outlined how the weighted linkage measures are constructed, we now discuss the different weighting schemes that are used in this chapter and why they might be useful, before presenting our results for Scotland.

Overview

Different weights, as we stated earlier, are useful for different reasons and the researcher needs to determine the best weighting for their own case. In our application of weighted linkage measures we focus on a couple of weightings that we believe add value to the linkage analysis presented thus far. It is not always the case that the same weight is applied to every linkage measure that we previously outlined.

In the case of the LBLI we focus our attention on two weighting measures, a weighting using total sectoral output, and another using export final demand. The weighting using total sectoral output is used as the scale measure. This allows us to consider the scale of the potential impacts as it adjusts the sectoral ranking to allow for differences in the size of each sector. Given the interest in the emissions embodied in trade, and the importance of this source of demand in supporting both Scottish emissions generation and Scottish output production, we also weight our backward linkage measures by export final demand.

Other weightings are available, and could have been used. We focus here on these two particular weightings to examine the impact of scale and export demand on sectoral rankings of backward linkages using a 1:1 weighting scheme. In the case of forward linkages we consider one weighting scheme, using as our weight sectoral gross value added. We again apply a 1:1 weighting of these components in the GFLIwv measure (Ghosh forward linkage index weighted by value added).

Weighting by sectoral value added allows us to introduce into the forward linkage ranking a measure of the importance of non-produced inputs to each sector. This is the scale measure for these forward linkage measures. This gives a sectoral ranking which recognises those sectors which have the greatest potential to impact aggregate cost, and are also the greatest users of primary inputs. This is useful in the context of identifying those sectors where an efficiency improvement will decrease output price the most, while having the scale to affect aggregate cost the most. We apply these weighting schemes to the backward and forward output linkages measures outlined above. We present these results in Tables 3.8 to 3.10 and discuss them below.

Backward linkages

The results of the output and export final demand weighted LBLI measure (the LBLIwx and LBLIwe) are presented in Table 3.8 below. Comparing the LBLI (see Table 3.3) and the LBLIwx there are 6 sectors which do not have above average LBLI strength according to the unweighted index, but which are ranked in the top 10 according to the output weighted index (sectors 7 (Food & drink), 44 (Retail distribution), 52 (Banking & finance), 55 (Real estate activities), 60 (Public administration), & 62 (Health & social work)).

This means that these sectors, while they do not have a particularly strong domestic supply chain attached to each £million of final demand compared to the other sectors, as a consequence of their size (in terms of their contribution to total output in the economy) have important total (or aggregate) supply chains. This is an important distinction. Recalling that the LBLI is equivalent to a standardised index of Type I multipliers, our result here would indicate the presence of a sector which is large in terms of total output but has a smaller Type I output multiplier.

In an unweighted index this kind of sector would be considered to be unimportant. A sector which is large, even if its supply chain per unit of final demand does not embody an above average quantity of output, is still important in determining aggregate output. The sectors which stand out in this regard are sectors 59 (Professional services), 60 (Public administration) and 62 (Health services). These three sectors all have below average unweighted linkage strength, but are promoted into the top 5 sectors according to the output weighted LBLI measure.

In the LBLIwe ranking, we can see again that there are a number of sectors whose ranking changes substantially between the unweighted LBLI and the LBLIwe. The most striking of these is sector 7 (Food and drink) which goes from having a LBLI score just below average to being ranked top in the LBLIwe ranking.

Sector 52 similarly moves up the sectoral rankings between the LBLI and the LBLIwe, moving into the top 5 in the weighted ranking from being below average in the unweighted ranking. These large changes reflect the different export propensities of these sectors. This means that the increase in domestic output, driven by an increase in export final demand, will be driven most by those sectors ranked highest by the LBLIwe.

Some sectors ranked highly by the unweighted index are demoted in both the LBLIwx and LBLIwe rankings. These sectors include 49 (Air transport), 22 (Rubber products), 24 (Glass & glass products) and 27 (Articles of concrete etc). These sectors may support an above average volume of output through each unit of final demand, but they do not satisfy a sufficient level of export final demand or are not large enough sectors, in terms of output, to be ranked highly in either of these weighted indices.

This means that if we want to increase aggregate output the most, we should target investment into those sectors where a given investment will yield the greatest increase in total output. These sectors are those ranked highest according to the output weighted backwards linkage measure or LBLIwx. In the case of an export driven growth strategy, attention should perhaps be given to investment to develop and expand those sectors ranked highly according to the LBLIwe. These are the sectors which, if they were expanded through an increase in export final demand, would be expected to support the most additional output in the Scottish economy.

Forward linkages

The GFLI weighted by value added (GFLIwv) results are presented in Table 3.10. There are a number of sectors which are not considered important according to the unweighted GFLI, which are ranked highly according to the value added weighted Ghoshian forward linkage measure (GFLIwv). Sectors 41 (Construction), 52 (Banking & finance), 55 (Property services), 59 (Other business activities) and 62 (Health services) stand out in this regard. All of these sectors have below average GFLI strength according to the unweighted index, but all are highly ranked in the GFLIwv index.

This shows that while these sectors may not have an above average ability to affect the price of sectoral output, when we consider the size of the sector in the ranking exercise (in this case represented by each sector's contribution to aggregate value added); it is clear that these are the sectors that have the potential to affect aggregate cost the most. This is very useful information. It may be that there are technological changes or efficiency improvements that can be developed. In this case, the GFLIwv ranking shows is that such a measure, if we wish to have the greatest impact on total costs, should be focused on different sectors to those selected as important by the unweighted GFLI.

The distinction here is between affecting sectoral output prices and affecting total cost. The unweighted index provides a ranking of sectors according to their ability to affect sectoral output prices. This weighted ranking, since value added here is the measure of scale, provides a means of assessing the ability of each sector to affect aggregate cost. The higher a sector is ranked according to the weighted ranking the greater its potential to impact total cost within the economy.

3.4 Pollution key sector analysis

In the preceding sections of this chapter we have introduced a range of linkage measures which attempt to assess the importance of particular sectors within the Scottish economy. We noted earlier that the tools used to assess the strength of these economic linkages had been applied and used to examine other linkages within the economy, such as employment, pollution or water use linkages.

In this part of the chapter we focus on pollution linkages within the economy. In applying these measures we examine only the CO_2 linkages within the Scottish economy, although the initial discussion is framed in the broader context of pollution as the methods are easily generalisable beyond CO_2 to any factor which can sensibly form the basis for a factor-output intensity.

As we discussed in the previous chapter, there are two main ways to think about pollution in economic models. One approach is to look at the pollution generated by each sector or agent in the model, the other is to look at the pollution supported by the behaviour of categories of final demand. In Chapter 2 we discussed this issue when we thought about directly generated pollution versus the pollution supported by each sectors final demand. It was the latter approach which formed the basis for the attribution work in Chapter 2. Here we develop this distinction slightly.

In the pollution version of the LBLI we still think in terms of the emissions supported by final demand for that sector, although in this case it is the pollution directly and indirectly required to generate a unit of the final demand of each sector. The carbon Leontief backward linkage index (CLBLI) case is therefore a direct extension of the LBLI introduced earlier. From an environmental perspective, a policymaker may be interested in ranking sectors according to the total emissions supported by each unit of their final demand.

This can be thought of as the environmental intensity of sectoral final demand. This is where the carbon extension of the Leontief backward linkage index, the carbon Leontief backward linkage index (CLBLI) measure, is useful.

In addition, the CLBLI provides a useful way of thinking about the impacts of a flat rate CO_2 tax on each sector of the economy. Working on the basis that following the implementation of such a taxation system, which unlike the EU emissions trading scheme we assume is universal, each sector would likely pass the cost of this new tax to the final consumer.

This would mean that those sectors which purchased the greatest amount of embodied CO_2 would be affected the most. In other words, sectors will be affected to the degree that they consume pollution embodied in their inputs under this kind of taxation scheme. The CLBLI ranking is therefore also the ranking of sectoral impacts in the face of such a flat rate CO_2 tax.

An alternative way to think about sectoral environmental impacts is according to the strength of the emissions embodied in their forward sales to the other sectors. This is where the Carbon Leontief forward linkage index (CLFLI) is useful. Recall though that this measure is the emissions in each sector that are supported by a unit of the final demand of all sectors, which as we noted earlier, is a peculiar stimuli- a point we will return to.

The other forward linkage measure considered here is the carbon Ghoshian forward linkage index (CGFLI). This measure is based on the carbon Ghoshian inverse outlined later in this chapter. This linkage measure can best be interpreted in the context of an environmental efficiency improvement. Although the interpretation of this particular measure is somewhat peculiar, for completeness we outline and consider it fully later in this chapter.

The next section reviews environmental key sector studies, and the section after that extends both the Leontief and Ghosh frameworks to examine pollution issues. In the sections that follow, we then outline and apply some linkage measures, detailed for the case of sectoral output, to these new pollution inverse for the case of CO_2.

3.4.1 Review of environmental key sector studies

Having provided some intuition for environmental linkage and key sector measures in the previous section, we review the applications of this type of analysis in the existing literature in this section. Lenzen (2003) was one of the first papers to look at environmental extensions to key sector methods[9]. In Lenzen (2003) three approaches are taken[10], these are:

1. Linkage analysis (similar to our approach).
2. Field of influence (Sonis & Hewings 1989) .
3. Structural path analysis (Defourny & Thorbecke 1984).

Unlike in the analysis presented earlier in this chapter, where we focused on the domestic use (**A**) matrix, Lenzen (2003) uses a use matrix that combines domestic use and imported use. This is equivalent to the **(R+M)** matrix used in the domestic technology assumption approach in the previous chapter (see Section 2.7.3). The advantage of using the combined use matrix is that it encompasses the ‘complete’ supply chain, rather than purely the domestic supply chain.

Indeed Lenzen (2003) notes this advantage in a pollution context with reference to the global nature of greenhouse gas emissions and climate change (Lenzen 2003, p6) . The alternative perspective would be that using the domestic use matrix allows you to examine the emissions linkages over which policymakers in the region or nation of interest have control. This is a similar argument to that developed by Turner et al. (2011b) in the context of territorial versus consumption based emissions measures, and is of considerable importance in a regional context.

Of Lenzen’s (2003) three approaches we extend the first (linkage) approach here by considering a broader range of linkage measures. Lenzen (2003) consid-

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[9] Fritz et al. (1998) is another early contribution in this literature. Their paper presents a Miyazawa decomposition of sectoral pollution linkages.

[10] In all these measures, Lenzen (2003) uses the combined use matrix discussed in the previous chapter.

ers but does not apply the Leontief forward linkage index (LFLI) measure, and only considers primary input, final demand and output weighted measures.

The other two approaches taken by Lenzen (2003) are not pursued in this chapter. The field of influence approach, which examines the impact on the Leontief inverse matrix of a change in the underlying A matrix, is a useful tool to assess the influence of particular coefficients in the **A** matrix. The aim being to determine '*inverse important coefficients*'. This is not a superior approach to the linkage analysis presented here, but a complementary one. The reason that we do not pursue this approach in this chapter is that, as Temurshoev (2009) demonstrates, the hypothetical extraction method utilised later in this paper is a closely related approach to the Sonis & Hewings (1989) method.

The third approach that Lenzen (2003) take in examining environmental linkages (or multipliers) is a decomposition of the linkages measures used. This is known as structural path analysis. We do not pursue this approach here for reasons of conciseness, although it is an established method and may provide additional information on the relationship between production and its environmental impacts.

Other studies have utilised and developed these different techniques to examine environmental linkages in the economy. We review some of these studies here, these include: Sánchez-Chóliz & Duarte (2003), Alcántara Escolano & Padilla Rosa (2006), Tarancón Morán & del Río González (2007), Tarancón Morán et al. (2008), Shmelev (2010) and Temurshoev (2010).

Sánchez-Chóliz & Duarte (2003) utilise a decomposition of the output-pollution multipliers in a similar way to Lenzen (2003). The innovation of Sánchez-Chóliz & Duarte (2003) was to decompose the total linkage measures that we examine here, into their components and they go further than Lenzen (2003) in motivating this decomposition, drawing on the work of Pasinetti (1975).

Sánchez-Chóliz & Duarte (2003), taking as their case study the Aragon region of Spain, calculate the key sectors in this region for 5 different pollutants, finding that the sectors determined as key vary across pollutants. Importantly, for our purposes, Sánchez-Chóliz & Duarte (2003) discusses the issue of intrasectoral effects in linkage analyses, and conclude that the "linkage effects are obscured by self-consumption" (Sánchez-Chóliz & Duarte 2003, p436), and so are best omitted in calculating these linkage measures.

Alcántara Escolano & Padilla Rosa (2006) carried out a pollution key sector analysis for the case of Spain. Instead of using the traditional key sector analysis techniques, which we have outlined in this paper, they focus exclusively on the supply perspective, specifically the impact of changes in value added on CO_2 emissions. This extends an approach taken by Alcántara & Roca (1995). Alcántara Escolano & Padilla Rosa (2006) calculate emissions-value added elasticities to determine which sectors are 'key' in terms of CO_2 emissions in the Spanish economy.

The idea is to derive an estimate for each sector of the responsiveness of its emissions to a change in primary inputs (or income to the sector). Formulating these in terms of an elasticity allows Alcántara Escolano & Padilla Rosa (2006) to report a fairly intuitive measure of the effect of changes in the 'profit' of a sector on the emissions it generates, and thus produce a ranking of sectoral importance.

It is not clear the extent to which this measure improves upon the existing suite of measures, except perhaps in providing a more intuitive measure. The justification given in the paper centers on the usefulness of this ranking in understanding the impact on emissions of the growth of this sector. Yet, it is not clear how this is an improvement upon a weighted backward linkage measure.

Tarancón Morán & del Río González (2007) and Tarancón Morán et al. (2008) apply linkage measures to the whole Spanish economy and the Spanish electricity sector respectively. Tarancón Morán & del Río González (2007) employ a somewhat abstract 'lineal' programming approach to determine the importance of each sector in determining total production emissions.

The approach taken is to introduce a change in total emissions, then determine which sectors require the smallest change in their technical coefficients or proportion of final demand to achieve this change in total emissions. This approach, while providing a different means of ranking sectoral importance, does not appear to improve upon the traditional linkage analysis and therefore is not followed in this chapter.

The approach in Tarancón Morán et al. (2008) shares some similarities with the Sonis & Hewings (1989) structural path analysis. Specifically it tries to understand the impact of changes in the a_{ij} coefficient of each sector on the output of the electricity sector (sector j). They then determine the average of the elasticity of each sector's column elements with respect to electricity sector output. A sector i where the emissions of the electricity sectors (sector j) are highly sensitive to its column elements, will be ranked highly according to this measure.

Alcántara & Padilla (2009) examines the sectoral pollution-economy relationships in the Spanish service sector. This builds in part on the work of Sánchez-Chóliz & Duarte (2003), but extends their approach by adopting a different decomposition technique. This approach allows them to focus on a decomposition of the emissions related to the service sector in Spain. This decomposition approach, similar to the other decomposition approaches noted in this section, is not applied in this chapter. Decomposition techniques could be applied to further analyse the linkage measures outlined in this chapter, but this is left for future work.

Shmelev (2010) from the perspective of industrial ecology examines the environmental key sectors in the UK. Although this paper is presented without details of how the backward and forward linkage measures are constructed, which is unhelpful since- as we have already established- there is a range of possible measures, the innovation of this paper is to incorporate key sector analysis techniques in a multi-criteria decision aid (MCDA) framework (see Zeleny (1982) for more on MCDA).

Lastly, Temurshoev (2010) used a hypothetical extraction approach to examine the key sectors in the Australian economy for several of what he refers to as ‘factors’; namely water use, carbon dioxide, profitability and wages. Using this approach he determines both the key sectors and the key ‘groups’ of sectors in the Australian economy. Establishing that by ‘key group’ he does not mean the set of key sectors, Temurshoev (2010) sets out to determine which collective of sectors (together) has the greatest impact on the overall economy according to each of the factors he investigates.

It is worth noting the similarity that Temurshoev (2010) claims his hypothetical extraction of key groups has to the ‘fields of influence’ approach of Hewings et al. (1988). Setting aside the technical proofs, it is intuitively clear that these measures are attempting to assess similar effects. The idea underpinning the ‘fields of influence’ approach was that it provided a means of assessing the impact of technological change within the input-output system.

The similarity with the hypothetical extraction of key groups is that it too allows us to assess the potential influence of technological change. In the Temurshoev (2010) case it does this by identifying a group of k sectors (out of the $n > k$ sectors in the economy) which have the largest impact on a particular macro variable of interest (for instance total output).

Highly interdependent sectors are less likely, by this measure, to appear in highly ranked key groups together. Since the ‘fields of influence’ approach assesses the impact that a particular sector has on the other sectors of the economy as a result of technological change in that sector (implicitly this approach seeks to identify sectors which are highly interdependent and thus the technological change will have the biggest impact). It should be fairly clear now how these two approaches relate to each other, at least intuitively.

One of the strongest messages that comes through the existing environmental linkage and key sector literature, is the lack of discussion about why particular measures are being used, but more importantly what the actual interpretation and implication is of different linkage measures. In some cases it is not clear which measures are being used (Shmelev 2010), in other cases measures are being used without any discussion about whether extending the traditional linkage measure to an environmental application makes sense, far less any discussion about how to interpret the measure in the environmental context (Sánchez-Chóliz & Duarte 2003). This is most obvious in the use of forward linkage measures based on the Ghoshian supply driven input-output model.

The fact that these measures can be extended to look at environmental issues is (potentially) useful, but there needs to be an understanding of why they might be useful, and what these measures mean. In introducing environmental linkage measures in this chapter, we seek to address these deficiencies in the existing literature, and explore the interpretation of these environmental linkage measures

3.4.2 Extending the input-output model

In Section 3.3 we introduced a number of measures of forward and backward linkages strength using the Leontief and Ghoshian inverses. In this section we outline how these measures can be adapted from the examination of output patterns in the economy, building on the intuition for these measures which was discussed at the start of Section 3.4, to the examination of CO_2 relationships within the economy.

To do this we utilise standard environmentally extended input-output models. The required modification to the earlier methodology is straightforward. Keeping as the workhorse of these measures, the Leontief and Ghoshian inverses, it is easy to see that these inverses can be translated into 'emissions unit' inverses using the sectoral emissions intensities.

Taking a vector p, of emissions intensities (emissions per unit of sectoral output (here tonnes of CO_2 per £million)) for each of the n sectors, we can turn it into a principle diagonal matrix. This gives us an n*n matrix $\hat{p}$ of emissions intensities containing non-zero elements along the main diagonal. Multiplying this n*n matrix by the Leontief and Ghoshian inverse, results in an n*n emissions inverse. That is, the new emissions inverses are constructed as:

$$\left[\begin{array}{cccccccccc} 68 & \ast & 68 & 68 & \ast & 68 & . & 68 & \ast & 68 \\ & \hat{P} & \ast & (I & - & B)^{-1} & = & & T & \\ n & \ast & n & n & \ast & n & . & n & \ast & n \end{array}\right] \tag{3.15}$$

$$\left[\begin{array}{cccccccccc} 68 & \ast & 68 & 68 & \ast & 68 & . & 68 & \ast & 68 \\ & \hat{P} & \ast & (I & - & A)^{-1} & = & & S & \\ n & \ast & n & n & \ast & n & . & n & \ast & n \end{array}\right] \tag{3.16}$$

Creating a CO_2 Leontief and Ghoshian inverse raises some interesting issues. In the demand driven input-output system with fixed input relationships (as discussed in the previous chapter) the assumption of a fixed output-pollution intensity (pollution per £million of sectoral output) is reasonable. In the supply driven input-output system on the other hand, output is produced using a production (or more accurately an ‘allocation’) function which is characterised by perfect substitutes.

This means that in producing sectoral output all inputs are considered perfectly substitutable. Assuming a fixed pollution-output relationship, alongside interchangeable inputs, seems untenable. This makes using the supply driven input-output model, with fixed output pollution coefficients, for modelling purposes difficult to justify.

We could attempt to resurrect the supply driven input-output system here by thinking about it purely as an accounting framework. In this context we could use it to attribute sectoral output to value added and then assume a fixed output- pollution relationship. The difficulty here is in justifying the use of a model which is not consistent as a model. The Ghoshian inverse does not really exist in an accounting sense. In fact, in an accounting sense, it is a pretty meaningless matrix, it only exists in the context of the input-output model. We therefore do not pursue this justification for the use of these measures.

An alternative approach lies in the price reinterpretation of Dietzenbacher (1997). This is the approach that we take in this chapter. However, while the price reinterpretation of Dietzenbacher (1997) rescues the output version of the supply driven model for both accounting and modelling work, it is not clear that the Dietzenbacher (1997) reinterpretation saves this measure in the environmental case, as we will discuss below.

While we have an interpretation for the environmental extension of the GFLI measure introduced earlier, it is not a straightforward one. In fact, as we will soon see, the only available interpretation of this measure is somewhat peculiar. The next section begins our pollution linkage analysis by outlining the calculation of the pollution Leontief backward linkage index.

3.4.3 Leontief backward linkage measures

In this section we build CO_2 backward linkage measures to parallel the output backward linkage measures introduced earlier. The CO_2 linkage measures presented in this chapter use the carbon Leontief and carbon Ghoshian inverse just outlined. Using these new inverses, it is straightforward to apply the standard backward and forward linkage calculations (Equations 3.1 - 3.16) to rank each of the n sectors according to the strength of their CO_2 linkages.

This approach yields the carbon equivalent of the Leontief backwards linkage measure (this is the pollution corollary to 3.1, and is equivalent to the traditional output-CO_2 multiplier):

$$\mathrm{CBLI_j}=\sum_{\mathrm{i=1}}^{\mathrm{n}}\mathrm{S_{ij}} \tag{3.17}$$

By defining a ‘global pollution intensity’, using the carbon Leontief inverse, as:

$$\mathrm{CK}=\sum_{\mathrm{i=1}}^{\mathrm{n}}\sum_{\mathrm{j=1}}^{\mathrm{n}}\mathrm{S_{ij}} \tag{3.18}$$

We can construct the carbon Leontief backwards linkage index (CLBLI) as:

$$\mathrm{CLBLI} = \left[\frac{\frac{1}{\mathrm{n}} \sum\limits_{\mathrm{i}=1}^{\mathrm{n}} \mathrm{S}_{\mathrm{ij}}}{\frac{1}{\mathrm{n}^2} \sum\limits_{\mathrm{i,j}=1}^{\mathrm{n}} \mathrm{S}_{\mathrm{ij}}} \right] = \left[\frac{\frac{1}{\mathrm{n}} \mathrm{CCBL}_{\mathrm{j}}}{\frac{1}{\mathrm{n}^2} \mathrm{CK}} \right] = \left[\frac{\mathrm{CCBL}_{\mathrm{j}}}{\frac{1}{\mathrm{n}} \mathrm{CK}} \right] \tag{3.19}$$

Applying this methodology to the Scottish input-output data for 2004 with our environmental data for 2004, yields the results in Table 3.5. From Table 3.5 we can see that the top 5 sectors according to the carbon Leontief backward linkage index (CLBLI) in descending order are: 26 (Cement & Clay), 38 (Electricity production and distribution), 48 (Water Transport), 49 (Air Transport), and 28 (Iron & Steel). This means that in terms of their output-CO_2 content, these five sectors have the largest output-CO_2 supply chain intensities. This could have some interesting policy uses, some of which we noted earlier. Figure 3.1 shows the top 20 sectors by the CLBLI.

Intra-sectoral impacts in the Leontief backwards linkage measure

In section 3.3.1 we saw that the pure Leontief backwards linkage index (PLBLI) measure was identical to the LBLI measure, except that it excluded the impact of the own sector coefficient L_{ij}, where i = j. In the same way, the pure carbon Leontief backward linkage (PCLBLI) is identical to the CLBLI except that it excludes the impact of, S_{ij} where i = j, i.e. the own sector coefficient.

The own sector coefficient here is the emissions embodied in purchases/sales from sector i to sector j where i=j- this incorporates both the direct and indirect effects. This means that the PCLBLI focuses only on the impacts that sector i has on the other n-1 sectors of the economy; in our case the emissions embodied in sector i's purchases from the other n-1 sectors. The top 5 sectors in descending order from Table 3.5 according to the PCLBLI are: 14 (Coke, refined petroleum and nuclear fuel), 27 (Articles of concrete etc), 24 (Glass & glass products), 6 (Metal ores extraction, other mining and quarrying), and 19 (Pharmaceuticals). Again, the top 20 sectors by the PCLBLI are presented in Figure 3.2.

Figure 3.1: Carbon backward linkage index results (top 20 sectors).

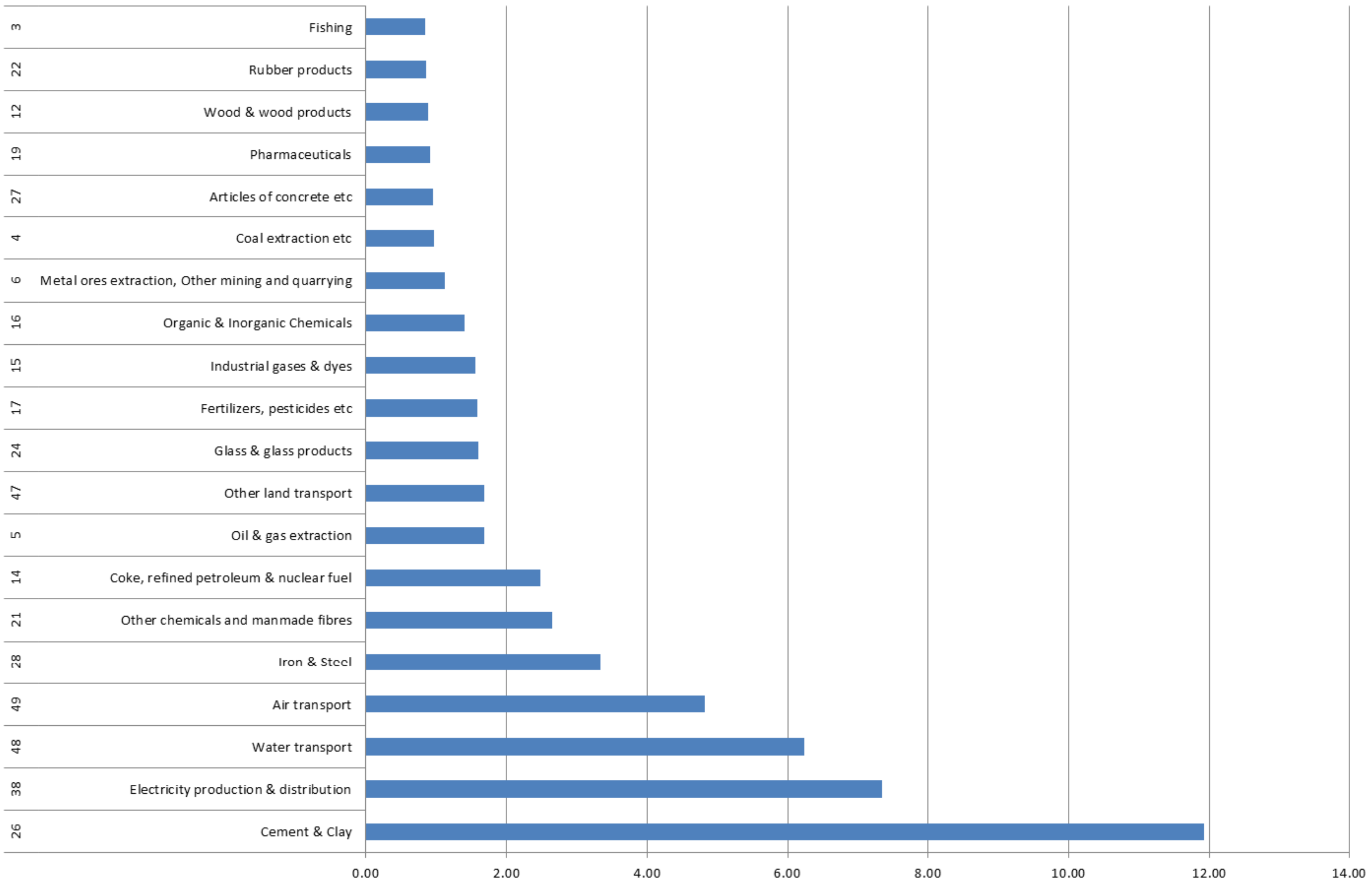
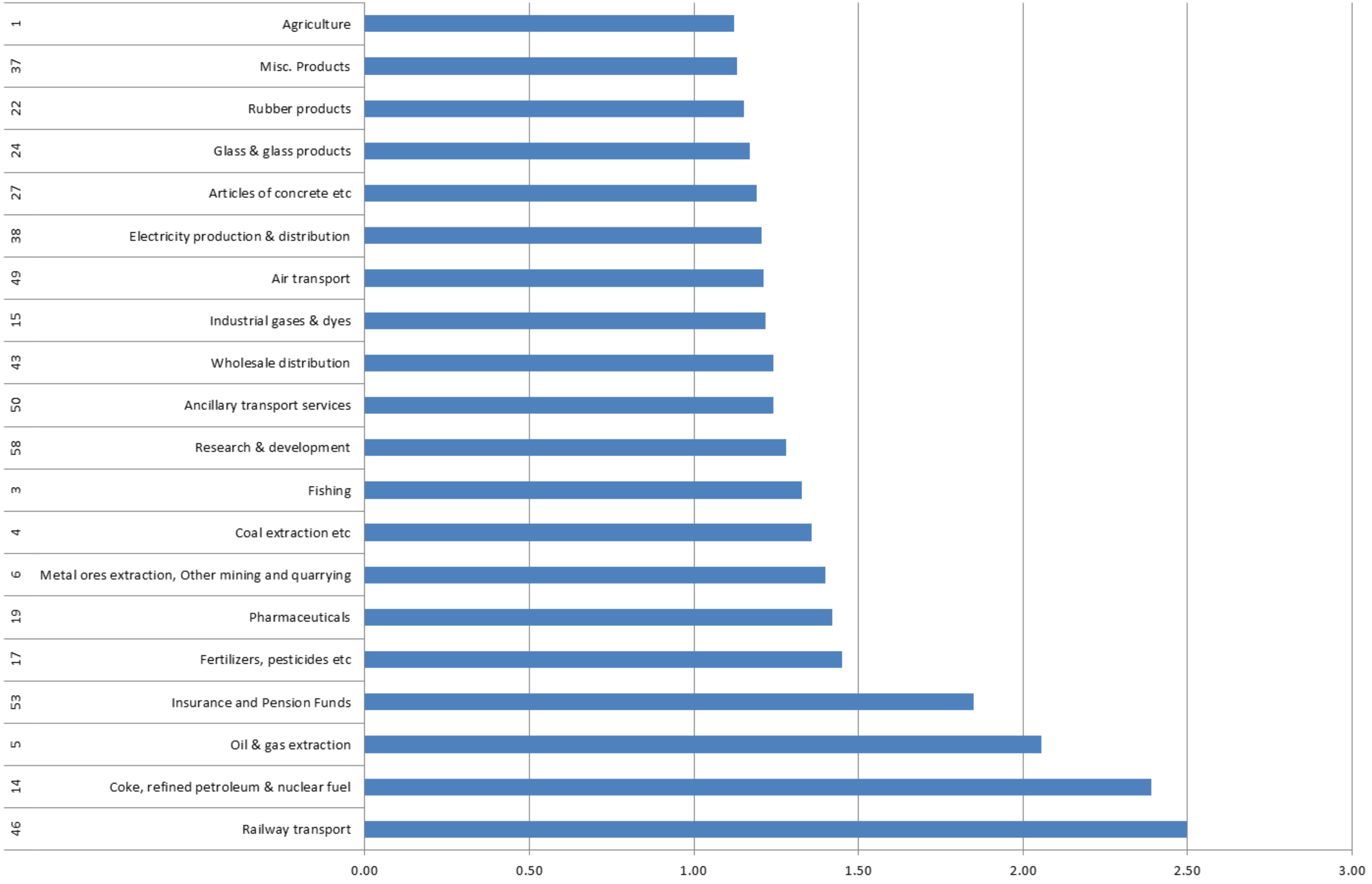


Figure 3.2: Pure carbon backward linkage index results (top 20 sectors).



Comparing this to the earlier results for the carbon Leontief backwards linkage index (CLBLI), not one of the top 5 by these two measures is the same. This means that the choice of linkage measure, in particular whether they focus on the total impacts or only on the intersectoral effects, is important in determining the ranking of sectors. As we discussed earlier, the omission of these own sector effects is likely to be more problematic, and to tell us less, where sectors are highly aggregated either in practice with highly vertically integrated companies.

Furthermore, in considering that backwards linkage measures can tell us something about the supply chain processes of a particular economy, we assume that the inter-sectoral relationships we model in the input-output system are true. Thus omitting these own sector effects, has the result that we are omitting a potentially important segment of the supply chain for that industry. In utilising such measures we must recognise that 'pure' carbon linkage measures are analysing incomplete supply chains.

Where the CLBLI and PCLBLI measures give a different ranking of sectors, it must be that those sectors that are considered in the top 5 according to the CLBLI ranking, but not the PCLBLI ranking, have significant embodied pollution in their intrasectoral sales.

3.4.4 Leontief forward linkage measures

Utilising the new carbon Leontief inverse constructed in section 3.1 we can calculate the carbon Leontief forward linkage index (CLFLI) for each sector i as:

$$\mathrm{CLFLI}=\sum_{\mathrm{j=1}}^{\mathrm{n}}\mathrm{S_{ij}} \tag{3.20}$$

Similarly, using the global intensity CK defined in Equation 3.18 above, the carbon Leontief forward linkage index is:

$$\mathrm{CLFLI_i} = \left[\frac{\frac{1}{n}\sum\limits_{j=1}^{n} \mathrm{S_{ij}}}{\frac{1}{n^2}\sum\limits_{i,j=1}^{n} \mathrm{S_{ij}}}\right] = \left[\frac{\frac{1}{n}\mathrm{CLFL_I}}{\frac{1}{n^2}\mathrm{CK}}\right] = \left[\frac{\mathrm{CLFL_I}}{\frac{1}{n}\mathrm{CK}}\right] \tag{3.21}$$

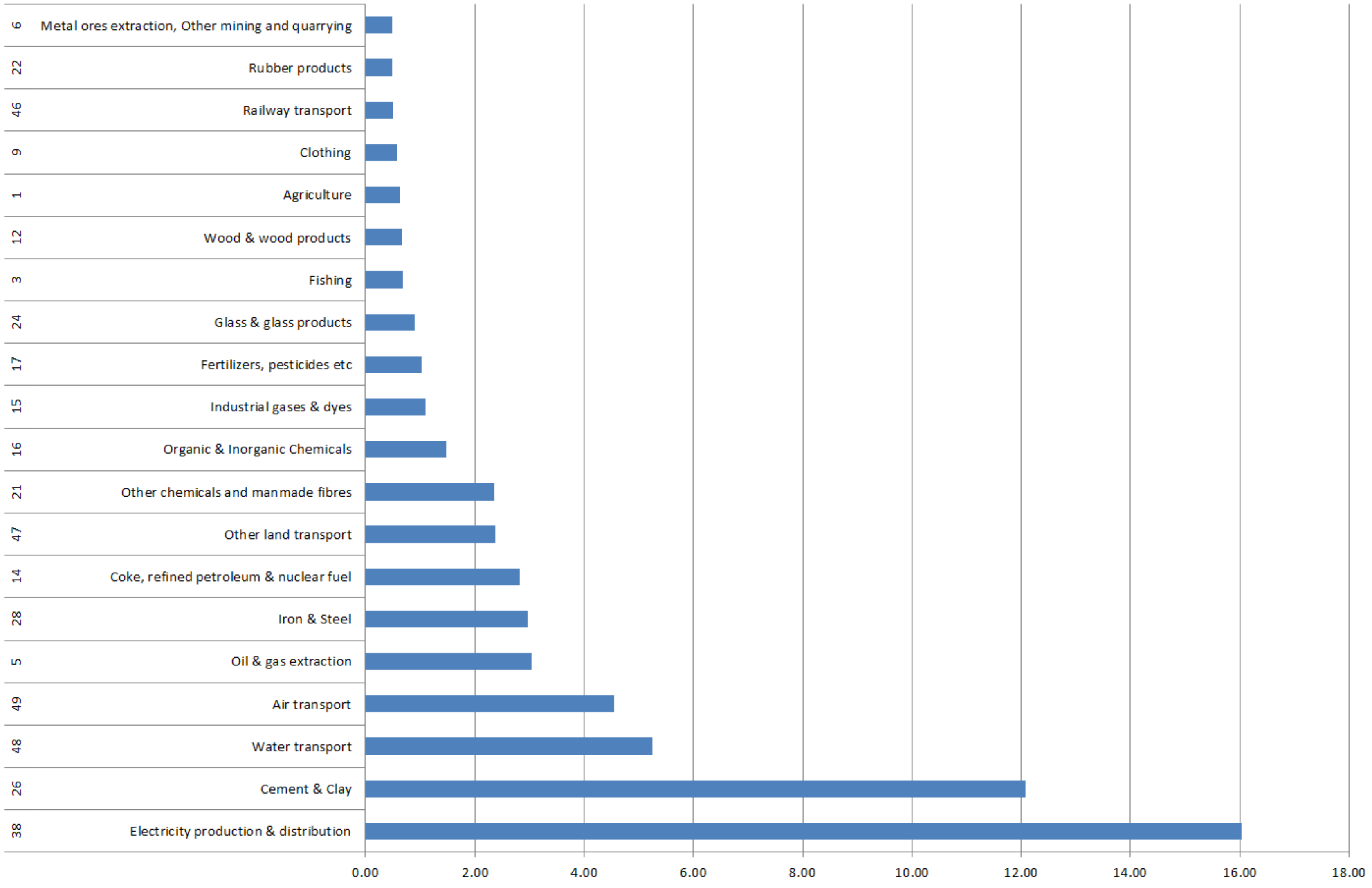
We mentioned earlier that there have been criticisms made of the use of the Leontief forward linkage index (LFLI) measure. As we noted earlier, these measures are calculated on the basis of a unit increase in the final demand for all sectors of the economy. We pursue it here for the environmental case, as we did earlier for the output case, because it provides a good sectoral level comparison of forward linkage strength- even if the underlying stimulus is unrealistic.

The CLFLI measure provides the following ranking of the top 5 sectors (in descending order of linkage strength): sectors 38 (Electricity production and distribution), sector 26 (Cement and clay), sector 48 (Water transport), 49 (Air transport) and sector 5 (Oil and gas extraction). The top 20 sectors by the CLFLI are presented in Figure 3.3. Despite the CLFLI measures being calculated as a response to a peculiar stimuli within the economy, this measure is useful (as we saw in Section 3.3.1) when examined alongside a standard deviation index of the row elements of the (here Carbon) Leontief inverse (S). Sectors with high CLFLI scores and low standard deviation index scores could be considered to be important in the sense of having strong forward carbon linkages that are dispersed widely throughout the economy.

At this point we examine the standard deviation index scores of each of the sectors. This information is contained in Table 3.7. 4 of the top 5 sectors according to the CLFLI measure have the highest STDI scores, while the other (5th) sector is ranked 8th highest in the STDI. This means that these sectors, while they have large carbon impacts on the economy (measured by the CLFLI measure), these impacts are concentrated over fewer sectors of the economy than others.

The result that the sectors with the strongest CLFLI scores are also those

Figure 3.3: Carbon Leontief forward linkage index results (top 20 sectors).



with the highest STDI score may be the result of aggregation issues within the input-output framework or because the sectors themselves are very highly vertically integrated. The point here is that the environmental impacts of these sectors are perhaps not sufficiently distributed throughout the economy to lead to economy wide changes that policymakers may be seeking. A policy targeted at a sector with narrow environmental linkages throughout the economy may not lead to the wider impacts that are hoped for.

A simple example would be a technological innovation which reduced the carbon emissions embodied in (or produced by) a particular product that was sold by one sector. If this innovation occurred in a sector with narrow forward linkages it would not be unlikely to lead to the economy wide adoption of that innovation, or to a wider improvement in reducing emissions. It was noted earlier that one of the reasons why the dispersion of impacts was considered important in the development literature was that technological progress was said to flow forward from an originating sector to the other sectors of the economy. In the case of pollution it may be useful to establish which sectors would be capable, through their strong and economy wide linkages, of leading this kind of environmental diffusion.

Another point to note is that the CLFLI and sectoral standard deviation rankings are very similar. Even though the standard deviation ranking maps closely to the CLFLI ranking there are sectors with some of the highest CLFLI scores which have far more asymmetric impacts than sectors with only slightly lower CLFLI scores. For example both sector 5 and sector 26 appear in the top 5 ranking of sectors according to the CLFLI, but have quite different STDI scores (2.0751 and 15.1675 times the average respectively). Next, we consider the carbon forward linkage measures based on the Ghoshian supply driven input-output model.

3.4.5 Carbon Ghoshian forward linkage measure

In this section we introduce the carbon Ghoshian forward linkage index measure (CGFLI). First we introduce the measure using the standard matrix algebra as before for the other measures in this paper, then we discuss the interpretation of this measure in the context of carbon forward linkages. As we will soon see, it is possible to provide an interpretation for this measure, however this interpretation is somewhat peculiar. It is for this reason that we do not dwell on the results of our application of this measure.

The calculation of the forward carbon linkage measure using the Ghoshian inverse for each sector i is identical to the CLFLI measure outlined above, but is based on the summation of elements of the carbon Ghoshian inverse T:

$$\mathrm{CGFL} = \sum_{\mathrm{j}=1}^{\mathrm{n}} \mathrm{T}_{\mathrm{ij}} \tag{3.22}$$

This is then transformed into an index, what is referred to here as the classic carbon forward linkage (CGFLI) index/measure, as follows:

$$\mathrm{CGFLI} = \frac{\frac{1}{\mathrm{n}}\sum\limits_{\mathrm{j}=1}^{\mathrm{n}} \mathrm{T}_{\mathrm{ij}}}{\frac{1}{\mathrm{n}^2}\sum\limits_{\mathrm{i,j}=1}^{\mathrm{n}} \mathrm{T}_{\mathrm{ij}}} = \frac{\frac{1}{\mathrm{n}}\mathrm{CCFL}_{\mathrm{i}}}{\frac{1}{\mathrm{n}^2}\mathrm{CK}} = \frac{\mathrm{CCFL}_{\mathrm{i}}}{\frac{1}{\mathrm{n}}\mathrm{CK}} \tag{3.23}$$

Where we redefine CK above as:

$$\mathrm{CK} = \sum_{\mathrm{i}=1}^{\mathrm{n}} \sum_{\mathrm{j}=1}^{\mathrm{n}} \mathrm{T}_{\mathrm{ij}} \tag{3.24}$$

We noted earlier that there are difficulties in extending the GFLI measure to the case of pollution. In the supply driven input-output framework, introduced and outlined in Chapter 2, we saw that sectoral output is driven by sectoral value added. In extending the supply driven input-output framework to the pollution case, we turned the Ghoshian inverse into a pollution inverse which is similarly driven by value added.

This gives us an interpretation of the CGFLI as ranking the sectors of the economy according to the responsiveness of the sectoral emissions intensity to changes in primary input efficiency. This becomes clear if we compare a carbon Ghoshian inverse to the original output based inverse. According to the reinterpretation of the Ghosh inverse (as the inverse matrix of a price driven input-output model) changes in the value of primary inputs -produced through changes in the price of primary inputs- determine the change in the value (or price, since value is simply price x quantity) of sectoral output. A change in the value of primary inputs can therefore be thought of as coming from either a change in the price of primary inputs or a change in the efficiency of primary input use.

Since the value of primary inputs is the product of the price and quantity, the change in the value of primary inputs can be driven by either, or both, of these factors. The problem with the original Ghosh interpretation of this system was that a change in the quantity of primary inputs in sector i led to changes in the output of all the sectors that sector i sold to. In the price interpretation of this model, changes in the value of sectoral output are driven by changes in the price of sectoral output, itself being driven by changes in the price of primary inputs in sector i.

Here though, the quantities of these sectors' outputs are taken to be fixed and any changes are attributed to changes in output price. The difficulty in extending this measure to an environmental context is that changes in the value of sector i's primary inputs would drive changes in the volume of pollution embodied in sales to the other sectors of the economy. This makes little sense. Why would changes in the price of primary inputs, taken as the basis for the change in the value of primary inputs, affect the volume of emissions embodied in a sector's forward sales?

Thinking about changes in the value of a sector's primary inputs, generated by an efficiency change (perhaps labour has become more efficient), in the context of pollution doesn't provide much promise. In this case efficiency changes would again lead to changes in the pollution content of forward sales without any convincing rationale as to why this might happen. The only potential interpretation is too peculiar for it to be of practical use.

Assume: changes in the value of primary inputs are driven by changes in the efficiency with which primary inputs are used, and that the only thing that changes as a result of a change in the value of primary inputs are prices. In an environmentally extended supply driven input-output model, with a change in the value of primary inputs, the estimated emissions sold to the other sectors will change. Recall that the price of output has changed, and we're applying a pollution-output relationship. This means that there needs to be an adjustment to the pollution-output intensity to recognise this change in price, and keep the same pollution-output relationship.

In case this is not clear, consider that a pollution-output relationship of 1, (1 unit of pollution for each unit (£million) of output), would require to be adjusted to maintain the same output-pollution link, if there was a price change. If the price of sectoral output fell to 0.9, in order to keep the pollution-output relationship constant, the pollution-output intensity would have to rise to 1.11. This adjustment is necessary as nothing has changed which suggests that less (or more) pollution will be generated by that volume of production, it is simply that the value of that output has changed.

This means that we can think of the CGFLI measure as ranking the sectors of the economy according to those where the greatest adjustment in the pollution-output intensity would be required, following a given change in the price of primary inputs, in order to keep the pollution-output relationship constant through the change in the price of sectoral output[11]. This is the only rationale for this measure that we can envisage, but as we noted above it is difficult to foresee a use for this measure given its peculiar nature. We therefore

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[11] It is worth noting that we gave the above example in the context of modelling changes in emissions in an environmentally extended supply driven input-output system. This was done purely to make the example as intuitive as possible, given the somewhat obscure nature of the interpretation being offered. It is not necessary to think in terms of a modelling environment, since the CGFLI measures themselves are an accounting identity. This prevents any difficulty about the use of a production function characterised by perfect substitutes alongside a fixed output-pollution coefficient (which assumes a Leontief constant returns to scale production function).

do not discuss any results using this measure in this chapter, although linkage index scores are generated and presented in Table 3.6.

3.4.6 Weighting carbon linkage measures

Table 3.9 presents the weighted carbon Leontief backward linkage measure. As we discussed earlier we do not think that weighting the LFLI measures further is particularly helpful given that they are, by definition, 'weighted' measures which reflect the underlying stimulus of a unit final demand in all sectors. The GFLI, for the reasons discussed earlier, is not discussed in the context of environmental linkages and therefore is not presented here as a weighted measure. The sectoral scores which are underlined in Table 3.9 are the sectors ranked in the top 5 according to each of these measures.

3.4.7 Weighted carbon backward linkage measures

Table 3.9 shows that 7 sectors are common to the top 10 of both the output and export final demand weighted rankings (5 (Oil and gas extraction), 7 (Food and drink), 13 (Pulp and paper; printing and publishing), 14 (Coke, refined petroleum and nuclear fuel), 38 (Electricity production and distribution), 47 (Other land transport) and 49 (Air transport)). Of these sectors 7 and 13 do not have above average backward linkage strength according to the CLBLI (see Table 3.5). This is interesting because it means that the output-CO_2 multiplier (or CLBLI score) is not itself remarkable (in the sense of having above average strength). However because of the size of the sector, in terms of total output and export final demand, it is ranked as one of the most important sectors.

The CLBLIwe measure is particularly interesting because it ranks the sectors according to which sectors will generate the most additional pollution in the economy in the face of a general (i.e. same %) increase in export demand. This means that if we were anticipating an increase in export demand, and wanted to know which sectors to focus supply chain emission reduction policies on to help meet territorial emissions targets, the CLBLIwe measure would tell us which sectors were most important.

Another way to think about this measure is that it gives us a ranking of which sectors would be most affected by the imposition of an import-emissions levy by our trading partners. This kind of import levy was recently suggested in the USA (see Fischer & Fox (2011)). The suggestion was that imports into the USA would be taxed according to the emissions embodied in them.

Under such a system the unweighted CLBLI would give the ranking of sectoral impacts, as the sectors ranked highest are those with the most embodied emissions per unit of final demand. However, the CLBLIwe would give the ranking of total sectoral impacts, in terms of where the greatest impact of this cost would fall, because it controls for the scale of sectoral exports.

3.5 Key sectors - a combined linkage view

Until this point in the presentation of our results we have focused on the strength of the backward and forward linkages separately. A traditional means of bringing these measures together is through the use of a 4 sector chart like those contained in Figures 3.4- 3.6 below. These chart the strength of the backward and forward linkage strength on the x and y axis respectively.

In these charts, any sector in the top left quadrant has above average forward linkage strength, but below average backward linkage strength. Similarly the top right quadrant contains sectors with above average backward and forward linkage strength, these sectors are what are normally thought of as being the 'key' sectors. Sectors in the bottom right quadrant have above average backward linkage strength but below average forward linkage strength. The final quadrant, in the bottom left, contain sectors with both below average forward and backward linkage strength.

In each quadrant, the further a sector is from the origin the stronger is its linkage strength. Thus these charts provide an easy way to understand the combined forward and backward linkage strength of these sectors. We present four charts, one output and three CO_2 key sector analysis. In Figure 3.4 we can see the Leontief backward linkage index against the Ghosh forward linkage index. From Figure 3.4 it is clear that the vast majority of sectors (51 out of 67) are found close to the origin, i.e. close to the average.

In Figure 3.4 there are seventeen sectors with both above average backward and forward linkage strength. Of these we pick out five: Electricity production and distribution; Ancillary transport services; Railway transport; Coke, refined petroleum and nuclear fuel; and Coal extraction etc. From Figure 3.4 we can see that while the Electricity production and distribution sector has stronger backwards linkage strength than the Coal extraction sector, the Coal extraction etc sector has stronger forward linkage strength than the Electricity production and distribution sector.

This means that even among those sectors classed as ‘key’ (by virtue of above average backward and forward linkage strength) there is a variation in the composition of this strength between stronger forward and backward linkage. In the case of the carbon linkage analysis, Figure 3.5 shows the carbon Leontief backward linkage strength of each sector (x axis) against the carbon Leontief forward linkage strength of each sector (y axis). Intriguingly no sectors have both above average Carbon forward linkage strength and below average Carbon backward linkage strength. Figure 3.5 is useful in allowing us to see visually the linkage strength that underpins the determination of a sector being ‘key’, i.e. between backward and forward linkage strength.

For instance, we can see that the Electricity production and distribution sector has stronger CO_2 forward linkage strength than the Cement and clay sector, while Cement and clay has stronger CO_2 backward linkage strength than Electricity production and distribution. It is also clear from Figure 3.5 that there are a small range of sectors which have the strongest linkage strength. The majority of the 67 sectors considered here have below average carbon forward and backward linkage strength. This is represented by the cluster of sectors in the bottom left quadrant of Figure 3.5. This is a useful visualisation of the

Figure 3.4: LBLI v. GFLI

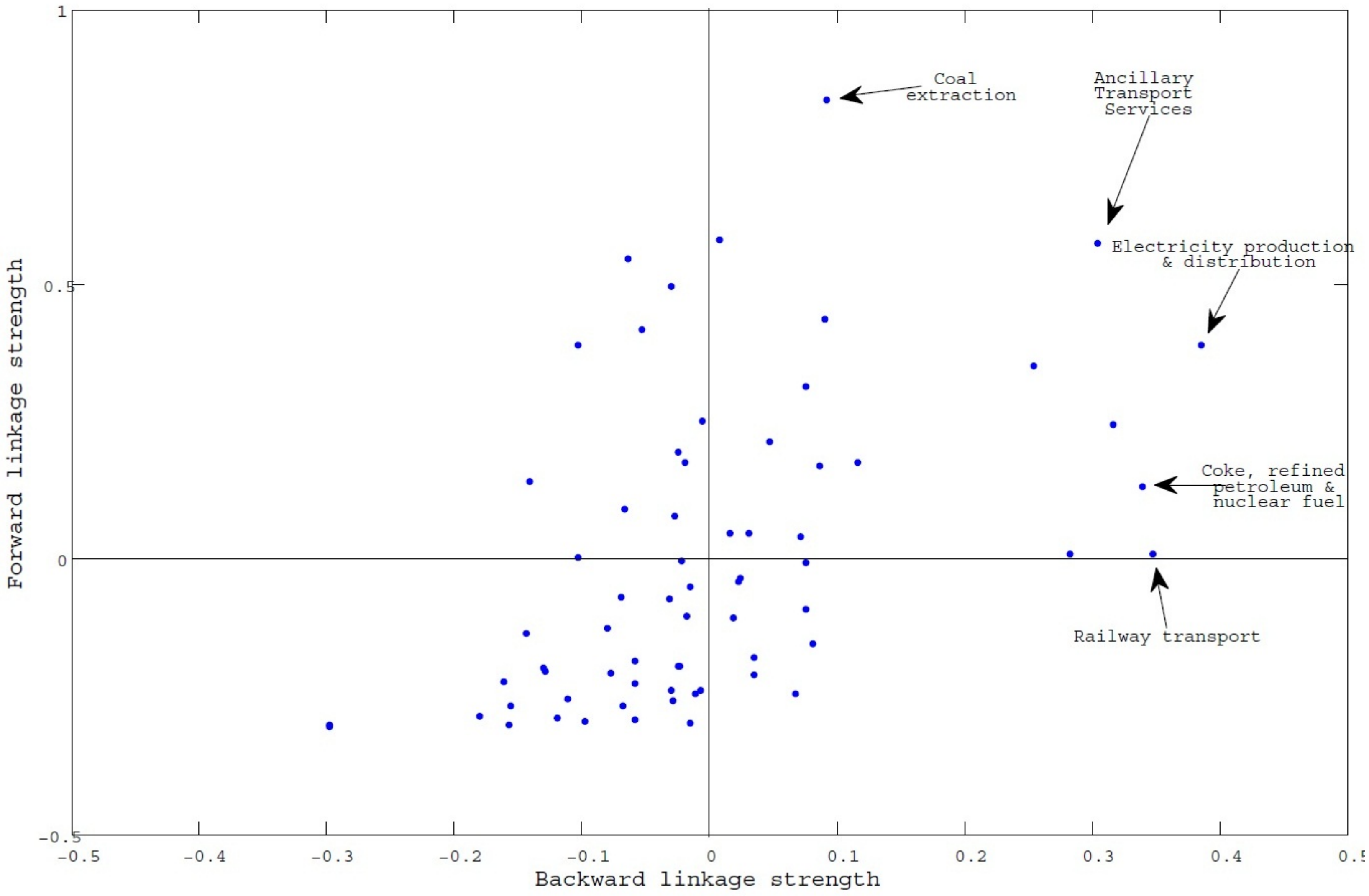
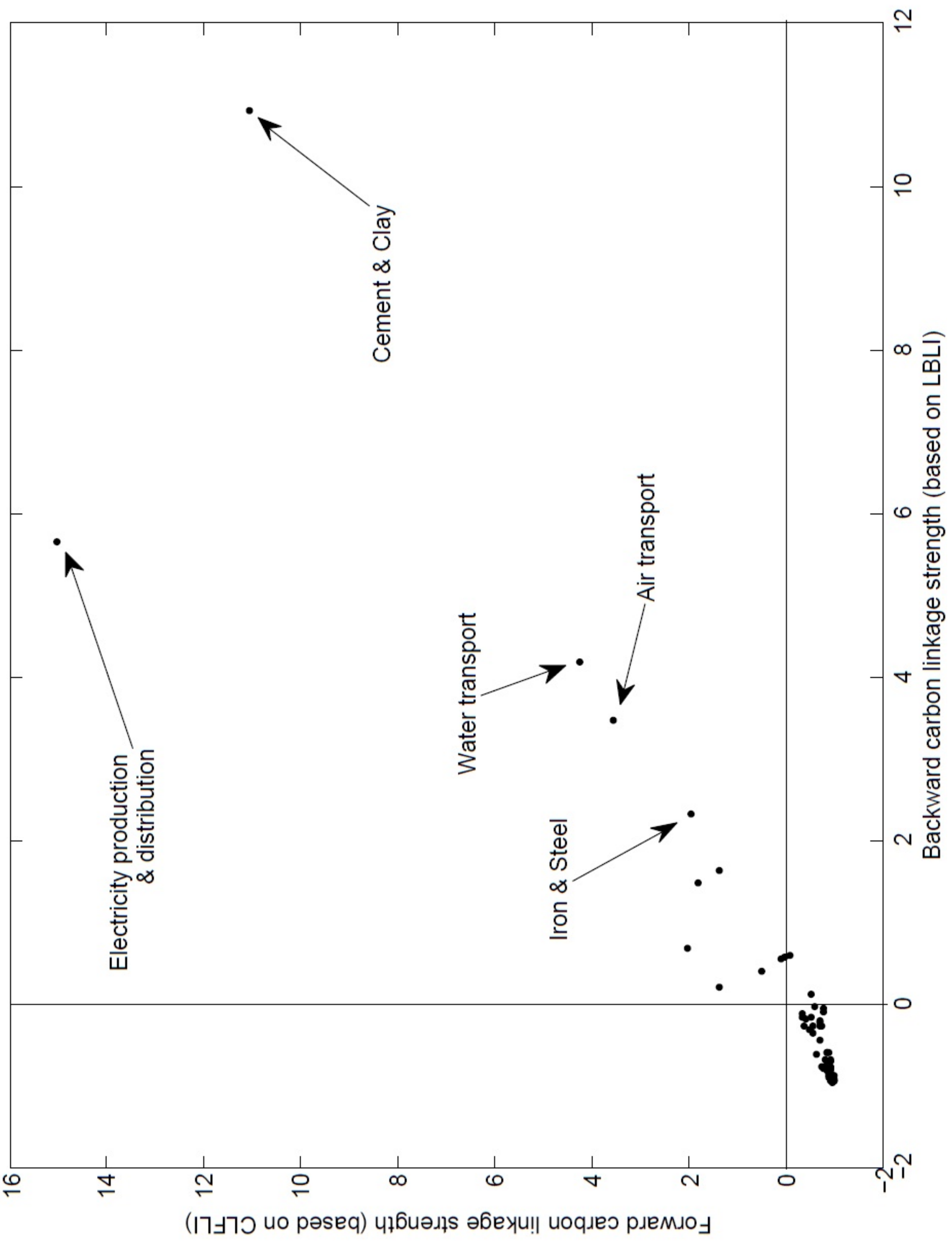


Figure 3.5: CLBLI v. CLFLI

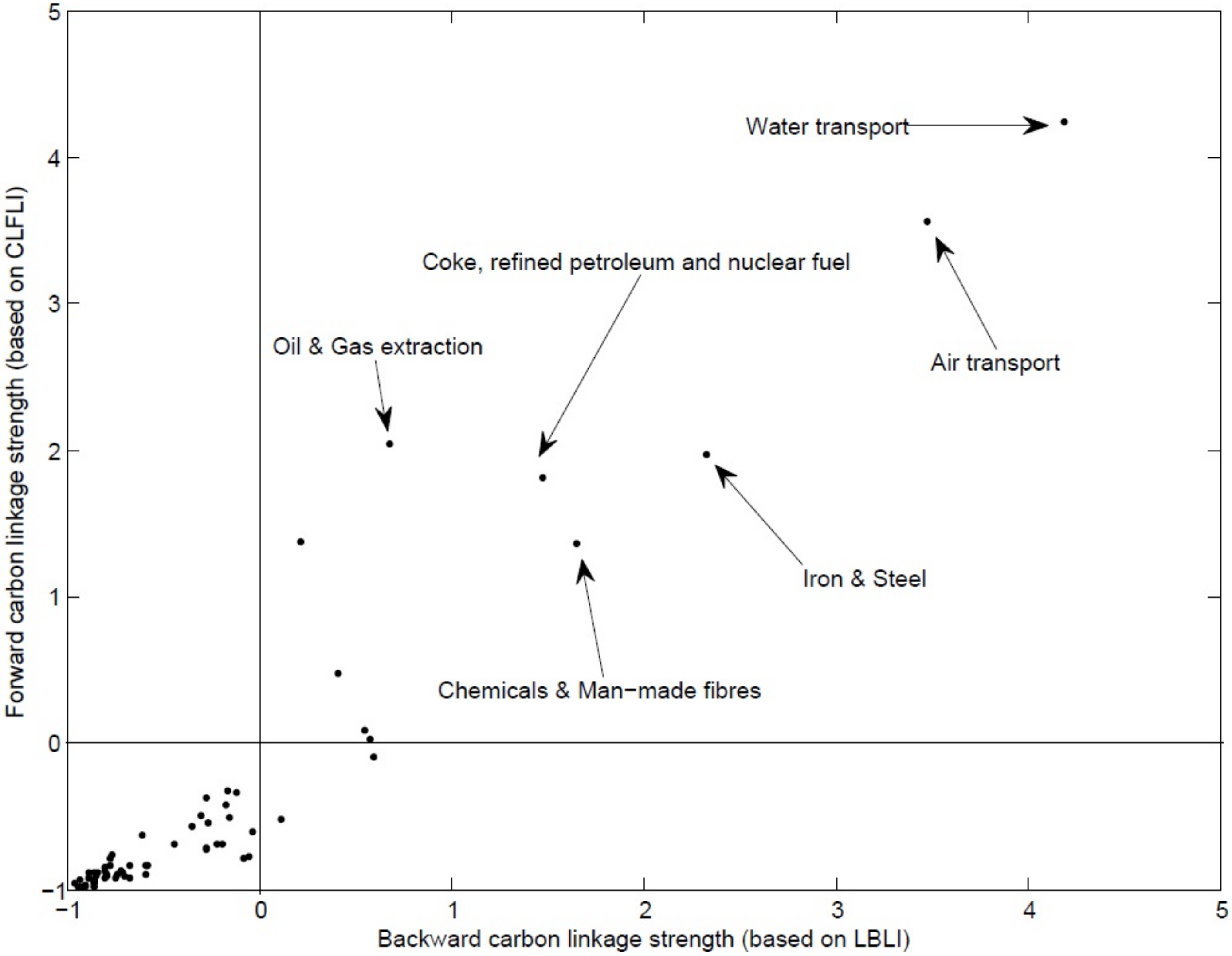


carbon linkage strength information. Figure 3.6 is identical to Figure 3.5 except that the Electricity production and distribution and Cement & clay sectors are not shown.

We presented these charts to bring together the discussion that we have just had about the relative strength of both the output and Carbon linkages of different sectors, together into a discussion of key sectors encompassing both the backward and forward linkage effects discussed earlier. The discussion that has taken place previously in this paper has emphasised the importance, particularly in terms of policy inference and empirical interpretation, of considering the backward and forward linkages separately.

The purpose of this section was to bring these separate measures together into a combined 'key' sector measure. It also acts as a link to the next section where we present the results of the hypothetical extraction analysis, which focuses on both key sectors and key groups of sectors (with no separate identification of backward and forward linkages).

Figure 3.6: CLBLI v. CLFLI (without sectors 26 & 38)



3.6 Hypothetical extraction approach

We made clear at the outset of this chapter that we would take two different approaches to determining which sectors are 'key'. We have already outlined and implemented one of these approaches, using the linkage analysis contained in Sections 3.3 and 3.4. In this section we take a different approach using the hypothetical extraction method. This approach will be outlined and implemented in this section.

There are two principle measures that can be calculated based on a hypothetical extraction approach. These are key sectors and key groups of sectors. The former is based on the extraction of each sector in turn from the economic or environmental-economic system, and measuring the effect that this extraction has on an aggregate variable, for instance total economic output or total pollution generation.

Calculating key groups of sectors takes a slightly different approach, and seeks to determine the impact on the same aggregate variables, of extracting a group of sectors of size k. For instance, we could ask which 3 sectors if simultaneously extracted would result in the greatest drop in total output. This will not necessarily be the three sectors which result in the greatest reduction in total output if we extract each of these sectors individually. The reason for this lies in the nature of the interrelations which are involved in extracting multiple sectors together.

Similarly, it is worth noting that the hypothetical extraction approach is a modelling as opposed to accounting exercise. This means that if you calculated the change in a particular macro variable of extracting each sector individually, and then summed these impacts across all sectors, it would not sum to the total of the macro variable you're examining. This follows from the same logic that explains why the ranking of key sectors and key groups of sectors may be different. So what is this logic?

Consider: in extracting each sector i, the elements of the A matrix extracted will have one element in common with the extraction of any other sector, (i.e. a_{ij} is extracted both when we extract sectors i and j) and in this sense there is 'double' counting happening. This is why the sum of all hypothetical extraction impacts will exceed the original total of the macro variable being examined. This is also explains why the ranking of key sectors and key groups of sectors need not be identical.

In this paper we present both key sector and key group results for group sizes from 2 to 4, and compare the sectoral ranking of those contained within the key group. First, we outline the calculation of the standard key sector measures and then, adopting the approach of Temurshoev (2010), we outline our calculation of the key groups for both output and CO_2 generation.

3.6.1 Hypothetical extraction analysis

The hypothetical extraction 'key sector' problem involves finding the sector which if extracted from the model, would result in the largest reduction in the chosen macro-level variable; such as total output or pollution. Formally, following Temurshoev (2010), the problem can be stated as:

$$\max\{\pi' x - \pi' x^{-i} | i = 1, ..., n\} \tag{3.25}$$

Where π is the 'factor' of interest, for example the pollution intensity of sectoral output[12], and x is total sectoral output (which is equal to L.Y, where L is the Leontief inverse and Y is the vector of total final demand). Also, x^{-i} is a vector of total output with the i^{th} entry set to zero (in other words sector i has been extracted). The mathematics underpinning this hypothetical extraction methodology makes it more difficult to get the intuition for this analysis than alternative approaches. The advantage though, is that it provides a computationally efficient approach to tackling the hypothetical extraction of

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[12] π here is generalisable to any factor that can be sensibly linked to sectoral output and constructed as a sectoral factor-output intensity (units of the factor per unit of sectoral output).

key groups.

What we are doing here is eliminating a sector from the economy, and measuring the effect that this has on total output or pollution. What Temurshoev (2010) proves is that the solution to the problem of maximising the drop in output or pollution following the extraction of a sector, is the same as the solution to the maximisation of the relative factor worth of each sector. Since they are equivalent, and the relative factor worth is more computationally efficient, we proceed to calculate the relative factor worth.

In terms of the demand driven input-output model that we examined in the Chapter 2, what we are doing here is setting the row and column elements of the A matrix, and the final demands for the sector in question, to zero. This means that the sector has been 'extracted' and total sectoral output becomes zero. In effect what we are assuming is that intermediate purchases by domestic firms from the sector which has been extracted are substituted for by imports from outside the region. Similarly, we are assuming that the final demands of the extracted sector are being substituted through imports.

When we extend to the examination of carbon key sectors we make the same amendments to the A matrix and sectoral final demand, but we do this in the context of the environmentally extended demand driven input-output model. This allows us to measure the impact on total pollution generation instead of total output. We begin here by outlining the calculation of the relative factor worth of a sector which, following Temurshoev (2010), is equivalent to the total output supported in the domestic economy by that sector (which is what is usually measured in a hypothetical extraction analysis).

The relative factor worth for each sector i is calculated as:

$$\omega_i^{\pi}(A, f, \pi) = \frac{m_i^{\pi} x_i}{L_{ii}} \tag{3.26}$$

Here the factor worth of sector i, is increasing in the factor multiplier (m) of sector i (in our case this is the output-CO_2 multiplier of this sector), and the output of sector i, x_i and is decreasing in the own sector element of the Leontief inverse L_{ii}. 'A' here is defined as before for the demand driven input-output model as the matrix of input coefficients. It may seem strange here that we are combining the factor multiplier with output, since output-factor multipliers are normally used in conjunction with final demand, however as Temurshoev (2010) demonstrates, Equation 3.26 follows directly (via mathematical manipulation) from the original identity in Equation 3.25.

We calculate the factor worth of each sector for output and CO_2 and, consistent with Temurshoev (2010), we present these in the form of the relative factor worth of each sector using the following normalisation, where $\pi' x$ is the total value of the factor we're measuring (for all sectors):

$$RFW_i = [\omega_i^{\pi}(A, f, \pi)/\pi' x] * 100 \tag{3.27}$$

In the case of key groups, we generalise the above calculation for key sectors to the consideration of key groups of size 2 to 4 (although the option does exist to consider larger group sizes still). The key sector problem just outlined is a special case of the key group problem where group size equals 1. In outlining the key group methodology our starting point, again following Temurshoev (2010), is our corollary to Equation 3.25:

$$\max\{\pi' x - \pi' x^{-\{i_1,\ldots,i_k\}} | i_1, \ldots, i_k = 1, \ldots, n; i_s \neq i_r\} \tag{3.28}$$

Here, $x^{-\{i_1,\ldots,i_k\}} = L^{-\{i_1,\ldots,i_k\}} * Y^{-\{i_1,\ldots,i_k\}}$ where L is the Leontief inverse and Y is the vector of final demands, and where the superscript indicates that the elements of the matrix or vector relating to the extracted sectors are set equal to zero (or are 'extracted'). Temurshoev (2010) demonstrates that this problem can be reduced to the maximisation of the group factor worth of the extracted sectors, and therefore in order to determine the sectors which comprise the 'key group' it is sufficient to calculate for each possible combination of sectors the group factor worth:

$$\omega^{\pi}_{i_1,\ldots,i_k}(A,f,\pi) = m^{'}_{\pi} E L^{-1}_{kk} E' x \tag{3.29}$$

Here E relates to an identity matrix where the elements E_{ik}, i=i,k=1,...n are equal to 1, and the other variables are defined as they were in the key sector problem in Equation 3.25. As before this factor worth can be transformed into a relative factor worth:

$$RFW_{i_k} = [\omega^{\pi}_{i_1,\ldots,i_k}(A,f,\pi)/\pi' x] * 100 \tag{3.30}$$

Calculating the maximum relative factor worth for each (mutually exclusive) group of size k in the economy, tells us which combination of sectors-if extracted together- would result in the greatest reduction in total output, total pollution, etc. It may not seem obvious why the key group of size k does not necessarily comprise the highest ranked k sectors according to the hypothetical extraction key sector ranking.

In simple terms, as we discussed earlier, the reason is that the effect on the Leontief inverse of extracting each sector individually is not the same as the effect of extracting multiple sectors simultaneously. The reason for this is that there are two routes by which a sector affects total output or the total of a chosen factor, the direct and the indirect. As Temurshoev (2010) demonstrates, factor worth has two components, these are:

$$\omega^{\pi}_{i_1,\ldots,i_k}(A,f,\pi) = \sum_{s=i_1}^{i_k} \pi_s x_s + \sum_{j \neq i_1,\ldots,i_k} \pi_j (x_j - {x_j}^{-(i_1,\ldots,i_k)}) \tag{3.31}$$

The first component on the right hand side of 3.31 is each sectors direct effect, while the latter terms is their indirect effect. We noted earlier that sectoral interdependencies (operating through common terms in the L matrix) mean that the ranking of sectors extracted individually may differ from the ranking of sectors extracted collectively. In other words if we extract sector i, we noted earlier that this removes the effect of l_{ij}. If we were then to extract sector j, one element of sector j's supply chain has already been extracted (i.e. l_{ij}) meaning that the impact of extracting sector j will be lower where its the second (or subsequent) sector to be extracted than if it is extracted on its own.

Intuitively, if sector A's sales to sector B embody a large amount of a particular factor, say water, then the extraction of sector A removes from sector B's supply chain or backwards linkage effect its purchases from sector A- which embody a large quantity of water use. Therefore the impact of the extraction of sector B here will not have as large an impact on total water use where sector A has already been extracted (or is being extracted simultaneously with Sector B in a key group analysis).

This effect centers on the dual role of elements of the input-output system, following from being classed as sales for one sector and simultaneously purchases for another. Therefore, sectors ranked highly according to the key sector hypothetical extraction method, which have more independent supply chains, are more likely to be found together in the highest ranked key groups according to the hypothetical extraction method.

3.6.2 Hypothetical extraction results

Key sector results

In this section we present the results from our hypothetical extraction analysis for the Scottish economy. This approach, as we discussed earlier, calculates the % reduction in total Scottish output that would result from the hypothetical extraction of each sector individually from the Scottish economy. This allows us to consider the hypothetical drop in output caused by the removal of that sector from the economy and the reduction in national purchases and sales of output that would (hypothetically) occur.

The results from this analysis are contained in Table 3.11 below. The top ranked sectors are: 60 (Public administration), 59 (Professional services), 41 (Construction), 55 (Property) and 62 (Health services). The extraction of each of these sectors individually will (hypothetically) reduce Scottish total output by between 10.6% and 7.12%. Interesting also, is that only 9 sectors support in excess of 5% of total output. Also, the extraction of any one of forty sectors in the Scottish economy (admittedly including sector 8 (Tobacco) which does not exist in Scotland) would result in a drop in total output of less than 1%.

One reading of Table 3.11 is that the Scottish economy is dependent upon a few sectors to generate the majority of total output. It is interesting that two of the top sectors are heavily dominated by the state (60 -Public administration and 62-Health). It should also be noted that the ranking of sectors according to the (hypothetical) effect on total output of extracting that sector from the economy is similar but not identical to the ranking of sectors according to their proportion of total output[13]. This is because the hypothetical extraction approach takes into account the economic interdependencies on which sectoral output is based; a sector can be large in terms of total output, but have a low domestic output multiplier.

Key output groups

Table 3.12 below reports the top twenty groups of sectors (for group size 2, 3 and 4) which would result in the greatest reduction in total Scottish output if they were hypothetically extracted from the economy simultaneously. Because of the number of different combinations of sector groupings that are available for groups of size two (2211), three (47,905) and four (766,480), we will not report all of them here, and restrict ourselves to consideration of the twenty groups that result in the largest overall reduction in output[14].

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[13] See Table 3.15 for the proportion of Scottish output comprised of the output of each sector in 2004.

[14] For information, the number of combinations that are possible is the result of the following formula where n is the total number of sectors, and k is the size of the chosen group (! is the factorial sign):

$$\frac{n!}{k!\,(n-k)!} \tag{3.32}$$

Comparing these key group rankings to the key sector rankings discussed above, we can see that the rankings are similar for group sizes of two and three, and only slightly different for the extraction of groups of size four. In other words, the sectors comprising the highest ranked key groups for groups sizes of 2, 3 and 4 sectors are similar. This is particularly true outside of the top few groups in Table 11 above. It is interesting to note that the extraction of just four sectors 41 (Construction), 59 (Professional services), 60 (Public administration) and 63 (Sewage & sanitary services) would (hypothetically) reduce total Scottish output by a third. In addition, all of the key groups of size 4 reported in Table 3.12 result in a drop in total output of over 30% when they are simultaneously extracted.

The reason, as noted earlier, why the key sector and the key group rankings are similar is because transactions between the highest ranked sectors are not that big. If they were large, then in the move from say groups of two sectors to groups of three sectors, we would expect that the sector selected as the 'third' (although recall that this is not a sequential process) in the group of three would be one where its impacts on the n-2 other sectors would be largest (since we have already made its links with the extracted sectors redundant) which means that where the links between the top ranked sectors are largest, we would expect a different ranking in the key group and the key sector analysis.

Key pollution sectors

Table 3.13 below gives the % reduction in CO_2 generation that would (hypothetically) result from the extraction of each sector individually from the Scottish economy based on the 2004 Scottish environmentally extended demand driven input-output system. The results of this exercise are stark, and show that no single sector, with the exception of 38 (Electricity production and distribution) if extracted, would result in a decrease in pollution in excess of 6%. This reinforces what we established in the previous paper about the impact that sector

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38 (Electricity production and distribution) has on aggregate production based pollution measures in Scotland.

Our results here contrast with our earlier result that the worst performing sector in terms of carbon linkages, was sector 26 (Cement & Clay). The reason for this, and it is a crucial point, is that while Cement and Clay may come top of a ranking of sectoral carbon linkages, it is a much smaller sector than sector 38 (Electricity production and distribution). This means that Cement & Clay's potential impact on aggregate pollution in Scotland is lower than that of the Electricity production and distribution sector, because of the effect of sectoral scale.

To see this, compare Table 3.5 and Table 3.9. From Table 3.5 it is clear that Sector 26 (Cement & Clay) is highly ranked by the unweighted measure, but when we introduce a measure of sectoral scale (here sectoral output) in Table 3.9 it falls down the ranking of sectoral carbon backward linkage strength. Similarly we can see that Sector 38 (Electricity production & distribution) is ranked as important in both indexes.

Key pollution groups

In addition to using the hypothetical extraction method to rank sectors according to their individual impacts on aggregate pollution, we also used the same approach to determine which sectors (in concert) would cause the greatest reduction in total CO_2 generation if they were extracted together. In our analysis here we again restrict consideration to groups of size two, three and four sectors. We present the results from our analysis in Table 3.14 below. In Table 3.14 we show the top 20 groups of sectors and the % hypothetical reduction in CO_2 that would result from their simultaneous extraction from the Scottish economy using the relative factor worth calculation outlined above.

The first thing to note about Table 3.14 is that sector 38 (Electricity production and distribution) appears in the each of the top 20 groups for all three group sizes. Closer analysis of the full results indicates that there is a significant drop in the % reduction in CO_2 after a certain point. In other words, there are certain sectors without which the hypothetical reduction in CO_2 is much smaller. For groups of size two this occurs in the 67th different combination, in other words given that we have 67 sectors in our model this suggests that this is happening after one sector is not included in the group.

Looking at the results it is clear that without sector 38, the proportional reduction in CO_2 obtainable from hypothetically extracting two sectors from the Scottish economy, is at most 11.5% (which occurs hypothetically extracting sectors 7 (Food and drink) and 14 (Coke, refined petroleum & nuclear fuel) together). In the case of groups of size three this drop occurs after the top 2145 combinations of three sectors, which again is when sector 38 (Electricity production and distribution) drops out (sector 38 occurs in every one of the top 2145 combinations of three sector groups). The maximum reduction in total CO_2 from the hypothetical extraction of a group of three sectors (which does not include sector 38) is only 15.73%.

For groups of size four, there is a significant drop in the hypothetical reduction in CO_2 generation after the top 45,760 combinations of sectors, with a maximum (hypothetical) reduction in CO_2 emissions by the extraction of four sectors simultaneously (again not including sector 38), of 19.44%. What this demonstrates is twofold. Firstly it demonstrates the importance of sector 38 (Electricity production and distribution) on total CO_2 generation in Scotland. It is clear that this sector generates the greatest reduction in aggregate CO_2 generation through its hypothetical extraction. Secondly, it demonstrates that because of the importance of this sector to total CO_2 generation in Scotland, key group analysis is not particularly insightful as a tool to identify alternative approaches to reducing Scotland's aggregate CO_2 generation.

Were this approach able to identify a group of sectors, which did not include sector 38 but which was able to significantly affect aggregate CO_2 generation, then this could have provided a new avenue for investigation in reducing Scotland's aggregate CO_2 generation. This would perhaps be more useful still, if this grouping it had comprised sectors not covered by the EU Emissions Trading Scheme. Interestingly, the sectors ranked highest according to the key sector hypothetical extraction analysis are not the sectors contained in the highest ranked group according to the hypothetical extraction approach. That is not to say that there is a huge difference between the two rankings.

Sectors ranked highly according to the key sector ranking are also those ranked highly according to the key group analysis. The point is that they do result in a slightly different ranking of sectoral importance, which emphasises the added value from key group analysis in general- even if the key group results are not particularly insightful in the CO_2 case for Scotland because of the dominant effect of sector 38 (Electricity production and distribution).

3.7 What do we learn from this carbon key sector analysis?

In the preceding pages, we have outlined the main results from our output and CO_2 key sector analysis. Here we explain the value of these results, both in terms of the potential conceptual and policy insights they provide. Traditionally when using un-weighted key sector indexes a sector is considered to be ‘key’ if it has an index score above 1. Given that the index has been normalised, an index score of >1 indicates that the sector has above average linkage strength. Looking at Tables 3.5 and 3.6 it is clear that according to the un-weighted indexes there are more than 5 sectors which have above average linkage strength. In presenting the traditional key sector results earlier, we focused on the five sectors with the largest above average linkage strength for simplicity, and not to suggest that there are only 5 ‘key’ sectors.

So what use is this information on Scottish carbon linkage strength (whether in terms of backwards linkages, forwards linkages or both)? Well, thinking only about the un-weighted indexes at this point, they each tell us something slightly different. For instance, taking the CLBLI (carbon Leontief backwards linkage index), this measure helps us to understand the sectors which have large and above average supply chain emissions 'purchases' embodied in the inputs they procure from the n sectors of the economy.

While the PLBLI does the same thing as the CLBLI, except that it removes any intrasectoral impacts from the calculation- that is we consider only the intersectoral backwards carbon linkages. In policy discussions this CO_2 is sometimes referred to as 'embodied' carbon. By calculating these backwards carbon linkage indexes we can now rank the sectors of the Scottish economy in terms of the relative size of their embodied supply chain carbon. This provides us with a new way of thinking about sectoral CO_2 emissions.

Instead of the conventional discussions about the CO_2 that each sector generates, or indeed the emissions supported by different sources of final demand, we can think about the CO_2 embodied in the supply chain of each sector. This provides a clear opportunity for policymakers to look at policy solutions aimed at reducing supply chain emissions.

Another use for a carbon backward linkage index would be as a ranking of the sectoral impacts of a flat carbon tax. In the context of a flat carbon tax (£x per tonne of carbon dioxide emitted) it seems reasonable that firms would simply pass on this tax to those who buy its output through an increase in the price of sectoral output. In this sense we are using the Leontief demand driven model as a price input-output model (see Miller & Blair (2009, p41) for more details on this model).

In this case, the sectors which purchase the most pollution embodied in their inputs will be most affected by this tax. The greater the emissions in your supply chain, the more of this tax you will be required to pay. In this case the unweighted CBLI measure would rank the sectors according to the tax paid per unit of final demand. The output weighted ranking in this context ranks sectors according to the total amount of tax that each sector would face.

Similarly, given that in the current economic climate there is substantial concern about boosting economic growth, but at the same time national governments are required to meet domestic emissions reduction targets, it may be useful to think about the issue of supply chain emissions in the context of sectoral final demand or elements of it. For instance, a country seeking to export its way out of an economic downturn (and faced with binding territorial pollution reduction targets) may find it useful to know which domestic sectors, given the size of current export demand, are important in terms of the domestically produced carbon embodied in their purchases.

If we take it that scale is a significant driver of competitiveness-in the sense that larger organisations are better placed to take advantage and satisfy export demand- (which it need not be of course, but assuming so for this example) then there is clearly a trade-off between broad action to boost exports which will in principle affect all sectors equally but in reality will benefit those best placed to take advantage, and targeted action designed to boost exports of particular sectors (which the export weighted rankings detailed in this paper may be useful in determining).

However, even in the face of a strategy aimed at boosting export growth across all sectors, it would be useful to understand which sectors would be likely to support significant amounts of embodied pollution if there were such export growth. Similar arguments could be made about other weighting schemes. The underlying backwards linkage indexes can give us useful information on the strength of the CO_2 linkages within the economy which can help policymakers to better assess potential impacts, and better design appropriate policy instruments. Considering these measures alongside information on the relative size of sectoral final demand or elements thereof adds additional insight into the underlying relationships in the economy; however as we made clear earlier it is for the individual analyst to select the appropriate measure and weighting scheme.

There is also useful information to be obtained from the carbon forward linkage measures. Although we acknowledge, as we have before in this paper, that there are difficulties in the use of the Ghosh input-output framework. In the output case we showed how Dietzenbacher's (1997) reinterpretation of this model allowed for the continued use of this model in generating measures of output forward linkage strength, even if the environmental extensions of these measures are more problematic.

In the case of the carbon Ghoshian forward linkage index (CGFLI) measure, we discussed different interpretations for this measure to make it useful. The Dietzenbacher (1997) reinterpretation of the supply driven input-output model opens up one avenue to interpret the CGFLI. This interpretation is not straightforward and is somewhat peculiar. While we report the results of this measure for completeness, we do not attempt to interpret them because of the peculiar nature of the interpretation that this measure has. This measure can be calculated and reported, but to understand what it is ranking the sectors in the economy by, we must have a plausible interpretation for it.

We also outlined the carbon Leontief forward linkage index measure earlier. We discussed in detail the advantages of this measure, particularly when coupled with an analysis of the standard deviation of the elements of the carbon Leontief inverse. This measure allows us to rank the sectors according to the forward carbon linkage strength of each sector. This allows us to uncover the sectors which are important sellers of embodied pollution within the domestic economy. By consulting the standard deviation index of the elements of the CLFLI measure, we gain information on the dispersion of these impacts across the sectors of the economy.

This provides additional information on whether the pollution embodied in each sectors' forward linkages are focused more evenly (a lower standard deviation score) or narrowly (a higher standard deviation index score) on the other sectors of the economy. In understanding why measuring the strength of forward linkages and their dispersion across the sectors of the economy is important, we have to consider how this information may influence policy.

For instance, Cella (1984) notes that: "according to some scholars technical change more frequently originates in a restricted number of sectors from which it flows by means of forward linkages with other sectors (Cella 1984, p73). In this case, a technical change could be initiated in sector i, the gains from which are then passed on to the other sectors that sector i sells its output to. This could be, for instance, an energy efficiency improvement which reduces the emissions embodied in that sector's output, reducing the emissions embodied in the output of the other sectors which purchase this sector's output.

The carbon Leontief forward linkage measure allows us to look in a different way at the same problem. Instead of thinking about the embodied pollution in each sector's supply chain, as we did in the carbon Leontief backward linkage case, we think instead about the impact of the emissions embodied in each sectors' sales to the other sectors of the economy. In this way, we think about the role of each sector in supplying pollution embodied in the output that it sells to the other sectors of the economy for use in their own production processes.

The policy angle in the CLFLI case is clear. It is the traditional industrial pollution abatement problem, where the pollution that an industry generates needs to be reduced. This is the basis of many industrial pollution regulations stretching from Victorian times with the Alkali Act of 1863, right through to the European Union emissions trading scheme that operates today. If a sector has a large volume of emissions embodied in its sales to other sectors of the economy, then reducing this sector's smokestack pollution will have a larger impact on total emissions reduction than reducing the smokestack pollution of a sector with a lower level of emissions embodied in their sales to the other sectors. This could be done directly by considering sales multiplied by the emissions intensity, but crucially this would again ignore indirect output (and hence emissions).

In the hypothetical extraction analysis, we found some interesting results. In the output case we found that there was a core group of sectors that had a much larger impact on aggregate output than others, 9 sectors if extracted individually would reduce total output by more than 5%, which leaves 58 sectors whose impact on total output is less than than 5% using this approach. In the results from the key group analysis, we can see that the impact of groups of sectors on total output is more balanced.

The top 20 groups of 2 sectors has an impact on aggregate output ranging from 19.12% through to 14.85%, while for groups of three or four sectors this increases. Perhaps the most interesting result is for groups of four sectors where we can find four sectors which in combination, if hypothetically extracted, would result in a reduction in Scottish output of one third. The range of hypothetical output reductions following from the extraction of any of the top 20 groups of four sectors is much narrower ranging from 33.67% to 30.93%.

The comparison between these results and the carbon results is stark. In the case of carbon we saw that one sector (Electricity production and distribution) if hypothetically removed from the Scottish economy would reduce Scottish production emissions by 63.18%. In looking at the key group results, the importance of this sector was reinforced by the finding that no four sectors -which did not include the Electricity production and distribution sector- would result in more than a 19.44% reduction in Scottish production based carbon emissions.

This is an important finding because it sets the impact of the Electricity production and distribution sector individually (in effecting a 63.18% reduction in carbon emissions) against the efforts of the four other sectors with the largest aggregate effect, which cannot achieve 1/3rd of the impact of the Electricity production and distribution sector.

3.8 Conclusions

This paper has outlined the principle approaches that have been taken in the literature to assess which sectors have the strongest economic and environmental linkages with the other sectors of the economy. We outlined in full, using standard input-output notation, each of the measures that we employed here, including incorporating information from outside the input-output inverses through sectoral weighting schemes.

Having implemented this approach to the case of Scotland for 2004, we proceeded to outline the results of our analysis for both the traditional output based measures, and our environmental extension. We discussed each of these in turn, and demonstrated the different sectoral rankings that were obtained from the use of each measure. This allowed us to see which of the measures detailed were responsive to changes in the weighting scheme, or in the case of a comparison between different measures, we were able to ascertain which sectors had larger intra as opposed to intersectoral impacts, a potentially valuable insight for a policymaker concerned about this issue.

What was particularly interesting in the examination of the carbon linkage measures was that we saw that the intersectoral relationships involving the pollution embodied in intersectoral sales/purchases are important in determining sectoral rankings. Further, we saw that the underlying sectoral relationships can highlight hitherto unremarkable sectors as having important pollution linkages with the rest of the economy. The contribution of this paper has been twofold: firstly to explore at the sectoral level the characteristics of the Scottish economy and the underlying pollution relationships. This builds on the work we carried out in the previous chapter to understand the implications for the national emissions total of different accounting perspectives. This chapter is an attempt to understand what sectoral level relationships underpin the headline national emissions totals established in the previous chapter.

In this chapter we have been able to identify sectors which, by dint of the size of their final demand or elements thereof, are such that they cannot be ignored in trying to reduce aggregate pollution. Despite otherwise unremarkable carbon linkage strength, or direct pollution intensities, these sectors were found to be important in determining aggregate emissions. Similarly, we found sectors where the linkage strength itself was such that, without considering sectoral size, it would appear to be one of the most important sectors for pollution abatement efforts. However when we then included a measure of the relative size of the sector, we saw that the sector dropped in relative importance.[15]

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[15] From Table 3.5 we can see, for example, that Sector 48 is ranked in the top 5 sectors by CO_2 backward linkage strength, but drops out of the top 5 according to all the weighted CO_2 backward linkage measures in Table 3.9. Similarly Sector 7 has below average CO_2 backward linkage strength according to Table 3.5, but is ranked among the top 5 sectors by all the

The second aspect of this paper's contribution has been to examine the different perspectives, implications and justifications for a range of pollution linkage and key sector measures. As we have seen in this chapter, there are a range of alternative linkage measures, not all of which are appropriate for the analysis of pollution linkages. We established earlier that the literature in this area does not properly address the implications of the extension of these measures to examine pollution linkages. In many cases the issue of interpretation of these measures, based on the implications of the underlying model, are entirely ignored. This chapter attempts to fill this gap by tackling this issue in a comprehensive manner while considering the interpretation of these linkage measures, particularly the Ghoshian forward linkage measure.

This chapter sought to better characterise the Scottish environmental and economic linkages, and to better illuminate the pollution relationships in the Scottish economy. However, in conclusion, it is worth stressing that this analysis is reflective of the underlying database. The results of this analysis could be different if a different year was selected, or if a different level of aggregation was employed. Future work is needed to better describe the structure of the underlying economy, particularly in terms of the electricity sector, and to better understand the sectoral level responses to changes in the different components of final demand. A further area of future work discussed earlier is to decompose some of the linkage measures presented here to see if this provides additional insights on the relationship between the economy and its environmental impact in Scotland.

The next paper will build on the work detailed here, and seek to utilise a more flexible modelling framework (in the form of a computable general equilibrium (CGE) model) to better understand the environmental implications of economic change. This approach will relax some of the restrictive assumptions of the input-output model which we discussed in the previous chapter. The adoption of the CGE modelling framework will allow us to consider the implications of

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weighted measures in Table 3.9.

growth in export demand for the national emissions totals, and the sectoral level impacts of this kind of economic growth.

3.9 Tables

Table 3.1: Summary of linkage measures used.

Abbreviation	Full name	Equation reference	Equation	Description
LBLI	Leontief backward linkage index	Equation 3.5	$\mathrm{LBLI_j}=\left[\frac{\frac{1}{n}\sum\limits_{i=1,i\neq j}^{n}\mathrm{L_{ij}}}{\frac{1}{n^2}\sum\limits_{i,j=1,i\neq j}^{n}\mathrm{L_{ij}}}\right]=\left[\frac{\frac{1}{n}\mathrm{BL_{j*}}}{\frac{1}{n^2}\mathrm{K}_{L*}}\right]=\left[\frac{\mathrm{BL_{j*}}}{\frac{1}{n}\mathrm{K}_{L*}}\right]$	The classic backward linkage measure (also known as the output multiplier) normalised into an index.
PLBLI	Pure Leontief backward linkage index	Equation 3.5 excluding intrasectoral effect		This is identical to the LBLI except that we exclude the effect of the ‘own sector’ transactions on the calculation.
LFLI	Leontief forward linkage index	Equation 3.8	$\mathrm{FLSD_i}=\left[\frac{\frac{1}{n}\sum\limits_{j=1}^{n}\mathrm{L_{ij}}}{\frac{1}{n^2}\sum\limits_{i,j=1}^{n}\mathrm{L_{ij}}}\right]=\left[\frac{\frac{1}{n}\mathrm{FL_i}}{\frac{1}{n^2}\mathrm{K_L}}\right]=\left[\frac{\mathrm{FL_i}}{\frac{1}{n}\mathrm{K_L}}\right]$	This measure is a normalised index based on the row sums of the Leontief inverse, and is the direct and indirect increase in sales/demand for the output of the focus sector if the final demand of every sector increased by one unit.
GFLI	Ghoshian forward linkage index	Equation 3.11	$\mathrm{GFLI}=\left[\frac{\frac{1}{n}\sum\limits_{j=1}^{n}\mathrm{G_{ij}}}{\frac{1}{n^2}\sum\limits_{i,j=1}^{n}\mathrm{G_{ij}}}\right]=\left[\frac{\frac{1}{n}\mathrm{FL_i}}{\frac{1}{n^2}\mathrm{K_G}}\right]=\left[\frac{\mathrm{FL_i}}{\frac{1}{n}\mathrm{K_G}}\right]$	This measure is a normalised index of each sectors output coefficients, or alternatively can be thought of as a normalised index of their forward output multiplier.
PGFLI	Pure Ghoshian forward linkage index	Equation 3.11 excluding intrasectoral effect		This is identical to the GFLI measure, except that we exclude the effect of the ’own sector’ transactions on the calculation.

Table 3.2: Sector numbers and names

Sector name	67 sector code
Agriculture	1
Forestry	2
Fishing	3
Coal extraction	4
Oil and gas extraction	5
Metal ores extraction, Other mining and quarrying	6
Food and drink	7
Tobacco	8
Textiles	9
Wearing apparel	10
Leather products	11
Wood products	12
Pulp and paper; printing and publishing	13
Coke, refined petroleum & nuclear fuel	14
Industrial gases and dyes	15
Inorganic chemicals, Organic chemicals	16
Fertilisers, Plastics & Synthetic resins etc, Pesticides	17
Paints, varnishes, etc	18
Pharmaceuticals	19
Soap and detergents	20
Other Chemical products, Man-made fibres	21
Rubber products	22
Plastic products	23
Glass, glass products	24
Ceramic goods	25
Structural clay products, Cement, lime and plaster	26
Articles of concrete, stone etc	27
Iron and steel, Non-ferrous metals, Metal castings	28
Metal products	29
Machinery and equipment	30
Office machinery	31
Electrical machinery	32
Radio, television, comms	33
Medical and precision instruments	34
Motor vehicles	35
Other transport equipment	36
Other manufacturing and recycling	37
Electricity production & distribution	38
Gas distribution	39
Water supply	40
Construction	41
Motor vehicle sales, repair & fuel	42
Wholesale distribution	43
Retail distribution	44
Hotels, catering, pubs etc	45
Railway transport	46
Other land transport	47
Water transport	48
Air transport	49
Ancillary transport services	50
Post and telecommunications	51
Banking and finance	52
Insurance & pension funds	53
Auxiliary financial services	54
Real estate activities	55
Renting of machinery	56
Computer services	57
Research and development	58
Other business activities	59
Public administration and defence	60
Education	61
Health & social work	62
Sewage & refuse services	63
Membership organisations	64
Recreational services	65
Other service activities	66
Private Households with employed persons	67

Table 3.3: Output backward linkage results

Sector	LBLI	Sector	LBLI	Sector	PLBLI	Sector	PLBLI
1	1.0711	35	0.8426	1	1.1210	35	0.5464
2	1.3173	36	0.9416	2	1.0034	36	0.8812
3	1.0683	37	0.9939	3	1.3280	37	1.1321
4	1.0915	38	1.3859	4	1.3566	38	1.2059
5	1.2546	39	0.9474	5	2.0560	39	0.9387
6	1.0870	40	0.9341	6	1.3994	40	0.9032
7	0.9893	41	1.1170	7	1.0380	41	0.7769
8	0.7022	42	0.8976	8	0.0000	42	0.7099
9	0.9715	43	1.0237	9	0.9819	43	1.2414
10	0.9026	44	0.9849	10	0.7810	44	1.1006
11	0.9418	45	0.8390	11	0.8975	45	0.5274
12	1.0314	46	1.3473	12	0.8748	46	2.4961
13	0.9845	47	0.9946	13	0.9279	47	1.0724
14	1.3391	48	0.9787	14	2.3887	48	1.0207
15	1.0354	49	1.0192	15	1.2186	49	1.2107
16	1.0225	50	1.3043	16	0.6399	50	1.2420
17	1.0764	51	0.8967	17	1.4515	51	0.5508
18	0.9763	52	0.9732	18	1.0568	52	0.9067
19	1.0816	53	1.2832	19	1.4201	53	1.8513
20	0.9420	54	1.0758	20	0.9319	54	1.0885
21	0.9326	55	0.9685	21	0.8946	55	1.0012
22	1.0350	56	0.9360	22	1.1511	56	0.8450
23	0.9818	57	0.9751	23	1.0706	57	1.0010
24	1.0161	58	1.0480	24	1.1683	58	1.2803
25	0.9234	59	1.0903	25	0.8306	59	0.7630
26	0.9700	60	0.9696	26	1.0323	60	1.0275
27	1.0080	61	0.8564	27	1.1908	61	0.4524
28	0.9769	62	0.8697	28	1.0394	62	0.3228
29	0.9201	63	0.9809	29	0.7928	63	0.5597
30	0.8892	64	0.8588	30	0.7035	64	0.5065
31	0.8815	65	1.0762	31	0.6987	65	1.0011
32	0.8444	66	0.9305	32	0.5445	66	0.8476
33	0.8714	67	0.7022	33	0.5423	67	0.0000
34	0.8202			34	0.4570		

Table 3.4: Output forward linkage results

Sector	GFLI	Sector	GFLI	Sector	PGFLI	Sector	PGFLI	Sector	LFLI	Sector	LFLI
1	1.0421	35	0.6990	1	1.0085	35	0.0101	1	0.9775	35	0.7028
2	1.2456	36	0.8142	2	0.7406	36	0.3985	2	1.0919	36	0.7802
3	0.7565	37	0.7609	3	0.1338	37	0.2418	3	0.7325	37	0.7188
4	1.8357	38	1.3884	4	4.1758	38	1.2207	4	0.8099	38	2.7048
5	1.3532	39	1.4194	5	2.4039	39	2.7323	5	1.5435	39	0.7993
6	1.1711	40	1.0918	6	1.7084	40	1.5029	6	0.9086	40	0.7973
7	0.7551	41	1.1767	7	0.1458	41	1.0146	7	0.9129	41	1.8755
8	0.6962	42	1.0048	8	0.0000	42	1.1233	8	0.7022	42	0.9705
9	0.7440	43	0.9653	9	0.1164	43	1.0115	9	0.7536	43	1.7012
10	0.7063	44	0.7035	10	0.0384	44	0.0267	10	0.7027	44	0.7310
11	0.7740	45	0.7791	11	0.2606	45	0.3096	11	0.7135	45	0.7780
12	1.0463	46	1.0112	12	0.9359	46	1.1803	12	0.8780	46	0.8012
13	0.9507	47	1.2529	13	0.8009	47	2.0512	13	0.9205	47	1.5861
14	1.1332	48	0.9986	14	1.5707	48	1.0945	14	1.2076	48	0.7484
15	0.8225	49	0.8927	15	0.4028	49	0.7230	15	0.7559	49	0.7535
16	0.9583	50	1.5741	16	0.4081	50	2.2690	16	1.1679	50	2.1914
17	0.9952	51	1.3884	17	1.1299	51	2.4304	17	0.7868	51	1.4316
18	0.8055	52	1.0784	18	0.4047	52	1.3081	18	0.7092	52	1.7120
19	0.8471	53	1.0097	19	0.5173	53	0.7925	19	0.7444	53	1.3936
20	0.7102	54	1.3157	20	0.0509	54	1.9994	20	0.7040	54	0.9474
21	0.7332	55	0.9293	21	0.1376	55	0.8509	21	0.7116	55	1.2523
22	0.7902	56	1.5469	22	0.2163	56	3.1693	22	0.7573	56	1.1454
23	0.8959	57	1.1941	23	0.7409	57	1.8318	23	0.7692	57	1.0448
24	1.0465	58	1.2148	24	1.2781	58	1.9061	24	0.7507	58	0.8089
25	0.7921	59	1.4358	25	0.3340	59	2.0863	25	0.7129	59	3.3159
26	1.4962	60	0.7606	26	3.0293	60	0.2307	26	0.7539	60	0.9179
27	1.5797	61	0.8668	27	3.3571	61	0.5047	27	0.7480	61	0.9889
28	0.8057	62	0.8021	28	0.3861	62	0.0833	28	0.7376	62	0.8817
29	0.8737	63	1.1761	29	0.6199	63	1.3149	29	0.8881	63	1.0013
30	0.7461	64	1.1424	30	0.1652	64	1.5956	30	0.7627	64	0.7750
31	0.7121	65	0.9094	31	0.0603	65	0.3691	31	0.7063	65	1.0042
32	0.7347	66	0.9325	32	0.1368	66	0.8577	32	0.7150	66	0.7846
33	0.7961	67	0.6980	33	0.2663	67	0.0070	33	0.8070	67	0.7024
34	0.7154			34	0.0704			34	0.7094		

Table 3.5: Carbon backward linkage results

Sector	CLBLI	Sector	CLBLI	Sector	PCLBLI	Sector	PCLBLI
1	0.7334	35	0.0707	1	0.8754	35	0.6670
2	0.3293	36	0.0984	2	0.6132	36	0.7474
3	0.8400	37	0.2593	3	0.6531	37	1.7743
4	0.9672	38	7.3441	4	2.3278	38	1.0550
5	1.6838	39	0.4833	5	0.9637	39	2.0642
6	1.1196	40	0.5260	6	2.8125	40	1.0487
7	0.5648	41	0.1338	7	1.2203	41	0.4714
8	0.0356	42	0.1244	8	0.0000	42	0.3828
9	0.8348	43	0.1079	9	1.0893	43	0.5599
10	0.3327	44	0.0770	10	0.9813	44	0.4758
11	0.2818	45	0.0625	11	0.5691	45	0.2929
12	0.8811	46	0.5704	12	1.0386	46	0.9705
13	0.7261	47	1.6759	13	1.8959	47	0.5276
14	2.4764	48	6.2373	14	3.0178	48	0.6478
15	1.5541	49	4.8165	15	1.9660	49	0.7344
16	1.4086	50	0.0660	16	1.2337	50	0.6126
17	1.5792	51	0.0951	17	2.5255	51	0.2999
18	0.4057	52	0.0094	18	1.1592	52	0.2855
19	0.9162	53	0.0131	19	2.7627	53	0.4906
20	0.4091	54	0.0449	20	0.9539	54	0.4178
21	2.6453	55	0.0146	21	1.1921	55	0.1672
22	0.8491	56	0.1784	22	1.4281	56	0.4087
23	0.7828	57	0.0158	23	1.9031	57	0.3269
24	1.5985	58	0.1009	24	2.8321	58	0.5190
25	0.7441	59	0.0436	25	1.1224	59	0.3288
26	11.9218	60	0.1186	26	2.4023	60	0.4289
27	0.9548	61	0.0697	27	2.8939	61	0.3100
28	3.3297	62	0.0619	28	1.8266	62	0.1942
29	0.4180	63	0.3896	29	1.0967	63	0.3224
30	0.3025	64	0.1086	30	0.8323	64	0.1594
31	0.0996	65	0.0463	31	0.2752	65	0.3643
32	0.2580	66	0.1114	32	0.6013	66	0.2612
33	0.1354	67	0.0582	33	0.2953	67	0.0000
34	0.1400			34	0.3225		

Table 3.6: Carbon forward linkage results

Sector	CGFLI	Sector	CGFLI	Sector	PCGFLI	Sector	PCGFLI	Sector	CLFLI	Sector	CLFLI
1	0.6003	35	0.0707	1	0.4404	35	0.0008	1	0.6312	35	0.0796
2	0.1781	36	0.0984	2	0.0803	36	0.0365	2	0.1750	36	0.1057
3	0.6218	37	0.2593	3	0.0834	37	0.0624	3	0.6748	37	0.2745
4	0.7975	38	7.3441	4	1.3750	38	4.8943	4	0.3943	38	16.0352
5	2.3806	39	0.4833	5	3.2056	39	0.7053	5	3.0434	39	0.3051
6	0.5576	40	0.5260	6	0.6165	40	0.5488	6	0.4848	40	0.4305
7	0.2307	41	0.1338	7	0.0338	41	0.0874	7	0.3126	41	0.2390
8	0.0315	42	0.1244	8	0.0000	42	0.1054	8	0.0356	42	0.1347
9	0.5089	43	0.1079	9	0.0604	43	0.0857	9	0.5777	43	0.2132
10	0.0696	44	0.0770	10	0.0029	44	0.0022	10	0.0776	44	0.0897
11	0.1299	45	0.0625	11	0.0332	45	0.0188	11	0.1342	45	0.0700
12	0.7069	46	0.5704	12	0.4793	46	0.5046	12	0.6649	46	0.5065
13	0.2650	47	1.6759	13	0.1692	47	2.0797	13	0.2875	47	2.3778
14	2.3557	48	6.2373	14	2.4750	48	5.1818	14	2.8137	48	5.2395
15	1.0591	49	4.8165	15	0.3932	49	2.9569	15	1.0910	49	4.5564
16	1.0838	50	0.0660	16	0.3498	50	0.0721	16	1.4804	50	0.1030
17	1.1638	51	0.0951	17	1.0015	51	0.1262	17	1.0312	51	0.1099
18	0.1063	52	0.0094	18	0.0405	52	0.0087	18	0.1049	52	0.0167
19	0.2086	53	0.0131	19	0.0965	53	0.0078	19	0.2054	53	0.0203
20	0.1453	54	0.0449	20	0.0079	54	0.0517	20	0.1614	54	0.0362
21	2.1732	55	0.0146	21	0.3091	55	0.0102	21	2.3637	55	0.0221
22	0.4555	56	0.1784	22	0.0945	56	0.2771	22	0.4892	56	0.1481
23	0.3256	57	0.0158	23	0.2041	57	0.0184	23	0.3133	57	0.0155
24	1.1238	58	0.1009	24	1.0404	58	0.1201	24	0.9035	58	0.0753
25	0.4500	59	0.0436	25	0.1438	59	0.0480	25	0.4540	59	0.1129
26	21.3880	60	0.1186	26	32.8240	60	0.0273	26	12.0783	60	0.1604
27	0.4062	61	0.0697	27	0.6543	61	0.0308	27	0.2156	61	0.0891
28	2.8897	62	0.0619	28	1.0495	62	0.0049	28	2.9651	62	0.0763
29	0.1445	63	0.3896	29	0.0777	63	0.3302	29	0.1646	63	0.3718
30	0.0809	64	0.1086	30	0.0136	64	0.1150	30	0.0927	64	0.0826
31	0.0254	65	0.0463	31	0.0016	65	0.0142	31	0.0282	65	0.0573
32	0.0945	66	0.1114	32	0.0133	66	0.0776	32	0.1031	66	0.1050
33	0.0569	67	0.0582	33	0.0144	67	0.0004	33	0.0646	67	0.0657
34	0.0510			34	0.0038			34	0.0567		

Table 3.7: Standard deviation of LFLI and CLFLI measures

	LFLI		CLFLI			LFLI		CLFLI	
Sector	STD	STDi	STD	STDi	Sector	STD	STDi	STD	STDi
1	0.1365	0.9530	38.5838	0.6801	35	0.1222	1.0642	6.0642	0.1069
2	0.1843	0.7055	12.9366	0.2280	36	0.1244	1.0453	7.3786	0.1301
3	0.1266	1.0276	51.0608	0.9000	37	0.1223	1.0631	20.4599	0.3606
4	0.1292	1.0063	27.5564	0.4857	38	0.1863	0.6980	483.7186	8.5261
5	0.1363	0.9538	117.7287	2.0751	39	0.1227	1.0597	20.5111	0.3615
6	0.1268	1.0257	29.6297	0.5223	40	0.1220	1.0662	28.8399	0.5083
7	0.1262	1.0302	18.9302	0.3337	41	0.1606	0.8097	8.9630	0.1580
8	0.1222	1.0645	2.7154	0.0479	42	0.1239	1.0494	7.5326	0.1328
9	0.1251	1.0393	42.0108	0.7405	43	0.1217	1.0689	6.6768	0.1177
10	0.1222	1.0645	5.9102	0.1042	44	0.1221	1.0647	6.5651	0.1157
11	0.1238	1.0506	10.1953	0.1797	45	0.1222	1.0638	4.8159	0.0849
12	0.1403	0.9272	46.5182	0.8199	46	0.1227	1.0596	33.9777	0.5989
13	0.1294	1.0047	17.7060	0.3121	47	0.1245	1.0442	81.7640	1.4412
14	0.1256	1.0356	128.1364	2.2585	48	0.1246	1.0435	382.0665	6.7343
15	0.1257	1.0349	79.4214	1.3999	49	0.1232	1.0559	326.1405	5.7486
16	0.1499	0.8675	83.2209	1.4669	50	0.1780	0.7308	3.6624	0.0646
17	0.1224	1.0628	70.2357	1.2380	51	0.1311	0.9922	4.4058	0.0777
18	0.1227	1.0603	7.9445	0.1400	52	0.1271	1.0230	0.5443	0.0096
19	0.1247	1.0428	15.0698	0.2656	53	0.1392	0.9340	0.8887	0.0157
20	0.1223	1.0635	12.2755	0.2164	54	0.1384	0.9399	2.3182	0.0409
21	0.1223	1.0634	177.9057	3.1358	55	0.1232	1.0559	0.9522	0.0168
22	0.1286	1.0109	36.3955	0.6415	56	0.1248	1.0424	7.0621	0.1245
23	0.1229	1.0584	21.9155	0.3863	57	0.1243	1.0462	0.8082	0.0142
24	0.1245	1.0442	65.6464	1.1571	58	0.1249	1.0409	5.0960	0.0898
25	0.1236	1.0524	34.4571	0.6073	59	0.1549	0.8394	2.3092	0.0407
26	0.1226	1.0604	860.5114	15.1675	60	0.1224	1.0626	9.3635	0.1650
27	0.1221	1.0650	15.4118	0.2716	61	0.1283	1.0134	5.0639	0.0893
28	0.1235	1.0530	217.4059	3.8320	62	0.1367	0.9516	5.1760	0.0912
29	0.1244	1.0458	10.0944	0.1779	63	0.1453	0.8952	23.6181	0.4163
30	0.1232	1.0558	6.5582	0.1156	64	0.1267	1.0264	5.9138	0.1042
31	0.1222	1.0645	2.1365	0.0377	65	0.1421	0.9150	3.5503	0.0626
32	0.1226	1.0609	7.7424	0.1365	66	0.1239	1.0499	7.2600	0.1280
33	0.1274	1.0209	4.4669	0.0787	67	0.1222	1.0645	5.0037	0.0882
34	0.1223	1.0636	4.2790	0.0754					

Table 3.8: Weighted output backward linkage measures

Sector	LBLIwx	LBLIwe	PLBLIwx	PLBLIwe	Sector	LBLIwx	LBLIwe	PLBLIwx	PLBLIwe
1	0.0169	0.0186	0.0177	0.0194	35	0.0018	0.0060	0.0012	0.0039
2	0.0020	0.0033	0.0015	0.0025	36	0.0098	0.0254	0.0092	0.0238
3	0.0038	0.0117	0.0047	0.0145	37	0.0043	0.0096	0.0049	0.0110
4	0.0012	0.0006	0.0015	0.0007	38	0.0512	0.0483	0.0445	0.0420
5	0.0197	0.0301	0.0323	0.0494	39	0.0015	0.0006	0.0015	0.0006
6	0.0030	0.0055	0.0038	0.0071	40	0.0025	0.0000	0.0024	0.0000
7	0.0404	0.1145	0.0423	0.1201	41	0.0787	0.0303	0.0547	0.0211
8	0.0000	0.0000	0.0000	0.0000	42	0.0113	0.0023	0.0090	0.0018
9	0.0042	0.0114	0.0042	0.0115	43	0.0328	0.0195	0.0398	0.0237
10	0.0010	0.0031	0.0008	0.0027	44	0.0420	0.0095	0.0469	0.0106
11	0.0005	0.0013	0.0005	0.0012	45	0.0199	0.0159	0.0125	0.0100
12	0.0052	0.0107	0.0044	0.0091	46	0.0063	0.0021	0.0116	0.0039
13	0.0159	0.0334	0.0150	0.0315	47	0.0153	0.0104	0.0165	0.0112
14	0.0157	0.0185	0.0281	0.0330	48	0.0014	0.0020	0.0015	0.0021
15	0.0012	0.0035	0.0014	0.0041	49	0.0046	0.0095	0.0054	0.0113
16	0.0084	0.0204	0.0052	0.0128	50	0.0320	0.0280	0.0304	0.0267
17	0.0017	0.0037	0.0022	0.0050	51	0.0194	0.0062	0.0119	0.0038
18	0.0004	0.0011	0.0004	0.0011	52	0.0459	0.0688	0.0428	0.0641
19	0.0041	0.0113	0.0054	0.0148	53	0.0526	0.0728	0.0759	0.1051
20	0.0011	0.0034	0.0011	0.0034	54	0.0079	0.0095	0.0080	0.0096
21	0.0017	0.0053	0.0016	0.0051	55	0.0525	0.0088	0.0543	0.0091
22	0.0027	0.0074	0.0030	0.0083	56	0.0062	0.0018	0.0056	0.0017
23	0.0042	0.0107	0.0046	0.0116	57	0.0135	0.0156	0.0138	0.0160
24	0.0015	0.0028	0.0017	0.0032	58	0.0029	0.0045	0.0036	0.0054
25	0.0005	0.0015	0.0005	0.0013	59	0.0841	0.0847	0.0588	0.0593
26	0.0005	0.0004	0.0005	0.0004	60	0.0749	0.0002	0.0794	0.0002
27	0.0019	0.0010	0.0022	0.0012	61	0.0352	0.0089	0.0186	0.0047
28	0.0024	0.0069	0.0025	0.0073	62	0.0560	0.0048	0.0208	0.0018
29	0.0104	0.0271	0.0090	0.0233	63	0.0077	0.0007	0.0044	0.0004
30	0.0102	0.0303	0.0081	0.0240	64	0.0021	0.0000	0.0013	0.0000
31	0.0068	0.0221	0.0054	0.0175	65	0.0357	0.0411	0.0332	0.0382
32	0.0038	0.0120	0.0024	0.0077	66	0.0057	0.0046	0.0052	0.0042
33	0.0090	0.0263	0.0056	0.0164	67	0.0011	0.0000	0.0000	0.0000
34	0.0060	0.0197	0.0034	0.0110					

Table 3.9: Weighted carbon backward linkage measures

Sector	CLBLIwx	CLBLIwe	CPLBLIwx	CPLBLIwe	Sector	CLBLIwx	CLBLIwe	CPLBLIwx	CPLBLIwe
1	0.0116	0.0127	0.0138	0.0152	35	0.0005	0.0018	0.0014	0.0048
2	0.0005	0.0008	0.0009	0.0015	36	0.0030	0.0079	0.0078	0.0202
3	0.0030	0.0092	0.0023	0.0071	37	0.0032	0.0071	0.0077	0.0172
4	0.0010	0.0005	0.0025	0.0012	38	0.2458	0.2319	0.0390	0.0368
5	0.0264	0.0404	0.0151	0.0231	39	0.0013	0.0005	0.0032	0.0012
6	0.0031	0.0057	0.0077	0.0142	40	0.0017	0.0000	0.0028	0.0000
7	0.0230	0.0654	0.0498	0.1412	41	0.0169	0.0065	0.0332	0.0128
8	0.0000	0.0000	0.0000	0.0000	42	0.0025	0.0005	0.0048	0.0010
9	0.0036	0.0098	0.0047	0.0128	43	0.0075	0.0045	0.0179	0.0107
10	0.0004	0.0011	0.0011	0.0034	44	0.0089	0.0020	0.0203	0.0046
11	0.0001	0.0004	0.0003	0.0008	45	0.0033	0.0026	0.0069	0.0056
12	0.0044	0.0092	0.0052	0.0108	46	0.0032	0.0011	0.0045	0.0015
13	0.0117	0.0246	0.0306	0.0643	47	0.0187	0.0127	0.0081	0.0055
14	0.0291	0.0342	0.0354	0.0417	48	0.0074	0.0108	0.0009	0.0013
15	0.0018	0.0052	0.0023	0.0066	49	0.0201	0.0419	0.0033	0.0069
16	0.0115	0.0281	0.0101	0.0246	50	0.0050	0.0044	0.0150	0.0132
17	0.0024	0.0054	0.0039	0.0087	51	0.0029	0.0009	0.0065	0.0021
18	0.0002	0.0004	0.0004	0.0013	52	0.0038	0.0058	0.0135	0.0202
19	0.0035	0.0095	0.0105	0.0288	53	0.0057	0.0079	0.0201	0.0279
20	0.0005	0.0015	0.0011	0.0035	54	0.0010	0.0012	0.0031	0.0037
21	0.0047	0.0152	0.0021	0.0068	55	0.0030	0.0005	0.0091	0.0015
22	0.0022	0.0061	0.0037	0.0103	56	0.0013	0.0004	0.0027	0.0008
23	0.0033	0.0085	0.0081	0.0206	57	0.0013	0.0015	0.0045	0.0052
24	0.0024	0.0044	0.0042	0.0079	58	0.0006	0.0009	0.0014	0.0022
25	0.0004	0.0012	0.0006	0.0018	59	0.0089	0.0090	0.0254	0.0255
26	0.0059	0.0049	0.0012	0.0010	60	0.0181	0.0000	0.0331	0.0001
27	0.0018	0.0010	0.0054	0.0030	61	0.0061	0.0015	0.0127	0.0032
28	0.0080	0.0235	0.0044	0.0129	62	0.0076	0.0006	0.0125	0.0011
29	0.0047	0.0123	0.0124	0.0323	63	0.0031	0.0003	0.0025	0.0002
30	0.0035	0.0103	0.0096	0.0284	64	0.0003	0.0000	0.0004	0.0000
31	0.0008	0.0025	0.0021	0.0069	65	0.0047	0.0054	0.0121	0.0139
32	0.0012	0.0037	0.0027	0.0085	66	0.0010	0.0008	0.0016	0.0013
33	0.0014	0.0041	0.0031	0.0089	67	0.0001	0.0000	0.0000	0.0000
34	0.0010	0.0034	0.0024	0.0078					

Table 3.10: Weighted output forward linkage measures

Sector	GFLIwv	PGFLIwv	Sector	GFLIwv	PGFLIwv
1	0.0118	0.0114	35	0.0009	0.0000
2	0.0015	0.0009	36	0.0070	0.0034
3	0.0019	0.0003	37	0.0027	0.0009
4	0.0009	0.0019	38	0.0271	0.0239
5	0.0109	0.0193	39	0.0031	0.0060
6	0.0027	0.0039	40	0.0042	0.0058
7	0.0228	0.0044	41	0.0764	0.0659
8	0.0000	0.0000	42	0.0157	0.0176
9	0.0023	0.0004	43	0.0364	0.0382
10	0.0006	0.0000	44	0.0372	0.0014
11	0.0002	0.0001	45	0.0261	0.0104
12	0.0039	0.0035	46	0.0021	0.0025
13	0.0131	0.0110	47	0.0234	0.0383
14	0.0027	0.0037	48	0.0016	0.0018
15	0.0007	0.0003	49	0.0039	0.0032
16	0.0054	0.0023	50	0.0241	0.0348
17	0.0009	0.0010	51	0.0387	0.0677
18	0.0002	0.0001	52	0.0605	0.0734
19	0.0024	0.0015	53	0.0171	0.0134
20	0.0004	0.0000	54	0.0083	0.0127
21	0.0014	0.0003	55	0.0704	0.0645
22	0.0014	0.0004	56	0.0123	0.0253
23	0.0033	0.0027	57	0.0182	0.0280
24	0.0016	0.0020	58	0.0032	0.0051
25	0.0004	0.0002	59	0.1079	0.1568
26	0.0010	0.0020	60	0.0533	0.0162
27	0.0028	0.0059	61	0.0529	0.0308
28	0.0013	0.0006	62	0.0723	0.0075
29	0.0088	0.0062	63	0.0115	0.0129
30	0.0077	0.0017	64	0.0042	0.0058
31	0.0040	0.0003	65	0.0282	0.0114
32	0.0038	0.0007	66	0.0072	0.0066
33	0.0064	0.0022	67	0.0021	0.0000
34	0.0069	0.0007			

Table 3.11: Key (output) sector results

Sector number	% reduction in output	Sector number	% reduction in output
60	10.61	66	0.80
59	9.40	49	0.65
41	8.57	12	0.64
55	7.38	37	0.62
62	7.12	23	0.59
53	6.51	9	0.58
52	6.20	19	0.57
44	5.98	32	0.54
7	5.58	3	0.52
38	4.75	6	0.41
61	4.75	58	0.41
43	4.65	22	0.36
65	4.35	40	0.35
50	3.24	28	0.33
45	2.83	64	0.29
5	2.71	27	0.27
51	2.56	35	0.26
14	2.17	21	0.24
1	2.16	17	0.23
47	2.13	24	0.21
13	2.13	39	0.21
57	1.88	48	0.19
42	1.58	2	0.19
29	1.45	15	0.17
30	1.44	4	0.16
36	1.38	20	0.15
33	1.23	67	0.15
54	0.99	10	0.14
16	0.97	25	0.07
31	0.97	11	0.07
63	0.92	26	0.07
46	0.89	18	0.05
56	0.87	8	0.00
34	0.86		

Table 3.12: Key (output) group results

Key groups k=2			Key groups k=3				Key groups k=4				
% reduction in output	Sector 1	Sector 2	% reduction in output	Sector 1	Sector 2	Sector 3	% reduction in output	Sector 1	Sector 2	Sector 3	Sector 4
19.12	59	60	26.79	41	59	60	33.67	41	59	60	62
18.68	41	60	26.04	59	60	62	32.79	41	55	59	60
17.71	60	62	25.81	55	59	60	32.71	55	59	60	62
17.67	55	60	25.74	41	60	62	32.28	41	44	59	60
17.53	41	59	25.00	41	55	60	32.14	7	41	59	60
16.97	53	60	24.79	41	53	60	32.08	41	53	59	60
16.56	44	60	24.73	55	60	62	32.03	41	55	60	62
16.49	52	60	24.72	44	59	60	31.95	41	52	59	60
16.39	55	59	24.63	53	59	60	31.77	41	53	60	62
16.34	59	62	24.51	41	44	60	31.63	44	59	60	62
16.18	7	60	24.51	7	59	60	31.56	41	44	60	62
15.65	41	62	24.43	41	59	62	31.47	53	59	60	62
15.22	38	60	24.42	52	59	60	31.43	41	52	60	62
15.22	43	60	24.40	41	52	60	31.42	7	59	60	62
15.18	41	55	24.20	7	41	60	31.32	52	59	60	62
15.15	60	61	23.98	53	60	62	31.24	7	41	60	62
15.02	53	59	23.79	41	55	59	31.18	7	55	59	60
15.02	44	59	23.65	44	60	62	31.08	38	41	59	60
14.97	52	59	23.58	53	55	60	31.01	41	59	60	61
14.85	60	65	23.57	38	59	60	30.93	53	55	59	60

Table 3.13: Key (carbon) sector results

Sector number	KS Score	Sector number	KS Score
38	63.18	6	0.73
7	6.00	55	0.72
14	5.68	51	0.68
5	5.23	24	0.64
60	4.42	17	0.60
49	3.90	3	0.59
47	3.69	63	0.57
13	3.40	42	0.57
41	2.84	22	0.53
44	2.33	40	0.46
1	2.26	15	0.43
16	2.17	27	0.42
59	1.83	57	0.36
28	1.69	39	0.35
43	1.68	33	0.35
62	1.65	32	0.32
61	1.47	56	0.31
48	1.41	34	0.29
29	1.34	4	0.28
53	1.30	54	0.26
26	1.19	66	0.22
19	1.14	31	0.19
65	1.07	35	0.16
30	1.01	58	0.14
21	0.98	20	0.13
52	0.97	10	0.11
23	0.95	25	0.10
37	0.91	2	0.07
12	0.90	64	0.06
36	0.87	18	0.04
50	0.87	11	0.04
9	0.84	67	0.02
45	0.78	8	0.00
46	0.76		

Table 3.14: Key (carbon) group results

Key groups k=2			Key groups k=3				Key groups k=4				
% reduction	Sector 1	Sector 2	% reduction	Sector 1	Sector 2	Sector 3	% reduction	Sector 1	Sector 2	Sector 3	Sector 4
68.13	14	38	71.82	14	38	49	74.98	14	38	47	49
67.00	38	49	71.31	14	38	47	74.40	7	14	38	49
66.94	5	38	70.72	7	14	38	74.23	14	38	49	60
66.58	38	47	70.68	5	38	49	74.13	5	14	38	49
65.91	7	38	70.58	14	38	60	73.98	5	38	47	49
65.78	38	60	70.47	5	14	38	73.81	14	38	41	49
65.32	38	41	70.38	38	47	49	73.78	7	14	38	47
64.95	1	38	70.26	5	38	47	73.66	14	38	47	60
64.67	16	38	70.13	14	38	41	73.64	5	14	38	47
64.56	28	38	69.80	1	14	38	73.48	1	14	38	49
64.54	38	48	69.73	7	38	49	73.36	5	7	38	49
64.39	38	43	69.63	5	7	38	73.28	14	16	38	49
64.33	38	44	69.59	14	16	38	73.22	14	38	41	47
64.26	26	38	69.56	38	49	60	73.19	5	38	49	60
64.18	38	62	69.49	5	38	60	73.17	7	14	38	60
64.09	13	38	69.48	14	28	38	73.16	14	28	38	49
64.07	38	59	69.41	14	38	48	73.09	14	38	48	49
64.02	21	38	69.20	14	26	38	73.06	5	7	14	38
63.94	38	61	69.19	14	38	44	72.97	7	38	47	49
63.81	38	53	69.17	7	38	47	72.91	5	14	38	60

Table 3.15: Each sector's proportion of total Scottish output

Sector	% of total Scottish output	Sector	% of total Scottish output
1	1.58%	36	1.05%
2	0.15%	37	0.44%
3	0.35%	38	3.69%
4	0.11%	39	0.16%
5	1.57%	40	0.27%
6	0.27%	41	7.04%
7	4.08%	42	1.26%
8	0.00%	43	3.21%
9	0.43%	44	4.26%
10	0.11%	45	2.37%
11	0.05%	46	0.46%
12	0.50%	47	1.54%
13	1.61%	48	0.14%
14	1.17%	49	0.45%
15	0.12%	50	2.45%
16	0.82%	51	2.16%
17	0.15%	52	4.72%
18	0.04%	53	4.10%
19	0.38%	54	0.73%
20	0.11%	55	5.42%
21	0.18%	56	0.67%
22	0.26%	57	1.38%
23	0.43%	58	0.28%
24	0.15%	59	7.71%
25	0.06%	60	7.73%
26	0.05%	61	4.11%
27	0.19%	62	6.44%
28	0.24%	63	0.79%
29	1.13%	64	0.25%
30	1.15%	65	3.31%
31	0.77%	66	0.61%
32	0.45%	67	0.15%
33	1.03%		
34	0.74%		
35	0.22%		

Chapter 4

The impact of export growth on CO_2 emission totals in Scotland

4.1 Introduction

We noted earlier that the Scottish Parliament passed climate change legislation in 2009 setting a series of territorial emission reduction targets for Scotland. In addition, the Scottish Government have adopted a 'National Outcome' target of reducing the emissions embodied in Scottish consumption. Scotland therefore has two emission targets, one based on territorial emissions (which includes the emissions embodied in exports) the other based on consumption emissions (which includes the emissions embodied in imports).

Alongside these environmental targets, the Scottish Government has prioritised economic growth through boosting Scottish export demand. One part of this strategy is focused on obtaining economic growth through the development of 'green' industries, thus recognising the potential impact of environmental improvements on economic growth. What has been largely ignored has been the impact of growing Scotland's economy through the preferred route (export growth) on the environment. The purpose of this chapter is to use an environmental CGE model to estimate the impact on different Scottish CO_2 emission totals (driven by either territorial or consumption emissions) of boosting export demand in Scotland.

CGE modelling is now widely used for the analysis of environmental policy issues, and is an appropriate tool for modelling the impact of economic change where that economic change is anticipated to have general equilibrium impacts (Bergman 2005). What is a CGE model? Well, in broad terms, it is a multi-sectoral model of the macroeconomy that is based on actual data for the country/region or countries/regions of interest (Bergman 2005, p1276) with key variables linked in a theoretically consistent manner. CGE models focus on the macro-economy and do not model, for example, financial asset markets (Bergman 2005, p1276).

The input-output database outlined in Chapter 2 can be thought of as providing a tool for the examination of the long run impacts of economic change, without being able to discuss the dynamics of this transition from one equilibrium to another- as the CGE model can. McGregor et al. (1996) demonstrates that a demand stimulus in a CGE model, in the absence of any supply constraints- which recall were also absent in the demand driven input-output model- will generate the same result in the long run as those from the demand driven input-output model. The key advantage in this case from adopting the CGE modelling environment is the ability to consider the dynamic adjustment from one equilibrium to another.

In this chapter we recreate the emissions totals calculated in Chapter 2, post the introduction of the stimulus to export demand. To do this, we use the CGE model results to recreate the demand driven input-output database for each period. If all we wanted was to calculate total pollution, we could take total output from the CGE model and multiply it by a vector of emissions intensities. We need to recreate the input output database in order to carry out the attribution of CO_2 emissions to final demand.

Doing so allows us to examine the evolution of different emissions attribution measures from the base period to the new long run equilibrium in much the same way as the evolution of sectoral employment or output has traditionally been examined using CGE models. The recreation of the input-output database each period is necessary to construct the emissions totals introduced in Chapter 2 for each period. In addition, total emissions generation must be calculated in each period of the analysis post the introduction of the export shock. How this will be done will be discussed in more detail later in this chapter. We consider two central cases for an increase in export demand, one with flow migration, and one with no migration. This allows us to consider the implications of the introduction of this supply constraint, with an increase in export demand, on economic growth and the CO_2 totals in Scotland.

This chapter is structured as follows: firstly we provide the policy and background motivation for this study, secondly we discuss the history of CGE models and their development, thirdly we review the features of a typical CGE model, fourthly we discuss the literature on regional and environmental CGE applications, then we review the strengths and weaknesses of CGE models. The next few sections of this chapter review previous application of the AMOSENVI model that we use here, before outlining the model in more detail. We then outline our simulation strategy, and discuss how we will recreate the emissions total(s) for each period of the analysis. The penultimate section presents our results, including a sensitivity analysis, and the final section concludes the work contained in this chapter.

4.2 Motivation for this analysis

Scotland is a small open regional economy, which as we have established in previous chapters, is engaged in a large volume of trade with both the rest of the UK (RUK) and the rest of the world (ROW). Scotland has, at least for the last thirty years, had a lower average rate of economic growth than the UK as a whole[1]. Recent attempts to increase Scottish economic growth to better match the rate obtained in the RUK have predominantly focused on boosting export demand.

The election of an SNP[2] minority Government in Scotland in 2007 led to increased concern about the relative performance of the Scottish economy within the UK. The new Government's first economic strategy (Scottish Government 2007) placed a particular emphasis on certain areas of policy, one of which was: "Target[ing] support to business in the pursuit of opportunities outside of Scotland and the development of internationally competitive firms" (Scottish Government 2007). This strategic objective was supported by three key action points (Scottish Government 2007):

- working in partnership with businesses with potential to be significant international players to identify development requirements
- supporting a range of product and tradable service exports and international partnership opportunities
- supporting foreign direct investment, where it has a positive impact on the Scottish economy

This was followed, importantly for our purposes, by: "...promot[ing] economic growth and environmental quality and responsibility as mutually advancing" (Scottish Government 2007). So, there is some recognition here of the connection between increasing economic activity and increasing environmental degradation or environmental resource use. To be fair to the Scottish Government, they recognise the problems that increased economic activity poses for their environmental targets, noting that: "Meeting [their sustainability] targets while increasing economic growth will be a major challenge" (Scottish Government 2007).

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[1] http://www.scotland.gov.uk/Topics/Statistics/About/NotesSP/TechnicalNotesSPPT1

[2] The Scottish National Party is a party which supports the separation of Scotland from the rest of the UK.

So recognising this difficulty, what do the Scottish Government propose as the solution? In the 2007 Scottish Government Economic Strategy (Scottish Government 2007), they point to increases in economic growth from environmental improvements and the growth of green industries[3] as proof that economic growth and lowering our environmental impacts could be achieved together. The difficulty then appears to be that, while the government saw growth coming through both increases in trade and the growth of 'green' industries, they only linked (explicitly) the latter to its impact on the environment.

In other words, they have not addressed the impact of increases in economic growth, stemming from increased export activity, on their environmental targets. Instead, they have addressed the broader issue of the compatibility of economic growth with reduced environmental impacts, by selecting as their example an industry where growth may well lead to reduced environmental impacts. The difficulty here in terms of national outcomes, such as improved economic growth and reduced environmental damage, lies in the fact that the sector they select as their example is very small, even if it is enjoying rapid growth at the moment[4].

The big sources of additional environmental impacts in the face of a general increase in export demand are expected to be those sectors we saw to be ranked highly by the carbon Leontief backward linkage measures weighted by export final demand (CLBLIwe) measure in Table 3.9. While it is perhaps true that if the only growth in export demand was in low carbon sectors or 'green' industries, such an increase may lead to only a small increase in Scotland's environmental impacts, the same cannot surely be said for a more general increase in export demand? If this new demand led to the displacement of existing -more pollution intensive- demand, it may be that emissions actually fall; otherwise any growth in exports would surely add to our environmental impact.

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[3] Scotland has also developed a low carbon economy strategy (Scottish Government 2010). One aspect of this strategy focuses on exploiting the "significant export opportunities [that] exist for all sectors of the low carbon economy..." (Scottish Government 2010, p7).

[4] Although it is thhe case that the Scottish Government are commited to decarbonising the electricity sector by 2020.

This situation is complicated by another passage in the same document which addresses the sustainability issue. The 2007 Scottish Government Economic Strategy (Scottish Government 2007) recognises the need to reduce the emissions that Scotland produces, but also notes that this is separate from the emissions embodied in Scotland's consumption activities. While they do not, in this particular document, make a commitment to reducing Scotland's consumption emissions, this has to be understood in the context of the Climate Change (Scotland) Act (2009) which at that time was only at an early stage. Subsequently, and as we noted earlier, the Scottish Government have accepted as a 'National Outcome', the reduction of the emissions embodied in Scotland's consumption activities (Scottish Government 2011*b*).

At this stage it is worth recapping slightly what the position was prior to the 2011 Scottish Parliament election, and the arrival of the latest Scottish Government economic strategy document. The Scottish Government had policy commitments to reducing both their production (or territorial) emissions and reducing their consumption emissions. Alongside these environmental goals they had adopted a policy of boosting export demand. What had not, except in the narrow case of 'green' industries, been addressed is the compatibility of these two policies.

In the 2011 Scottish Government Economic Strategy (Scottish Government 2011*a*), again gives a commitment to boosting international trade, together with a commitment to: "foster[ing] a self-sustaining and ambitious climate of entrepreneurialism, international trade and innovation" (Scottish Government 2011*a*, p12). However, in this updated strategy the route to economic growth is restated in an interesting manner, we are told that: "Only by promoting environmental sustainability, and delivering a significant reduction in our greenhouse gas emissions, will we be able to deliver growth and benefits for all over the long-term" (Scottish Government 2011*a*, p16). So it is now *only* through environmental improvements that economic growth can be realised in the long term[5].

The Scottish Government (2011*a*) document then later contradicts itself slightly by countering that export demand is: "a vital source of growth and will be essential to our future prosperity as world trade continues to expand" (Scottish Government 2011*a*, p39). Indeed the Minister in charge of economic affairs at the Scottish Government later argues in this document that: "International trade and investment is a key theme of the Government Economic Strategy with additional efforts and support being targeted toward increasing... the number of Scottish exporters" (Scottish Government 2011*a*, p41). So increasing export demand is *vital* and boosting export trade is a *key theme* of the government's economic strategy, but what about the associated environmental impacts?

In the 2011 Scottish Government Economic Strategy there is a new 'strategic priority' titled: 'Transition to a low carbon economy' (Scottish Government 2011*a*, p51-2), which explicitly builds on the 'Low Carbon Economy Strategy' published in 2010 (Scottish Government 2010). In this section (C2) of the economic strategy document, again no mention is made of the environmental impacts of economic growth other than through the growth of 'green' industries. A broad commitment to the decoupling of emissions and economic growth is made, but the means to obtain this are quite narrow, focusing on a: "shift towards renewable energy, ...[a] focus on energy and resource efficiency, and... [the Scottish Government's]...commitment to the low carbon and environmental goods and services (LCEGS) sector" (Scottish Government 2011*a*, p51).

While reference is made to the ability of these 'green' industries to build upon our existing economic strengths, the thrust of what is contained in this part of the economic strategy does not address reducing the environmental impacts of the economic growth recommended in the earlier sections of the strategy. While there are broad commitments to improving the efficiency of resource use and a range of other commitments to reducing the emissions generated by

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[5] What seems to be implicit in this statement is the notion of 'sustainable' growth.

consumers, the main point of this section seems to be aimed at how we can increase investment in these 'green' industries in Scotland.

While it is the case that increases in renewable energy will help reduce Scotland's emissions from electricity production, although the electricity sector is 'covered' by the EU-ETS and in a sense emissions reductions in this sector can be taken for granted as a consequence of the permit market, there is not a discussion of how increases in economic growth-driven by whatever means- will be met by renewable sources. Will there be that capacity, and how is the supply of renewables expected to match changes in demand?

If the Scottish Government succeed in both boosting renewable energy production and export demand, will the increase in energy demand needed to produce these exports be able to be met out of renewable sources? Or will energy demand outstrip renewable energy supply? This depends on the emissions and energy content of these exports and the extent to which there is a decarbonisation of Scottish energy supply[6]; it is the first part of this which we focus on here.

In essence, and perhaps not unreasonably, the Government Economic Strategy focuses on what environmental improvements and investment can do for economic growth and also the implications for the economy of not making improvements in environmental quality, not what economic growth implies for environmental impacts. However, if environmental and economic objectives are both important, its crucial to understand the impact of each of these policies on the other. What is missing at the moment is an understanding of the implications of economic growth -specifically a growth in external demand- which is an explicit government economic objective, on environmental totals such as CO_2 emissions.

This chapter bridges this gap, with an analysis of the implications of growth in export demand in Scotland on both the emissions produced within Scotland (the TAP emissions total) and the emissions embodied in Scottish consumption

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[6] Another way to think about this issue is in terms of the decoupling of economic growth and emissions/energy demand.

(the CAP emissions total). This provides an assessment of the implications of the desired growth in demand in Scotland on the production based emissions targets contained in the Climate Change (Scotland) Act, and the 'National Outcome' target of reducing the emissions embodied in Scottish consumption.

Part of what the Government Economic Strategy seeks to do is encourage differential growth across sectors of the economy, particularly through supporting the growth of 'green' sectors. In this Chapter we only consider the implications of economy-wide export demand growth (i.e. equal % increase in all sectors). We believe this to be a useful scenario to consider the environmental implications of general export growth, but acknowledge that the implications of sectoral specific growth policies would require additional and separate analysis. In order to assess the impacts of increases in export demand on economic and environmental variables in Scotland, we utilise a computable general equilibrium modelling approach.

As Bergman (2005) notes, CGE models are an appropriate modelling environment for understanding the impact of economic or public policy changes where the 'change' being modelled is expected to have 'general equilibrium effects', which perhaps explains their wide utilisation for the analysis of climate change problems (Bergman 2005, p1277-8). In the next section, we begin our description of this modelling approach by discussing the historical development of this class of models.

4.3 Historical background and development of CGE Models

The key advances in general equilibrium modelling are due to Arrow & Debreu (1954) who proved the existence of a market clearing general equilibrium, to Johansen (1960) who solved a model to produce an equilibrium solution, to Scarf (1967) who developed an algorithm to compute a Walrasian general equilibrium solution and to Jorgenson (1984) who first introduced econometrically estimated parameters into CGE models.

The theoretical basis for computable general equilibrium models is derived from the proof of the existence of general equilibrium by Arrow & Debreu (1954) and Debreu (1959). Arrow & Debreu (1954) state two theorems under which they prove that a competitive (Walrasian) equilibrium exists in an economy, although they don't prove the uniqueness or stability of this equilibrium in their paper, these are that:

1. ...every individual has initially some positive quantity of every commodity available for sale...
2. ...if there are some types of labor with the following two properties:
    - ...each individual can supply some positive amount of at least one such type of labor...
    - ...each such type of labor has a positive usefulness in the production of desired commodities...

Debreu (1959) provides a further exposition of the proof of general equilibrium, and notes that modelling the economy in this way requires that in each attainable 'state', the economic actions of agents are compatible, and are compatible also with the total available resources in the economy.

Johansen (1960) produced one of the first attempts to analytically solve a multi-sectoral economic model that had endogenous prices. Johansen's (1960) approach is to take a linearised equilibrium system and solve it by approximating for an equilibrium (Shoven & Whalley 1984). Bergman (2005, p1280) and Shoven & Whalley (1984, p1021) note that Johansen's (1960) approach doesn't adhere to the idea of a Walrasian economy. The reason being that, as Varian (1978, p322) notes, Walras's law rests on the idea that consumers face a budget constraint, which isn't necessitated by Johansen (1960) (see Johansen (1960, p29) for a discussion of the specification of consumer demand in Johansen's (1960) model).

Mitra-Kahn (2008) argues that Johansen's (1960) study "had nothing to do with Arrow and Debreu's notion of general equilibrium" (Mitra-Kahn 2008, p10). His argument is that, since Johansen (1960) formulated his problem as a macro-balancing one and acknowledged that the solution derived needn't be optimal- while not referencing either Arrow & Debreu (1954) or Debreu (1959)- it is clear that Johansen (1960) didn't have Walrasian or Arrow Debreu general equilibrium in mind in formulating his model. This is despite the construction that has later been put on Johansen's (1960) study as being an originator of the CGE modelling approach (Mitra-Kahn 2008, p9). Among those making such a claim for Johansen (1960) is Bergman (2005, p1275).

Mitra-Kahn (2008) argues that the only contribution of Johansen (1960) to the development of CGE models has been that he linked an input-output database with national accounts data and a series of macro balancing equations. Bergman (2005) acknowledges that Johansen (1960) however may have had only a 'flavour' of Walrasian general equilibrium, and rested on 'ad-hoc' assumptions about key prices (on wages and capital) (Bergman 2005, p1280). It seems that Johansen's (1960) claim to be the first CGE model, may be better described as being a claim to be the principle 'forerunner' of modern CGE models.

Scarf (1967) developed an algorithm to compute a Walrasian general equilibrium (Bergman 2005, p1280), which until that point had existed as a purely theoretical framework (Partridge & Rickman 1998, p205). It was this algorithm that was employed by Shoven & Whalley (1984) to construct and solve a CGE model with taxes (see Shoven & Whalley (1992) for more on this). The Shoven & Whalley (1984) model was, in contrast to Johansen (1960), based explicitly on a Walrasian general equilibrium framework (Bergman 2005).

Bergman (2005) notes that there is no precise definition of what a CGE model is, as such. However, CGE models tend to exhibit certain characteristics, for example a multi-sectoral modelling environment based on real world data (Bergman 2005, p1276). Mitra-Kahn (2008, p16), credits Taylor & Black (1974) with developing the first '*post* Johansen (1960)' model in the spirit of Adelman

& Robinson (1975), despite their paper being published in advance of Adelman & Robinson (1975)[7]. He argues that Taylor & Black (1974) was still not a CGE model in the spirit of either Walras or Arrow & Debreu (1954) as it essentially mimicked the Johansen (1960) approach[8].

The argument about which was the 'first' CGE model is not what is important, so much as the evolution of this type of model. It is clear that Johansen (1960) played an important part in the development of this type of model, although it is debatable whether it in fact represents the 'first' CGE model, since it lacks some of the features that are considered crucial to the definition of these models. Deverajan & Robinson (2002) however, argues that Johansen (1960) did indeed develop a CGE model (or an AGE model, since they treat these as synonyms)[9].

Another major contribution to the development of CGE modelling is due to Jorgenson (1984), who introduced econometric parameter estimates into the CGE model, which had until then relied mostly on parameter estimates derived in other ways. We discuss the specification of key parameters and the calibration process in more detail later in this chapter.

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[7] This discrepancy is explained by Mitra-Kahn (2008) by claiming that Taylor & Black (1974) had early access to the Adelman & Robinson (1975) paper.

[8] That being said, Mitra-Kahn (2008) later contradicts himself by suggesting that Taylor & Black (1974) represents one of the first CGE models. Either Johansen (1960) uses a CGE model, and thus Taylor & Black (1974) also uses a CGE model or neither of these papers do, since they are in the strictest sense not CGE models but macro balancing models. The truth is perhaps more complicated, with Johansen (1960) preceding and being used as a building block for what is now called a CGE model. This conclusion finds some support from Mitra-Kahn's (2008) note that the term 'CGE model' wasn't in circulation as late as 1974, and the admission by Adelman & Robinson (1975) that they: "took [their] inspiration from the early work on price endogenous planning models by L. Johansen" (Adelman & Robinson 1975, p3), quoted in Mitra-Kahn (2008).

[9] It is noted by Mitra-Kahn (2008) that little attention is now paid in the literature to differences between *computable* and *applied* general equilibrium models (CGE and AGE models). Mitra-Kahn (2008) argues that they are different, in particular that AGE models were based on the notion of Arrow & Debreu (1954) general equilibrium, and were developed using Scarf's (1967) algorithm for finding the Arrow & Debreu (1954) general equilibrium. This approach being first operationalised by Shoven & Whalley (1972, 1973). Mitra-Kahn (2008) classes models in the tradition of Johansen (1960) as macro balancing 'CGE' models, while models using Scarf's (1967) algorithm to solve for Arrow & Debreu (1954) general equilibrium are AGE models. He also suggests that the merging of the CGE and AGE terminology happened in the 1980's with the increased use of these classes of model in policy analysis. In effect, as he argues, AGE modelling was absorbed into CGE modelling, but the only aspects of AGE modelling to remain are the language and rhetoric of AGE models, being joined with the macro balancing focus of Johansen (1960) type models.

4.4 Features of a typical single region CGE model

In this section we adopt a modified version of the structure of Partridge & Rickman's (1998) seminal review of regional CGE models to outline a 'typical' regional CGE model. This is similar to the approach of Bergman (1988) in that we present a 'standard' model to illustrate the general framework before discussing departures from this 'standard' specification. The production/output dimension (i.e. the specification of the production function) is discussed first, followed by a discussion of the role of private (household) demands and public (government) demand, this is then followed by a discussion of the specification of factor markets.

The final two sections deal with the specification of the product market, and model parameterisation and solution. I add here three other sections, one addressing the role of external demand (i.e. export demand), one addressing the specification of the core database on which CGE models are built, which is the basis of Section 4.4.2, and another, discussing the specification of dynamics in CGE models, which is where we begin.

4.4.1 CGE model dynamics

Before discussing the details of particular aspects of the CGE model it is worth briefly noting the distinction between 'dynamic', 'recursive dynamic' and 'static' CGE models. This section focuses on the broader issue of dynamics in CGE models. Partridge & Rickman (2010) address and review the specific issue of regional dynamics in CGE models covering both the myopic/forward looking agent issue, and the issue of whether to specify a steady state path or simply assume an initial steady state[10] (Partridge & Rickman 2010, p1316). CGE models have historically used a 'comparative statics' basis (Gilmartin 2010) where

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[10] Partridge & Rickman (2010) describe this approach thus: "The most common approach to producing a baseline projection has been that of specifying values for the state variables to produce a steady-state path... A policy shock then causes the economy to diverge from the baseline steady-state path, such that the differences between the new variable levels and the steady-state levels represent the policy effects" (Partridge & Rickman 2010, p1316).

the impact of economic change on the base case is assessed without including recursive dynamic or dynamic effects.

Recursive dynamic effects involve the specification of a series of stock-flow relationships in the CGE model so that, for example, investment and population changes in one period are linked to the stock of similar variables in the period before, and the endogenously determined desired level. In addition, agents are assumed to be myopic (Bergman 2005, p1277). These kinds of recursive dynamic updating relationships have been used in a range of CGE models, including the AMOS model that has been used extensively for economic analyses in Scotland. In recent versions of AMOS, for example, (which originated in the work of (Harrigan et al. 1991)), population and the capital stock adjust according to recursive dynamic relationships. In the case of population, net migration is modelled as a function of differences in the real wage, the lagged real wage and lagged population differences.

Fully dynamic CGE models in contrast, model all agents as being forward looking at all time periods which requires that the model is solved for all time periods simultaneously (Bergman 2005, p1277). An example in the literature of this type of model is Bröcker & Korzhenevych (2011). In Bröcker & Korzhenevych (2011) the evolution of the capital stock in each period is determined by real gross investment less the depreciated capital. In order to prevent what Bröcker & Korzhenevych (2011) describe as 'implausible' jumps in the capital stock, they also specify quadratic adjustment costs.

Before reviewing a couple of papers which look at the implications of different dynamic specifications for environmental CGE models, it is worth noting a study undertaken recently using the AMOS framework (a variant of the model that is used in this study) which looked at this issue. This paper, Lecca et al. (2011a), examined the implications for the model results of assuming a myopic versus forward looking specification in the presence of a pure demand shock. Lecca et al. (2011a) conclude that in a properly specified[11] regional CGE model, the

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[11] This refers to the absence of a binding balance of payment constraint, which would typically be included in a national CGE model, and the recognition in the modelling of sav-

specification of the model dynamics makes little difference, and no difference in the long run (Lecca et al. 2011a); we should emphasise that Lecca et al. (2011a) compares the myopic and forward looking specifications of the same model with the same quadratic adjustment costs.

The adjustment of the model to the long-run equilibrium does vary between the two specifications, but in each case the adjustment path is particularly sensitive to a certain parameter. In the myopic case the transition is sensitive to the speed of adjustment parameter that is assumed, while in the forward looking case the transition is sensitive to the inter-temporal elasticity of substitution parameter. This is not the case in the long-run in a regional CGE model which has a supply constraint (Lecca et al. 2011a).

An interesting environmental CGE study in the context of model dynamics is Babiker et al. (2009), where both a recursive dynamic and fully dynamic CGE model specification are used to examine climate policy issues. Their model, called the MIT Emissions Prediction and Policy Analysis (EPPA) model, was traditionally a recursive dynamic model, but was made fully dynamic to allow better consideration of some aspects of environmental policy, e.g., the borrowing and banking of emissions credits. Using a fully dynamic model, the important role played by intertemporal decision making with environmental regulation is shown to be crucial for the estimates of the cost of environmental policies. Intuitively, where the model is fully dynamic the optimal, least cost, compliance path can be determined and used by agents who have perfect foresight[12].

A recursive dynamic model with myopic agents does not reach the same least cost abatement strategy. Meanwhile in other areas, for example the energy sector itself and the emissions 'price', the distinction between fully dynamic and recursive dynamic models is shown not to be important. Babiker et al. (2009)

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ing/investment decisions that the economy being studied is a regional and not a national economy.

[12] There is a related issue here which arises in the use of CGE models for this type of analysis; namely that these models determine the economically optimal outcome given the information known at that point (either perfect information in the forward looking case, or imperfect information in the myopic case). It is not necessarily the case that the economically optimal route and the actual route to achieving a particular outcome are the same.

for instance show that following a similar exogenous change, the “GHG emission path from the recursive model is very similar to the forward-looking one...” (Babiker et al. 2009, p1352). This would suggest that where the environmental CGE model is being used to help understanding the macroeconomic costs of particular changes in policy, using a fully dynamic model is going to be important. In other analyses where the focus is on the evolution of energy demand, or emissions, the specification of the model as fully dynamic is likely to be of lesser importance.

Again, intuitively, the assumption of forward looking agents allows these agents to minimise their costs compared to the myopic case, while the regime (permits, taxes, etc) ensures that the emissions reduction is made in either case. It may well be the case, for instance, that the cost minimising method of reducing emissions by a certain amount over a given period involves little abatement activity in the first few periods (offset by using borrowed permits from future periods), and polluting less in later periods. In the myopic case the agent is unable accurately to forecast changes in compliance costs (for instance) and thus cannot optimally make a pollute/abate decision in each period. This means that they are unable perfectly to offset the most costly abatement activity using the permit, and thus their costs are higher than in the perfect foresight case.

In our model, we make certain assumptions about conditions in the short run and long run cases, for instance we impose a fixed population and capital stock in period 1 (corresponding to the short run case). We will discuss these further later on in this chapter.

4.4.2 Database

The database on which CGE models are built is called a social accounting matrix (SAM). The SAM is a balanced income-expenditure matrix for the territory of interest in the year of interest. A key component of the SAM is the input-output database outlined in Chapter 2. The schematic in Figure 4.1, taken from Telli et al. (2007) gives an overview of the components of a typical SAM. See Miller & Blair (2009, Chapter 11) for a fuller exposition of the SAM framework.

The SAM national accounting representation is a more complete representation of national income/expenditure than that in an input-output database, indeed this is the principle extension of the input-output framework (Miller & Blair 2009). The SAM, for example, shows the transfers between businesses and households, between government and domestic businesses etc, and expands to encompass details on the labour market (wages and salaries), taxation, welfare transfers etc (Miller & Blair 2009, 500). The focus in the SAM is on capturing and representing all monetary transactions between institutions, in addition to the input output database which captures industry and commodity flows (Miller & Blair 2009, 500).

In Figure 4.1 the columns denote expenditures while the rows denote income flows. This works in a similar way to the input-output database that we outlined in Chapter 2, where the columns referred to sectoral purchases (expenditures) and the rows referred to sectoral sales (income). In Figure 4.1 the use matrix from the input-output accounts is called 'intermediate inputs' while the make matrix is marked 'domestic supply'. Final demand is also shown individually for each category of final demand.

4.4.3 Production/output

The production structure within the CGE model is perhaps its most important element. There are a number of different ways of specifying the production relationship in a CGE model, the most commonly used method is by nesting a series of production relationships with each other in order to capture all the potential substitution possibilities in the most appropriate manner. A key decision to be made is the choice of functional form at each level of the nested production function.

The three most common are the Leontief, constant elasticity of substitution (CES) and Cobb-Douglas (CD). In addition, there is the so-called flexible

Figure 4.1: Schematic (Aggregated) Social Accounting Matrix from Telli et al. (2007)

			Factors						**Capital account**				
	Activities	Commodities	Labor	Capital	Households	Enterprises	Social Sec. Inst.	Government	Domestic Banks	Private Investment	Public Investment	ROW	Total Receipts
Activities		Domestic Supply										Exports	Total Sales Revenue
Commodities	Intermediate Inputs				Private Consumption			Government Consumption		Private Investment	Public Investment		Domestic Absorption
Labor	Wages												Labor Income
Capital	Operating Surplus + Depreciation												Capital Income
Households			Labor Income			Distributed Profits (Net)	Social Security Expenditures	Transfers to Households	Distributed Profits (Net)			Remittances	Private Income
Enterprises				Capital Income				Transfers to Enterprises				Private For Transfers	Corporate Income
Social Sec. Inst.			Soc. Security Premiums					Transfers to Soc Sec Institutions					Social Security Income
Government	Net Indirect Taxes on Production	Sales Taxes (VAT) + Tariffs			Direct Tax + Non-Tax Rev +Wealth Taxes	Pub. Sector Factor Income + Corporate Taxes							Public Income
Domestic Banks					Private savings			Interest Paym on Dom Debt				Foreign Resources	Banking Sector Funds
Private Investment									Private Investment				Private Investment
Public Investment								Public savings	(Pub I-Pub S)				Public Investment
Rest of the World		Imports						Foreign Interest Payments on Ext Pub. Debt	Foreign Interest Payments on Ext Priv. Debt				For. Exch. Earnings
Total Expenditures	Production Costs	Aggregate Absorption	Labor Costs	Capital Expenditures	Private HH Expenditures	Corporate Expenditures	Social Security Expenditures	Public Expenditures	Banking Sector Use of Funds	Private Investment	Public Investment	For. Exch. Expenses	

functional form (FFF) approach. The two most common FFFs, as Diewert & Wales (1987) note, are the generalized Leontief (Diewert 1971) and the translog (Christensen et al. 1971, 1973, Sargan 1971). Helpfully, Varian (1978, p209-210) has a textbook exposition of these particular functional forms.

First, let us briefly outline the three most common forms (Leontief, CES and CD). The Leontief and CD functions can each be considered (at least in theory) as a special case of the CES form, hence we focus here on the CES functional form. The CES production function takes the form, following Varian (1978):

$$y = [a_1 x_1^{\rho} + a_2 x_2^{\rho}]^{\frac{1}{\rho}} \tag{4.1}$$

The CES function is linear where $\rho = 1$ (i.e. Equation 4.1 reduces to $y = x_1 + x_2$, as Varian (1978) shows as ρ approaches zero the CES function approximates a CD function (where $\rho = 0$ the function $\rightarrow \infty$ and is undefined), and when $\rho \rightarrow -\infty$ the function approaches the Leontief form. This can easily be seen by calculating the elasticity of substitution from Equation 4.1, which is:

$$\sigma = \frac{d\ ln\ \frac{x_2}{x_1}}{d\ ln\ |TRS|} = \frac{1}{1-\rho} \tag{4.2}$$

Plugging in values for ρ from above, linear $\Rightarrow \rho = 1$, CD $\Rightarrow \rho \rightarrow 0$, Leontief $\Rightarrow \rho \rightarrow -\infty$, we can see what happens to the elasticity of substitution. Now, we turn to the flexible functional form specifications, starting with the generalised Leontief specification. What Varian (1978) refers to as the Diewert (1971) cost function is what is generally thought of as the generalised Leontief cost function, and takes the form, following (Varian 1978, p209):

$$c(\mathbf{w}, y) = y \left[\sum_{i=1}^{k} b_{ii} w_i + \sum_{i \neq j} \sum_{j \neq i} b_{ij} \sqrt{w_i w_j} \right] \tag{4.3}$$

Individual factor demands in the generalised Leontief form are given by:

$$x_i(\mathbf{w}, y) = y \sum_{j=1}^{k} b_{ij} \sqrt{w_j / w_i} \tag{4.4}$$

The advantage of the generalised Leontief structure or translog specification, as opposed to say the CES or CD specification, is that there are no restrictions on the elasticities between factors (Varian 1978), and as Bergman (2005, p1285) notes if the FFF is not used then nesting is imposed and elasticities are generally "guesstimated". The translog cost function meanwhile, following (Varian 1978), can be represented as:

$$log\ c\left(\mathbf{w}, y\right) = a_0 + \sum_{i=1}^{k} a_i\ log\ w_i + \frac{1}{2}\sum_{i=1}^{k}\sum_{j=1}^{k} b_{ij}\ log\ w_i\ log\ w_j + log\ y \tag{4.5}$$

Where the following restrictions must be met: $\sum_{i=1}^{k} a_i = 1$, $b_{ij} = b_{ji}$ and $\sum_{j=1}^{k} b_{ij} = 0$. This functional form is CD where $a_i > 1$ and $b_{ij} = 0\ \forall\ i, j$. Factor shares are then given by:

$$s_i\left(\mathbf{w}, y\right) = a_i + \sum_{j=1}^{k} b_{ij}\ ln\ w_i \tag{4.6}$$

As Lecca et al. (2011b) makes clear, the adoption of more flexible functional forms, as opposed to CES-type functional forms, will likely "boil down to a trade off between flexibility and tractability" (Lecca et al. 2011b, p2833). The downside of the flexible functional form approach is that elasticities of substitution need to be specified between each pair of goods. This is a demanding econometric exercise and in practice usually requires the imposition of many elasticities rather than full econometric estimation. The advantage of this approach though is that it is possible to investigate the sensitivity of the model results to the elasticity between each pair of goods.

Varian (1978, p81-93) also discusses the issue of the primal v. dual representation of the cost function. The issue is whether given a particular production technology (i.e. production function), we solve the cost minimisation problem to derive the cost function (the primal approach), or whether we reverse this process and solve for the technology from the cost function (the dual approach).

Varian (1978, p89) explains this nicely using a geometric representation to show that the curvatures of the isocost and isoquant curves are inversely related. For our purposes, this issue is largely unimportant, except to note that some CGE models approach this issue in different ways. In the AMOSEVI model we outline later, we solve directly for cost minimisation from the specified production function.

Having outlined how elasticities of substitution between inputs can be specified in this model, it is worth outlining a more detailed specification of the production structure, in which these elasticities of substitution play a part. In order to do this we utilise the outline provided by Conrad (2002). Following Conrad (2002) we can specify the cost function of a particular sector (j), where p_n is the price of intermediate input n and p_k and p_l are the price of capital and labour, as:

$$C_j(x_j; p_1, ..., p_n, p_k, p_l) \tag{4.7}$$

assuming marginal cost pricing and CRTS we get a system which we can solve for the n prices $p_1, ..., p_n$:

$$p_j = MC_j(p_1, p_2, ..., p_n, p_k, p_l) \;\; for\ j = 1, ..., n \tag{4.8}$$

which via an application of Shephard's lemma produces a set of output coefficients as:

$$\frac{x_{ij}}{x_j} = a_{ij}\left(\frac{p_j}{p_i}, \sigma, t\right) \;\; for\ i = 1, ..., n+2, j = 1, ..., n \tag{4.9}$$

Here we can see that the input demands are a function of relative prices p_j/p_i, as well as the elasticity of substitution between these inputs σ and technical change (represented in Conrad (2002, p1063) by t). Supply can then be introduced, where FD represents final demand, as:

$$x_i = \sum_{j=1}^{n} x_{ij} + FD_i \; for \; i = 1, ..., n \tag{4.10}$$

Note that Equation 4.10 looks very similar to the input-output Equation 2.1 introduced earlier, and that x_{ij} in Equation 4.10 can be replaced, drawing on Equation 4.9 as:

$$x_i = a_{ij}\left(\frac{p_j}{p_i}, \sigma, t\right).x_j + FD_i \; for \; i = 1, ..., n \tag{4.11}$$

Equation 4.11 can then be solved to determine the output of each sector j. As Conrad (2002, p1063) notes, this system then needs to be built upon by adding factor market equations (capital and labour primarily), as well as a representation of household/government behaviour, and by incorporating a model of trade. These are the issues that we now address.

4.4.4 Private demands

One of the main advantages that CGE modelling methods provide over input-output type modelling is that household income and expenditure can explicitly, and in line with theory, be linked in the CGE model (Conrad 2002, p1062). In the CGE model, households purchase locally produced and imported goods and services, and receive income by selling their labour, and owning capital. Type II input-output models and SAM models incorporate households, but do so under stronger assumptions than the CGE model[13], and only provide an estimate of the long run impact of any economic change.

There are several issues raised by the nature of household income in a regional CGE model. Capital owned by residents in a region, may be located far outside the region, in other words, the income that households derive through the capital rental, may not be as a result of investment within the region. Sim-

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[13] Although, as we noted earlier, McGregor et al. (1996) proved that in the long run, in the face of a pure demand shock (i.e. with no supply constraints) the input-output and regional CGE model produce almost identical results.

ilarly, households purchases of capital goods may be purchases of 'foreign' capital. This means that investment by households which are located in the region may not increase that region's capital stock for instance. In the case of labour income, labour income earned in the region may be accrued to commuters not resident in that region[14].

Partridge & Rickman (1998) note two ways that this has been dealt with in CGE models. One is by specifying a direct correspondence between regional factor ownership and regional factor usage (see Jones & Whalley (1989, p371)), another approach is to adjust household income so it reflects place of residence rather than place of employment (see Rickman (1992)). The former approach, almost mechanically, ensures that factor supplies and factor ownership in the region balance, while the latter approach addresses the problem of factor income leakage, for instance payments to labour accruing to a non-resident, but does not make the same strong assumption about the relationship between, say, labour supply and household income (Partridge & Rickman 1998). Another approach, also noted by Partridge & Rickman (1998), is simply to incorporate interregional factor ownership into the model.

A more fundamental issue is how saving is incorporated into the model. Partridge & Rickman (1998) noted that at that time, many models simply omitted savings and investment entirely, while others, such as Li & Rose (1995) endogenised saving by linking it to investment, and Kraybill et al. (1992) aggregated saving and specified investment as a exogenous process. Other papers, for instance Lisenkova et al. (2010), have specified investment as being independent of savings by following a Tobin's Q type approach (Lisenkova et al. 2010). This is the approach that is usually taken, including in this paper, when using the AMOS family of CGE models[15].

Perhaps the most important aspect of private demands in a CGE frame-

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[14] The labour income adjustment is somewhat easier to address than any capital income adjustment, because of the availability of commuting data.

[15] One issue which does arise in regards to capital income in a number of CGE models, including the one we use here, is that while domestic residents can accumulate foreign capital, and indeed do so in these models, they do not then accumulate ongoing capital receipts from the ownership of this capital.

work is the specification of the household utility function. The most common specifications of household utility are constant elasticity of substitution (CES) and Cobb-Douglas (CD) which impose homotheticity[16], other utility function specifications used (e.g. Stone-Geary) do not impose homotheticity (Partridge & Rickman 1998, p212). Just as the production function in CGE models can take advantage of a multi-level nesting structure with different elasticities of substitution between nested components, so too can the utility function (Partridge & Rickman 1998, p212). This admits of the potential for a different elasticity of substitution between energy and non-energy goods, or imported and domestically produced goods in the utility function.

4.4.5 Government

There are a range of different specifications for government demand used in regional CGE models. One issue that has to be addressed in a regional model is whether regional government demand in the region will be treated separately to national government demand in the region. Thereafter, it must be determined how government (or governments) demand is determined: one option is simply to specify it exogenously[17], another approach would be to endogenously link it to household demand, i.e. to take government expenditure as a function of household demands.

There are more elaborate specifications of government final demand in regional CGE model, particularly so in models which examine fiscal policy issues. Jones & Whalley (1989) in their CGE model for Canada, specify the federal government as an optimising agent which maximises its expected utility subject to its budget constraint (Jones & Whalley 1989, 374). It collects taxes, provides transfers to households and the regional government, as well as purchasing

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[16] The imposition of homotheticity refers to the property of a utility function, for example, which means that the relative composition of the consumption bundle selected depends only on the ratio of the relative prices of different goods (see Varian (1978, p146-152)). That is to say, all goods have unitary income elasticity.

[17] One argument for exogenously specifying government final demand is where government final demand cannot be disaggregated into regional government and national government final demand in the region (Partridge & Rickman 1998, p213).

locally produced and imported goods, but it does not produce anything itself. The regional government in their model only provides lump sum transfers to households, but like a production sector it requires inputs.

In some models regional government is treated as a linear function of consumer spending- if so the distribution of government expenditure is unresponsive to changes in the size of government spending (Partridge & Rickman 1998, p213). In other words, irrespective of the size of government consumption, it is treated as consuming the same combination of goods and services. Other models, for instance Berck et al. (1996), specify a very detailed level of government where revenue from specific taxes are explicitly modelled and this revenue is then linked to specific government expenditures.

4.4.6 External demands

There are different means of specifying external demand in a CGE model. As Conrad (2002, p1074) notes single region/country CGE models usually use a small open economy framework, implying that the 'home' country is unable to affect world prices and therefore that this effect can be ignored (Conrad 2002, p1074). The starting point for incorporating trade into a CGE model might be thought to be a model based on traditional trade theory, however as we will soon see, this proves unsatisfactory.

Bergman (2005) notes that the natural starting point for the modelling of trade in a CGE model is the general equilibrium Heckscher-Ohlin model of international trade (see Markusen et al. (1995, p98-126) for a textbook exposition of this trade theory). This model predicts that countries will specialise in producing and exporting goods which require significant inputs of those factors (land, labour, capital) of production in which they are abundant. The important aspects of this theory of trade for a small open economy are constant returns to scale with price taking producers in the home country.

The implications of this theory of trade produce stark results for the predicted patterns of trade. For example, as Bergman (2005) notes, if there are n goods and m factors of production where n>m, equilibrium output will - according to this theory -only be positive in a maximum of m sectors (Bergman 2005, p1290)[18]. This means that, depending upon relative factor abundance in the small open economy, a sector may go from being an important producer in the domestic economy, to being eliminated as a result of this model of trade. Similarly, absent sectors may suddenly become important domestic producers as a result of this approach to modelling trade. Bergman (2005) refers to this problem as the 'overspecialization' problem.

The most common approach to modelling international trade in CGE models uses the so-called Armington assumption (Armington 1969, Conrad 2002, Bergman 2005). This involves modelling traded goods as imperfect substitutes for the equivalent domestically produced good, which as Bergman (2005) notes, amounts to including a CES composite of domestically produced and imported goods in the CGE model with an elasticity of substitution greater than 1.

In this way the relative price of domestic and imported products becomes the factor which determines the strength of imports of a given product, which as Bergman (2005) shows "implies that the price of the domestically consumed composite of a given type of goods is a linearly homogeneous function of the prices of imported and domestically produced goods of that type" (Bergman 2005, p1290FN). One issue that does arise in the use of the Armington assumption is that "the current pattern... of product differentiation... [is] assumed to persist" (Bergman 2005, p1291). The difficulty that this creates is in fully understanding the structural changes that might follow in the long run from a change in relative prices, in other words, the Armington assumption might underestimate the reallocation of production following changes in relative prices where the goods are indeed homogeneous as opposed to imperfect substitutes.

A recent paper, Zhai (2008), introduced a different approach to modelling trade in a CGE model environment. Zhai (2008) noted that while the Armington (1969) approach allowed CGE model to incorporate national product

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[18] To see this, note that full factor specialisation would predict that all quantities of a particular factor would be used in the industry in which they were most (relatively) productive.

differentiation, and therefore incorporated the idea of an *intensive* margin[19], it did not incorporate the so-called *extensive* margin effect. Using the Melitz (2003) model, the trade model that first incorporated the extensive margin, Zhai (2008) shows how the extensive margin can be built into CGE models. This allows changes in the composition of exports, based on the ability of firms in different sectors to meet this export demand, to be reflected in the model results. This better aligns the model, theoretically at least, with the observation that not all firms who can export, do export.

4.4.7 Factor markets

Factors in this context mean labour and capital, but in some cases this category also includes energy and land. There are two crucial issues that have to be considered in modelling factor markets. The first is the nature of competition in these markets, and the second is the degree of factor mobility in the model. Factor markets, at least historically, were generally taken to be perfectly competitive (Partridge & Rickman 1998) with firms and workers assumed to be price takers. A range of different assumptions about the degree of labour and capital mobility have been utilised in regional CGE models (Partridge & Rickman 1998, p214, 216). Partridge & Rickman (1998) argue that the key issue in deciding the extent of labour and capital mobility is the period of analysis being considered.

A short run analysis might be compatible with immobile factor assumptions, this would be consistent with the Marshallian view that the short run was the period during which at least some factors of production are fixed. However, even in the longer term, there may be different degrees of inter-regional and intersectoral factor mobility. Perfect factor mobility will ensure that the price of these factors is equalised across sectors and regions (for instance in the case of labour that the real wage is equalised across regions). Factor immobility raises

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[19] The *intensive* and *extensive* margins are well defined by Chaney (2008): “When transportation costs vary, not only does each exporter change the size of its exports (the intensive margin), but the set of exporters varies as well (the extensive margin)” (Chaney 2008, p1707).

the prospect of differential factor returns in the model (Partridge & Rickman 1998, p214).

As Partridge & Rickman (2010) notes the issue with the assumption of immobile labour is that it is “inconsistent with [the] empirical evidence” (Partridge & Rickman 2010, p1316). Different approaches to the issue of determining the degree of labour mobility have included McGregor et al. (1995*b*) who used econometrically estimated net migration flows and Trela & Whalley (1986) who used a measure of the ‘intensity of locational preference’ as the basis for estimating the immobility of labour.

However as Partridge & Rickman (2010) notes while the number of studies incorporating a labour market characterised by something less than perfectly mobile labour are few, those that do tend to retain the assumptions of homogeneous labour which is perfectly mobile in the long run (Partridge & Rickman 2010, p1317). Exceptions include, for example, Deepak et al. (2001) which allows for two labour ‘types’. The advantage of assuming that labour is not homogeneous is that it allows you to examine issues surrounding the distribution of labour income and differential responses/impacts of different ‘types’ of labour (Partridge & Rickman 2010, p1317).

The importance of the assumption of homogeneous labour on the model results will, of course, depend upon the issue being examined. Partridge & Rickman (1998, p233) note the only study at that time to have compared the accuracy of different regional labour market closures was Rickman & Treyz (1993), who found that econometrically estimated labour market parameters outperformed ‘extreme’ labour market closures imposed based on theoretical views of the labour market.

In terms of modelling capital markets, Partridge & Rickman (2010, p1320) notes that in the single region case, since “capital and savings are not linked at the small region level, savings can be omitted” (Partridge & Rickman 2010, p1370). This allows the capital stock to be adjusted, or more properly updated, according to the gap between the supply and demand for capital on the basis of a specified responsiveness parameter, this implicitly require a recursive dynamic setting.

Holland (2010) makes a similar argument to Partridge & Rickman (2010) that linking saving and investment at the regional level may not be sensible, noting specifically that: “Clearly, financial capital is totally mobile across regional boundaries” (Holland 2010, p443). Given interregional capital mobility, both in the sense of capital in and outflows to the region, the imposition of a regional savings-investment constraint seems unrealistic.

4.4.8 Product markets

In the same way as the degree of competition in the factor markets needed to be specified by the modeller, so does the degree of competition in the product market. Regional CGE models historically tended to assume perfect competition in the product market, this means that price equals marginal revenue and is independent of sectoral output, and that there are zero profits in the long run; with margins providing the only reason for a divergence between production costs and consumer prices (Partridge & Rickman 1998, p215)[20]. One important aspect to the competitiveness of the product market is the extent to which imports are considered to be good substitutes for domestically produced inputs. This is where the Armington (1969) assumption, which we discussed in detail above, is often used.

4.4.9 Parameterization and solution

The database for CGE models, discussed in Section 4.4.2, is typically for a single year and thus represents a ‘snapshot’ of the economy in question in that year. Given the specified equations and structural relationships in the model, some parameters are calculated to ensure that the model recreated this base period data. This process is known as calibration and it is acknowledged to be

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[20] Gilmartin (2010, p233) discusses the practical difficulties of developing CGE models that incorporate imperfect competition.

a 'contentious' aspect of CGE modelling (Partridge & Rickman 2010, p1317). This is where those parameters not provided by the data or specified by the modeller[21] (as, for instance, the elasticities of substitution usually are) are determined. These calibrated parameters are required to ensure that the model replicates the base period economic data.

Whether or not elasticities of substitution need to be imposed or calculated depends upon the production structure adopted. If a CD specification is used, the exponents from Equation 4.1 are given by the expenditure shares from the underlying input-output or SAM database. If a CES specification is used, the elasticities need to be imposed by the modeller. In the case of a FFF specification, both expenditure shares from the database and elasticities of substitution between each pair of products is required (Partridge & Rickman 1998, p218).

After imposing the required parameters, the model can be solved to produce estimates of the missing parameters. The calibrated parameters are specified to ensure that the model recreates the base period data. This is the first test of the model. At this point simulation work can proceed and the results of a simulation compared to the base case. It is then straightforward to calculate the proportional change in each macroeconomic variable from the base value.

Bergman (2005, p1278) notes that a "lack of data usually prohibits econometric estimation of key supply and demand parameters" (Bergman 2005, p1278)[22]. But nonetheless, Bergman (2005) argues that even if parameter estimates are guesstimated and as a result are uncertain, the CGE modelling approach is still valuable in uncovering general equilibrium effects (Bergman 2005, p1279). In addition, Bergman (2005) notes that sensitivity analysis allows the analyst to understand the impact of these parameters on key outcomes, and therefore an understanding of the importance of these parameters in determining the principle conclusions of the study.

Figure 4.2 below, taken from Greenaway et al. (1993), is a useful way of

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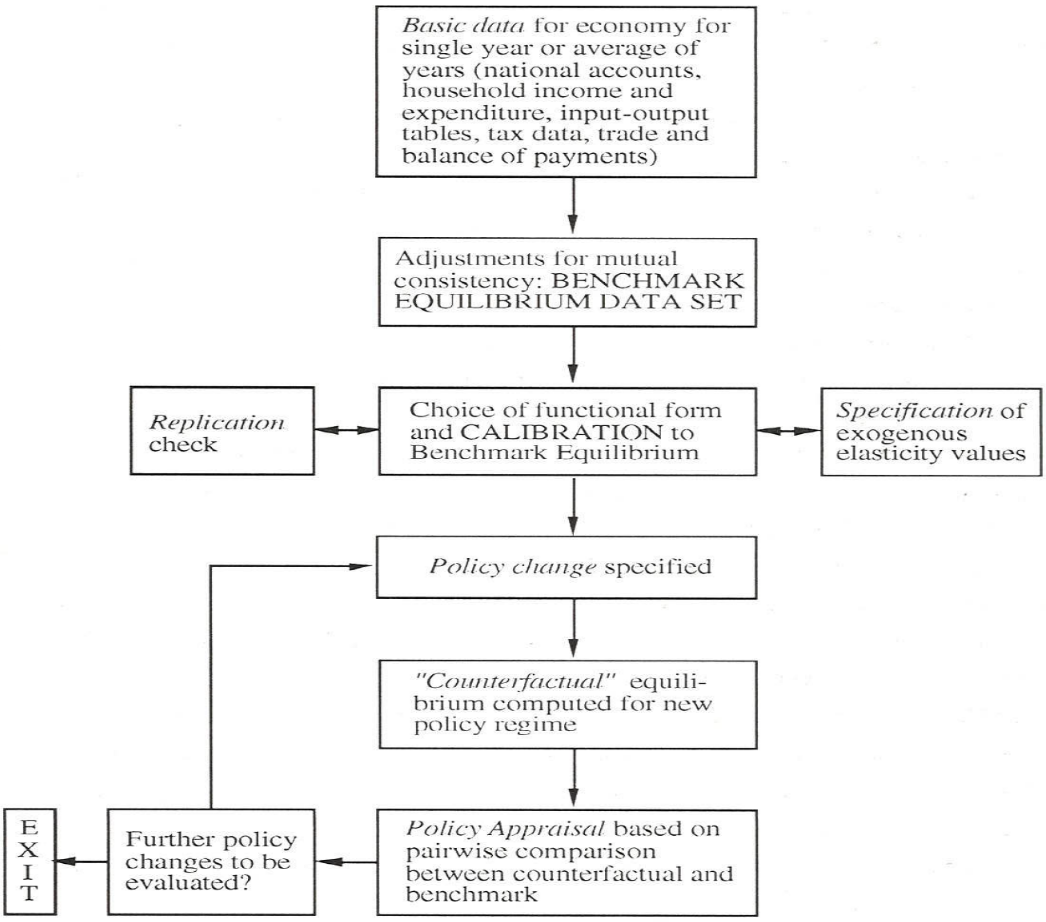
[21] These are usually the result of either econometric estimation or best guess estimates.

[22] Notable exceptions which do utilise econometric methods to estimate these parameters include Adkins et al. (2003) and Arndt et al. (2002).

thinking about the modelling approach that is usually taken when using a CGE model. We begin with a set of base year data for the economy of interest which is adjusted into a SAM framework which inputs into the calibration process. The calibration process allows us to establish the calibrated parameters so that our model recreates the base year outcomes, given the specified exogenous parameters. This results in the replication check where we compare the calibrated model results to the original model data.

Having satisfied ourselves that the model that we have specified is properly calibrated, we can proceed to specify the exogenous policy change that we wish to analyse. We can then use the model to produce a counter factual policy evaluation, so that we can compare our model results *with* the policy to the base case *without* the policy. This analysis allows the appraisal of the impacts of this policy. Having done so, alternative policies may be evaluated, or the same policy evaluated with different exogenous parameters, as part of a 'sensitivity' analysis, which we discuss in the next section.

Figure 4.2: Schematic of CGE modelling approach from Greenaway et al. (1993)



4.4.10 Sensitivity analysis

It is now an accepted aspect of CGE analysis that the sensitivity of the results obtained to the parameters that are "guesstimated" and imposed needs to be examined. Partridge & Rickman (1998) encouraged the development in the literature that followed a more systematic approach to the sensitivity analysis of CGE model results. As they point out, "it is [often] unclear whether the particular combination of elasticity values are biased towards some outcome" (Partridge & Rickman 1998, p231). In order to fully understand the impact of the imposed elasticities, Partridge & Rickman (1998) advocate the development of unconditional sensitivity analysis, in order that all possible combinations of elasticity values, and their impact on the model results, are understood.

Partridge & Rickman (1998, p231) discuss examples of unconditional sensitivity analysis in the literature including McGregor et al. (1996) who adopted the approach of Harrison & Vinod (1992) and Harrison et al. (1993). Random draws from specified distributions are made for each parameter and applied to the CGE model to generate estimates of the endogenous variables. This approach allows the modeller to create a distribution for the endogenous variables.

Another approach noted by Partridge & Rickman (1998, p231) is Li & Rose (1995) who used GAMS (General Algebraic Modeling System) to generate a series of random number estimates of key parameters within specified ranges. These parameter estimates are then used in the CGE model, the model solved, and the results compared to the base case.

The final approach to the sensitivity analysis of CGE models noted by Partridge & Rickman (1998, p231) is Pagan & Shannon (1985). Pagan & Shannon (1985) detail different measures of the sensitivity of CGE models, each based on two simple pieces of information: the derivative of output with respect to the coefficient of interest, and a measure of the uncertainty of estimated parameters. Pagan & Shannon (1985) also discuss the merits of each measure for examining sensitivity within particular CGE models.

4.5 Literature review

In this section we begin by reviewing regional CGE models. We then review the literature on environmental CGE models, focusing specifically on regional environmental CGE models. Following Ferguson et al. (2005) we note the presence of a number of global CGE models, e.g. Burniaux et al. (1992), Rutherford (1992), Whalley & Wigle (1992), but restrict ourselves here to regional (more localised) impacts, and the local contribution to global emissions. There are a number of excellent review articles on regional CGE models which go into much more detail than is possible here. These review articles include Robinson et al. (1999) who focus on building a CGE model; Kraybill (1993), Partridge & Rickman (1998, 2010) who cover regional and/or national CGE models, and Conrad (2002) and Bergman (2005) who review environmental CGE models. Rickman (2010) also provides a useful discussion of the role of regional CGE models in the context of 'modern' macroeconomics and regional economic modelling, with suggestions to improve the usefulness of regional CGE models.

There is also an extensive literature reviewing applications of CGE models in different fields. For instance, Shoven & Whalley (1984) for taxation issues, Pereira & Shoven (1988) for dynamic taxation issues, De Melo (1988) and De Melo & Robinson (1989) for trade analysis issues, Bandara (1991) and Robinson et al. (1999) for development issues. Menezes et al. (2006) list a number of regional CGE applications, organised by different attributes (e.g. production functions used).

4.5.1 Regional CGE models

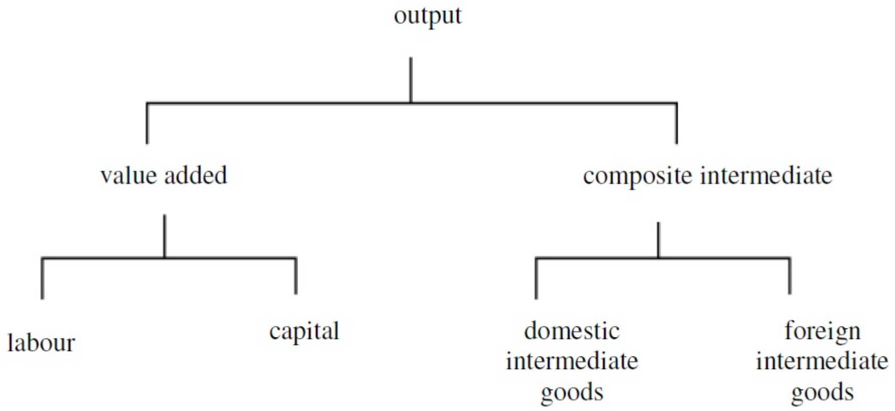
The seminal review paper on regional CGE models is Partridge & Rickman (1998). This paper has since been updated, and a second review article published (Partridge & Rickman 2010). Some of the issues raised in their earlier paper have now been overtaken by developments in the literature, and where these have occurred we will focus on the more recent literature. We discuss these review papers, and other contributions in the literature, below. We focus on methodological developments rather than on different applications. However the interested reader is referred to Partridge & Rickman's two review papers for details of specific applications. In addition, note that while we focus here on regional CGE models, as Partridge & Rickman (1998) state, regional CGE models are constructed in a similar way to national level CGE models (Partridge & Rickman 1998, p207); although there are some differences in approach, e.g. in the nesting of production functions.

At the time that Partridge & Rickman (1998) was written, national models were generally less disaggregated than regional models; as a result it was more common to use nested production functions in regional CGE models. Partridge & Rickman (1998) discussed a number of uses for these nests. Generally, at that time, in one nest materials and value added were combined to make output, while in lower order nests intermediate goods were combined, and these intermediates goods were themselves specified as a function of another nest which combined domestically produced intermediates with imported intermediates (more on the issue of imports in a moment). Value added was also, generally, specified as the product of a nest or series of nests combining different forms of value added (labour, capital, etc...) (Partridge & Rickman 1998, p209).

To see how this works in practice, Figure 4.3 shows a simple representation of a nested production structure, taken from Gilmartin (2010). In this diagram there are three nests over two levels. The nests are best read from the bottom to the top. The first nest combines labour and capital to produce value added. This can be combined using different production technologies, for instance fixed proportion (Leontief), Cobb Douglas or CES technologies. Similarly, domestic and imported intermediates are combined using a specified production technology to produce an intermediate composite good at this level.

The second nest is where value added and a composite intermediate are combined using a specified production technology to produce sectoral output. In this way there are three different nests, each of which can use a different production technology to produce the composite good, and which can also include combining domestic and imported goods. The real advantage of using different nests is therefore that it allows different elasticities of substitution to be used between different goods, or composite goods (Jones & Whalley 1989, p373).

Figure 4.3: A simple 2 level production nest structure from Gilmartin (2010, p18)



Moving to the specification of trade in these models, Partridge & Rickman (1998) discusses different ways that trade has been recognised in regional CGE models. Given the increased openness to trade of a region compared to a nation, the appropriate treatment of trade is important for regional CGE models. Regional CGE models often utilise a CES function for trade, i.e. the Armington assumption (Armington 1969), which treats imports as imperfect substitutes for domestically produced inputs. Intermediate imports from different regions and or countries are generally combined to create a composite import which is an imperfect substitute for domestic intermediate production (Partridge & Rickman 1998, p209).

The exact specification of the production technology at the level of each of these nests is a matter for the individual modeller, although Partridge & Rickman (1998) note that Leontief, CES, or Cobb-Douglas specifications are commonly used, with flexible functional forms less common (Partridge & Rickman 1998, p209). This scope for the adoption of different specifications allows for a combination of fixed coefficients (the Leontief case) and more flexible price responsive demand specifications. For a detailed sectoral breakdown however, Leontief production structures are often used to address the problem of the prevalence of zero entries.

Regional CGE models are now widely used in economic impact analyses and other economic studies. Some of these include: Kilkenny (1998) who looked at the implications of 'New Economic Geography' using a CGE model, McGregor et al. (1995*a*) who looked at the role of the value of local amenities using a CGE model, Conrad & Heng (2002) who looked at the impact on economic growth of public infrastructure, and Deepak et al. (2001) who assessed the role of public policy in reducing bottlenecks to boost regional growth. There are far too many regional CGE application to review these in detail. However as noted earlier, Partridge & Rickman (1998, 2010) provide excellent reviews of this literature.

4.5.2 Environmental CGE models

Most environmental CGE models are used to evaluate the impact of particular environmental policies. This means that certain features are included within these models which would not typically be incorporated within more conventional CGE models. The most obvious of these features is the explicit and elaborate treatment of energy supply and demand (Bergman 2005, p1283). While, as we will outline below, our analysis uses an 'environmental' CGE model, the principle extension of the conventional CGE model on which it is based is a more detailed disaggregation of the energy sector.

The extensions made to traditional CGE models that are used to analyse environmental policy issues is an interesting and important topic. While the analysis here focuses on the environmental impacts of economic change, the logical next steps in this investigation would involve the use of a CGE model with a yet more elaborate environmental dimension, for instance a renewable/non-renewable electricity specification, or environmental taxes. We discuss the model specification used in this analysis later in this Chapter. First though we review the literature on environmental CGE models. We restrict ourselves to single country/region CGE models for the most part in this section. Papers such as Bergman (2005) discuss multi-country environmental CGE models in more detail.

The first CGE model to incorporate an environmental externality was Mäler (1974) who based it on an extended version of the public good model of Samuelson (1954). In order to focus on its environmental elements, the model was initially presented (in Chapter 2 of his book) with certain aspects (for instance capital accumulation) ignored or assumed away, with these assumptions later relaxed (Mäler 1974). The production function had as inputs: energy, labour, intermediates, raw materials and a 'residual' input (discussed and defined further below). The key features of this model were: price taking profit maximising producers, an 'environmental management agency' which would seek to maximise the net benefit according to a stated 'environmental interaction function', and consumers who seek to maximise their utility (over a consumption and environmental good) given their budget constraint.

Crucially, however, while 'environmental quality' is important in this model, it does not affect the production possibilities, and is modelled as a public good affecting all consumers equally. In Mäler's (1974) model production is partitioned into 'regular' goods and 'residual' goods, the latter being perhaps more commonly considered 'waste', 'wastage' or 'production discharge'[23]. This residual is then discharged into the environment altering environmental quality.

This environmental residual is assumed to have a negative price, with consumers or producers needing to make a payment for the disposal of this residual. This also opens the possibility of paying consumers or producers to dispose of this residual. Mäler (1974) though, raise the possibility that given a sufficient increase in demand for a regular good to which this residual is an input, producers themselves may *want* to pay for this residual in order to meet demand for their output.

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[23] Mäler (1974) leaves open the possibility that this waste residual can be negative for individual sectors, but cannot be negative in sum across all sectors. Essentially this allows for the possibility that more of this waste residual is recovered in a particular sector than is generated by that sector. An example of this might be where a sector can recover embodied wastage in their inputs (i.e. embodied wastage) as well as those generated in their use of that input.

In this model, there is a vector Y which describes environmental quality, the value of the elements of Y are chosen by the models 'environmental management agency'. This agency then uses an 'environmental interaction function' to determine the level of environmental quality to deliver. This function, to determine the optimal value of Y, takes the existing level of environmental quality Y_0 as given, and is decreasing in the volume of 'residual' discharge (z), and increase in environmental improvements (e), which it purchases from the production sectors.

The environmental management agency then produces a price (q) for consumers and producers to pay for the discharge of 'residuals'. In addition to which, consumers are assumed to pay a charge to the environment agency for their share of the public good (environmental quality, Y), the charge reflects the value the consumer places on this environmental quality, and therefore varies across consumers. From this, the environmental management agency derive their revenue from penalising residual discharges and charging for environmental quality. Its costs are equal to P^Te (i.e. price of environmental improvements x the quantity of environmental improvements).

This gives the agency the role of maximising the following, where δ is the demand price for environmental quality-i.e. summed across consumers, and F^1 and F^2 are functions relating quantities of environmental goods and residual discharge to environmental quality:

$$\begin{aligned} Net\ income = q^Tz + \delta^TY - p^Te \\ s.t. \\ Y = Y_0 - F^1z + F^2e \\ e, z \geqq 0 \end{aligned} \tag{4.12}$$

The net revenue of this environmental agency is then remitted to each consumer in equal amounts, and in this sense the environment 'belongs' to these consumers in this model. Mäler (1974) then rests his proof of an equilibrium on making it compatible with the general equilibrium approach of Arrow-Debreu. Mäler (1974, p97-104) proves analytically the existence of a unique equilibrium for this model. Mäler (1974) then used this model to evaluate different environment/economy issues[24].

Bergman (1988) produced a review of general equilibrium approaches to modeling energy policy issues. After outlining their own energy CGE model, Bergman (1988) reviews different, and more elaborate, treatments of energy demand in CGE models. These include the models of Hudson & Jorgenson (1974), a revised version of Johansen (1960), and Bergman (1986), which we briefly summarise here.

Hudson & Jorgenson (1974) presented a two-stage production model which, in the first stage, combined primary inputs with an energy and non-energy composite. The second stage of the model determined the energy and non-energy content of each of these composites. This model was then linked to a macro-economic model to provide constraints on key macroeconomic variables (e.g. consumption and investment). A similar structure for production was used in the updated version of Johansen (1960) which Bergman (1988) reported was in use at that time by the 'Central Bureau of Statistics' in Norway.

The model outlined in Bergman (1986) was constructed to examine the macroeconomic impact of exogenous oil price shocks, and incorporated agents with both fixed and adaptive expectations. In the fixed expectation case, agents do not expect any changes in oil prices while in the adaptive expectations case, agents expectations are a function of current oil prices. The model has different 'vintages' of production technology which have different energy input requirements. In this way changes in the oil price affect the unit cost function which in turn determine which technology vintage is used and the required investment.

For a more elaborate treatment of energy supply, Bergman (1988) reviews the approach of Manne (1977) which he argues was the basis for Jorgenson

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[24] Mäler (1974) was the forerunner of this class of models which include an explicit environmental welfare function with pollution abatement.

(1982) and Lundgren (1985). It is worth noting that Bergman (1988) prefaces his discussion of these studies by noting that: “for most analyses in which a CGE model might be used, there is no need to give the energy supply side more elaborate treatment” (Bergman 1988, p394). Only where there is an intention to introduce, or there already are in place, energy supply constraints, or where there is an expected technology shift in energy production, would this type of modelling be needed. In other words, only where there is expected to be changes in the energy supply sectors which cannot be represented through ‘parameter changes’ in the standard sectoral technology specifications is a more elaborate treatment needed.

Where the research problem requires the inclusion of an energy supply change which cannot be modelled through a change in a parameter in the standard sectoral production technology, an alternative approach is needed. The way that the three models that Bergman (1988) reviews introduce a more detailed energy supply treatment is by using a ‘process-analysis’ model for the energy sector alongside a macro model for the non-energy sector (there is only one sector in the macro models used in these three applications).

The earliest CGE models to look at a climate policy issue were Burniaux et al. (1992) and Bergman (1991), however, we focus on reviewing Bergman (1991), as Burniaux et al. (1992) outlines a global environmental general equilibrium model, whereas our focus here is on single region environmental general equilibrium models.

Bergman (1991) introduces a CGE model with a market for tradable pollution permits to examine the impact of reductions in SO_x, NO_x and CO_2. Bergman’s (1991) starting point is that the most popular approach at that time to estimating the impact (in terms of cost) of pollution reduction, was using a partial equilibrium approach. The appropriateness of a partial equilibrium modelling approach depends on whether the pollution abatement measure being considered has general equilibrium effects (Bergman 1991, p43). Using Swedish data Bergman (2005) demonstrates that when considering significant emissions abatement, a *general* equilibrium framework is more appropriate than a *partial* equilibrium framework.

Bergman (1991) is a static CGE model, but it is worth noting that the same author later argued (Bergman 2005) that, "environmental CGE models should be dynamic or at least quasi-dynamic[25]" Bergman (2005, p1283-84). Bergman (1991) develops his environmental CGE model by making the following amendments to the standard CGE model framework:

1. An explicit treatment of emission abatement activity and the inclusion of a market for pollution permits.

2. Distinguishing between old and new technologies in certain sectors (this operates through some sectors having no substitutability in their input mix (i.e. have Leontief technology) and others having elasticities of substitution which are based on guesstimates).

3. Allowing for a different treatments of trade in different sectors (i.e. in some the sector is a price taker and in others they are not).

In determining the specification of the production side of his model, Bergman (1991) uses the same Leontief-CES production structure in all sectors, although he employs different elasticities in different sectors in all but the base case[26]. Bergman (1991) employs several nests (levels) in his production structure. Electricity and fuels are nested in a composite energy input Q_j[27], which is combined in another nest with capital K_j, the product of this, i.e. $U_j = U_j(Q_j, K_j)$, is then combined with natural resources N in another nest $H_j = H_j(U_j, N_j)$[28].

At a different level again, H_j is combined using a CES function with labour L_j, into $Y_j = Y_j(H_j, L_j)$. This composite Y_j is then combined with the output

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[25] The latter being equivalent to a recursive dynamic specification.

[26] From what was said earlier about the use of 'old' and 'new' technologies based on the substitutability of inputs in certain sectors, it makes sense that the only case in which the elasticities in all sectors are the same is the base case.

[27] This includes imports of fuels, mainly oil according to Bergman (1991).

[28] There are three types of sectors in this model, T sectors which are price takers in international markets, M sectors where domestic producers, collectively, have some influence on trade prices but individually are price takers, and N sectors which are non-traded sectors. Electricity falls into the N sector category.

of the other sectors to produce output- in this model, Bergman (1991) specifies this as a Leontief production relationship (or CES with an elasticity approaching zero).

In relating emissions to production, Bergman (1991) notes that it *may* be the case that pollution could be considered a factor of production and modelled accordingly[29], but is more frequently included into production in two different ways. Emissions can be taken as being proportional to sectoral fuel use, or as being proportional to gross output (Bergman 1991, p46). In Bergman (1991) this is important, because emissions are taken to be proportional to inputs in response to fuel combustion, while emissions associated with industrial processes are taken to be proportional to sectoral output (Bergman 1991, p54).

Conrad (2002) reviews the use of environmental CGE models for policy analysis. He identifies two main uses for these CGE models, the analysis of the implications (costs) of pollution abatement, and an assessment of the welfare implications of changes in environmental policies. The former purpose focuses on quantifying the costs of different approaches to pollution abatement. The latter approach focuses on assessing the welfare implications of alternative approaches to environmental policy. The distinction here is between an assessment of the 'economic costs', and the 'welfare costs'. Conrad (2002) outlines the standard CGE modelling framework then demonstrates how pollution abatement instruments can be incorporated into a CGE model (Conrad 2002, p1070).

Conrad (2002) outlines two ways that the impact on cost of an environmental regulation can be introduced. The first of these approaches is based on incorporating the cost of pollution abatement into the base period model. This is done by inserting a cost share for pollution abatement into each sector's unit cost function, on the basis of which the model is then calibrated. This cost can then be changed or even eliminated from the model and the impact of this cost on the economy can be assessed. Defining λ_i as each sector's abatement cost as

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[29] Bergman (1991) suggests that if pollution was considered a factor of production, it could be modelled using an elasticity of substitution between pollution and e.g. labour or capital (Bergman 1991, p46).

a share of their total cost. This cost share can then be incorporated into the unit cost function, giving:

$$ln\ p_i = ln\ \lambda_i + ln\ c_i(w,t) \tag{4.13}$$

In Equation 4.13, p_i is the unit cost function of sector i, λ is the share of total cost represented by the cost of pollution abatement, and $c_j(w,t)$ is the cost function where w is the price vector of intermediate inputs and t is technological change.

The alternative approach to incorporating an environmental cost, discussed in Conrad (2002), is based on altering the user cost of polluting inputs (for instance fuels). Using Conrad's (2002) notation, we define d to be the ratio of abated to total emissions (this is the actual emissions plus the abated emissions). *c(d)* is the abatement cost per unit of pollution (e.g. the cost of abating a unit of emissions), with *c'(d) >0* and *c"(d) >0.* That is, the cost function is increasing in the proportion of emissions that are abated, and these costs are increasing at an increasing rate.

If we define the user cost of a fuel input to be:

$$\tilde{w}_F = w_F + w_M \cdot c(d) \cdot d \cdot e \tag{4.14}$$

w_F is the price of the fuel input, w_M is the cost of the abatement technology used, d and *c(d)* are as defined above, and e is pollution per unit of fuel input. The cost of the fuel input is now $\tilde{w}_F$ which comprises the original cost of the fuel input, w_F, and the cost of achieving the degree of abatement required per unit of fuel use. An environmental policy mandating emissions abatement in response to fuel use can now easily be incorporated into the structure of a CGE model. This allows an assessment of the economy wide impacts of the change in the price of fuel inputs, as a result of the implementation of a given pollution abatement policy.

Conrad (2002) also shows how an emissions tax can be incorporated into

Equation 4.14:

$$\tilde{w}_F = w_F + w_M \cdot c(d) \cdot d \cdot e + t(l - d) \cdot e \tag{4.15}$$

t here is a tax per unit of pollution *(e)*. In the case where there is no abatement technology available (or in use) then $d = 0$, and Equation 4.15 reduces to:

$$\tilde{w}_F = w_F + t \cdot e \tag{4.16}$$

Equation 4.15 is a useful means of considering the decision facing firms in this type of framework. It may be that firms are required to meet a certain level of abatement d, in which case they must pay a price for that fuel input that incorporates a given minimum level of abatement d and pay tax t on the remaining level of emissions e. However, in a situation where firms do not need to meet a given level of abatement d, then they can choose d themselves. In this case, firms can choose d knowing that those emissions not abated, will accrue a tax t which they will have to pay. Equation 4.15 therefore incorporates both the potential for a government imposed minimum abatement level, and a tax on the remaining emissions, or the ability for firms to fully optimise over their choice of d and e.

It is not always clear in CGE models exactly which forms of abatement are being envisaged. There are a number of different types of emissions reduction which might be considered 'abatement', for instance the application of end of pipe technologies, the work of a pollution cleaning sector, substitution to a less energy intensive production process etc. (Conrad 2002, 1071) thinks about this abatement in two ways, firstly the cost of 'materials or abatement technologies' and secondly through the substitution towards non-energy inputs. In the AMOSENVI model we use here, the easiest way to incorporate such abatement is through increasing the price of energy and stimulating a switch to non-energy inputs; we discuss this again in the future work section of the next chapter.

There are other important issues that can be analysed using an environmental CGE modelling framework, for example Conrad (2002) discusses the usefulness of environmental CGE models to examine what he calls ‘ecological’ tax reform. In other words, broader changes in the economy beyond simply the introduction of an environmental tax. This includes the examination of the potential for a ‘double dividend’ (for instance Conrad & Schmidt (1998)). This would be where the revenue from the introduction of an environmental tax to reduce a ‘bad’ (i.e. pollution), is used to lower distortionary taxation elsewhere in the economy. A good example would be where the environmental taxation revenue is used to reduce labour taxes (Conrad 2002, p1079).

Conrad (2002) outlines 9 different examples of environmental CGE analysis. These are:

1. Assessing the impact on economic growth of environmental regulation (Jorgenson & Wilcoxen 1990).
2. Assessing the impact of oil price increases on environmental outcomes (Jorgenson & Wilcoxen 1993).
3. Assessing the cost effectiveness of CO_2 pollution abatement instruments, for instance pollution permits, including the assessment of non-coordinated and coordinated international and interregional instruments (Conrad & Schmidt 1998).
4. The assessment of the introduction of SO_2 regulations (both coordinated and un-coordinated) in a single region, interregional and international context.
5. Examining the potential for a ‘double dividend’ with environmental taxes (Conrad & Schmidt 1998, Jorgenson & Wilcoxen 1992).
6. Comparing the efficiency of proposed pollution abatement instruments against the current pollution abatement regime (Conrad & Schroder 1993).

7. Assessing the impact on environmental outcomes of trade liberalisation (Beghin et al. 1995).

8. Analysing the relationship between economic growth, trade policies and environmental degradation (Lee & Roland-Holst 1997, Beghin et al. 1996).

9. Looking at the costs and benefits[30] of different sectoral technologies being adopted, for instance pesticides and fertilisers in the agriculture sector, on environmental quality and welfare (Hrubovcak et al. 1990).

Just as Conrad (2002) notes the many uses of environmental CGE models for the evaluation of environment/economy issues, Bergman (2005, p1277) points out that not all environmental problems lend themselves to analysis using CGE models. Specifically, and importantly for our purposes, he makes clear that only where it is expected that the pollutant in question has, or is expected to have, *general equilibrium* effects, in terms of the costs of CO_2, should the CGE framework be adopted. A category into which Bergman (2005) places "climate change" problems, although he notes that one difficulty with the use of CGE models for climate policy issues, is that these issues are largely driven by the stock of pollution, rather than the flow, and therefore the analysis of climate issues in a CGE framework requires an 'elaborate treatment' of the market for energy inputs.

An additional, and often overlooked issue, in environmental CGE analysis is the time horizon of the analysis. The appropriate time-horizon for understanding the impact of climate policy issues is likely longer than it may be for a standard economic policy analysis (Bergman 2005). One consequence of this, is that it must be acknowledged that this long time horizon may encompass significant changes in the polluting technology and in the pollution abatement technology (Bergman 2005, p1283). One problem therefore with analyses of en-

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[30] One point which Bergman (2005, p1283) and Bergman (2005, p1288-89) raise about the use of CGE models for this kind of analysis is that many of the benefits that accrue following an improvement in environmental conditions, are not explicitly measured in a CGE modelling framework. An analysis of this type of issue requires the adaptation of the CGE model to calculate these effects and impacts separately.

vironmental issues using traditional CGE models is that they are, for the most part, unable to account for this technological progress. Bergman (2005) notes that one way that environmental CGE models have attempted to incorporate this phenomenon is by introducing 'autonomous energy efficiency improvements' into the production function[31].

In addition to reviewing and raising a number of critical issues in the design of CGE model for environmental analysis, Bergman (2005) also outlines a different approach to extending the traditional CGE framework than Conrad (2002). Bergman (2005) begins[32] by arguing that in order to properly examine climate policy issues in a CGE framework we must distinguish "fossil fuel intensive sectors as separate production sectors" (Bergman 2005, p1284)[33] Bergman (2005, p1285-1286), in contrast to Conrad (2002), begins his extension of the traditional (economic) CGE model at an earlier stage of the modelling process by making clear that environmental and energy issues should be distinguished in the production structure itself. The production structure, he argues, must be extended in the following manner:

$$X_j = f_j(K_j, L_j, M_j, F_j, E_j) \tag{4.17}$$

In Equation 4.17, X is output, K is capital, L is labour, M is materials (non-energy intermediate inputs), F is fuel inputs and E is electricity inputs. This kind of production structure is typically referred to as a KLEM production function (Capital (K), Labour (L), Energy (i.e. fuels and electricity) (E) and Materials (M)). The KLEM structure has been discussed and used extensively in the literature, see for example Klein (1978), Chang (1994) and Rose & Chen (1991).

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[31] This has been done previously using the AMOS model.

[32] Bergman (2005, p1291-95) also discusses a number of the issues that arise in global externality CGE models which we do not cover here given our focus on single region models.

[33] In addition, he notes that it may be useful to make a distinction between models with "bottom up" technology representations. These are models which separately identify each stage of the fossil fuel production process (extraction, conversion, transportation etc.). This would seem more appropriate/important where an energy sector specific policy was being implemented, rather than the environmental impacts of economic change being assessed.

The paper by Lecca et al. (2011b) provides a useful study of the implications of different production structures in the context of environmental CGE models. In Lecca et al. (2011b) alternative production structures are compared. In one specification energy is combined with capital in one nesting level, then combined with labour at another nesting level to create a value-added composite. In another specification energy is treated simply as an intermediate input.

Simulations of a *pure* demand shock show that where energy enters the production structure has important implications for the model results. Lecca et al. (2011b) argues that these results demonstrate the need to consider alternative production specifications, just as it is normal to consider the sensitivity of the imposed exogenous parameters in a CGE model. A different, but related, issue arises with the specification of the production structure, a point raised by Partridge & Rickman (1998), which is the decision about which functional form the production function should use, i.e. CES, CD, Leontief or a FFF. Partridge & Rickman (1998, p228) notes that a FFF might be more appropriate for modelling the energy sector.

4.6 Strengths and weaknesses of CGE Models

In this section we review the key strengths and weaknesses of the CGE model approach. Bergman (2005) summarised the appropriateness of using a CGE model in an analysis well when he noted that “[t]he usefulness of a carefully designed and implemented CGE model depends on what it is intended for and what the alternatives are” (Bergman 2005, p1278-79). The purpose of this section is to review some of the often discussed strengths and weaknesses of the CGE modelling framework. These strengths and weaknesses will be of a general nature, rather than focusing on the appropriateness of the CGE modelling framework for the analysis in this chapter. In a later section of this chapter we will argue the appropriateness of the modelling environment used in this study with direct reference to the strengths and weaknesses of the approach we have taken and the alternatives available.

This section has been written though, in acknowledgment of the argument of Partridge & Rickman (1998) that: "[s]ince policy makers continue to demand both qualitative and quantitative regional analysis, regional CGE models should be evaluated against their alternatives" Partridge & Rickman (1998, p206). With this in mind, we begin with a review of the strengths of CGE models for economic and environmental policy evaluation, followed by a discussion of their weaknesses.

4.6.1 Strengths

The main strengths of CGE modelling relate to the database and the specification of key equations of the model (Conrad 2002). The SAM database on which CGE models are based typically has a number of sectors identified. This allows the modeller to select the appropriate sectoral disaggregation for the analysis, subject to the limitations of the CGE model. As Greenaway et al. (1993, p84) make clear, this is very useful when a modeller wants to further investigate the impact of a particular policy or change on a given sector (Gilmartin 2010, p50). In our case here, we started with 67 sectors for consistency with the environmental accounts. We aggregated this up to 25 sectors for compatibility with AMOSENVI, but ensured that we left important environmental sectors disaggregated.

In addition, CGE models have the flexibility to consider disaggregated types of final demand. One useful application of separating out a category of final demand is in examining issues of inequality. This could be achieved, for example, by separating household final demand by income group. This allows each group to be considered separately, a potentially valuable addition to the analysis being undertaken.

Perhaps the biggest strength of CGE model, as compared say with econometric estimation, is the micro-foundations of CGE models (Greenaway et al. 1993, Gilmartin 2010). What do we mean by micro-foundations? Essentially we mean that we specify equations for the behaviour of government, firms and agents in the economy, which determine the behaviour of the model. The degree of optimisation in the model is determined by the model specification, but even when the model does not fully optimise all agents actions, agents behaviour is consistent with theory and determined via a market mechanism.

The flexibility of the CGE modelling framework, in terms of the range of different specifications for the behaviour of agents and markets, the ability to vary key elasticities in the model or the ability to consider different functional forms, is also an advantage. It provides a straightforward means of evaluating alternative scenarios in a transparent manner (Gilmartin 2010).

This is particularly obvious in terms of the assumptions that underpin the analysis. Greenaway et al. (1993, p83) note a number of studies which demonstrate the importance of the key assumptions that the modeller has made for the model results. It also allows unusual results to be 'unpicked' to assess what is underpinning the particular result (Greenaway et al. 1993, p81).

In assessing the impact of economic change the CGE modelling approach, as distinct from partial equilibrium approaches, allows consideration of the complex interdependencies and feedback effects in the economy (Greenaway et al. 1993, p82). This is particularly valuable in the context of assessing the welfare impact of proposed policies.

Greenaway et al. (1993) note that the potential to analyse, and decompose the welfare impacts of a proposed policy (which also raises the prospect of how these can be offset) is "probably the most distinctive and valuable feature of CGE modelling" (Greenaway et al. 1993, p86). As Gilmartin (2010, p51) notes this also extends to the consideration of 'policy packages' which involve the use of multiple policy levers. This would allow the calculation, for instance, of the increase in one tax that would be required to offset a reduction in another tax while keeping total tax revenue constant.

To summarise: the key strengths of CGE modelling are the micro-foundations, the disaggregated nature of the analysis, the flexibility and transparency of the analysis, the ease with which particular assumptions/specifications can be altered to understand their impacts on the key results, and the ability to consider the whole range of impacts of proposed policies or changes- extending the analysis beyond the partial equilibrium analysis- and capturing feedback and economic interdependencies in the economy.

4.6.2 Weaknesses

There are some areas in which CGE models are not as strong as other modelling environments. The purpose of this section is to review the key weaknesses of CGE models. These weaknesses can be grouped into the following main themes: spatial dimension, econometric estimation, model assumptions and model evaluation. In this section we take each of these themes in turn, but first we cover a couple of conceptual issues that are considered to be weaknesses of this approach.

These are firstly that the economy is assumed in the base period to be in a long run equilibrium. Conceptually this is a necessary starting point, but there is often little reason to believe that the base year of the SAM represents such an equilibrium- or as Partridge & Rickman (1998, p228) note that it reflects the 'normal' economic structure. Further, the assumption means that all markets must be in equilibrium at that point which is hardly realistic (Conrad 2002, p1084)[34].

CGE models have traditionally ignored the spatial dimension or at most, had a limited treatment of spatial issues (Bergman 2005, p1284), although this has started to change with the development of spatial CGE models (see Thissen et al. (2011) for an application of this type of model) which try to build in specific spatial issues, typically transportation costs.

While some CGE models now incorporate econometrically estimated elasticities of substitution, and other key parameters, this is not always the case.

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[34] This assumption is not unique to CGE modelling, and is also found in input-output and social accounting matrix modelling.

The issue, which is particularly acute in terms of regional CGE models, is the availability of a sufficient time series of data to enable econometric estimates to be obtained (Bergman 2005, p1278). In these cases, parameters are often found in the literature or from other studies for neighbouring/similar areas and used in the model. This is not ideal, but a comprehensive sensitivity analysis allows the researcher to explore the impact of different parameters on the model output.

Conrad (2002) notes that where yearly input-output tables are available, econometric estimation of key parameters can be undertaken (Conrad 2002, p28). The difficulty at the moment in doing this for Scotland is that while yearly input-output tables are produced by the Scottish Government, there are at present only 10 consecutive years of data available. In addition to which, in the case of environmental CGE parameter estimates, the energy sectors are quite highly aggregated within these input-output tables which makes estimation of the elasticity of substitution between different energy types difficult.

CGE models are also criticised because of the calibration process that is essential to their use. This is where those parameters that are not specified from the raw data or by the modeller, are determined as a consequence of the structural equations of the model. An useful review paper on this is Mansur & Whalley (1984).

One of the areas where more work is needed, is in developing different means of evaluating CGE models. To take an example, it may well be that different model specifications produce different assessments of the impact of a particular policy on regional output. The difficulty is that, unlike in econometric estimates, there are no diagnostics for CGE models. There are no CGE parallels to the R^2, F statistics, and Durbin Watson statistics which are used to evaluate different econometric models. In addition, part of the difficulty with the imposition of key parameters is that doing so "...excludes statistics tests of their quality..." (Conrad 2002, p1084).

One theoretical consideration is that, as we discussed earlier in this chapter, it is possible for there to be multiple equilibria. We assume when we generate a long run equilibrium using our model that it is unique. This is an issue addressed by Greenaway et al. (1993, p88) who note that there has been no evidence of such a phenomenon in practice when using what are known as 'well behaved' functional forms. A related issue, is the "...limited usefulness of a comparison between two equilibria in the long run" (Conrad 2002, p1084). The reason being that the long run is often too long a time period to provide a useful inference for policymaking.

We do not discuss how we can improve/extend CGE models using dynamic stochastic general equilibrium and vector autoregressive methods here, but there is an excellent review paper which does (Rickman 2010). This section has attempted to sketch out the main strengths and weaknesses of CGE models. In a later section we discuss the appropriateness of the modelling approach undertaken in the analysis in this chapter. Before doing so, we outline previous applications of the AMOS and AMOSENVI framework we use in this analysis.

4.7 Environmental applications of AMOS and AMOSENVI

The AMOS and AMOSENVI models have been used in a variety of environmental analysis. The model itself is outlined in more detail in the Section 4.8. Here we briefly review some applications of the model. The first environmentally extended version of AMOS, called AMOSENVI, was Ferguson et al. (2005) which illustrated a means by which the impact of devolved Scottish policies on 'sustainability' could be tracked. Ferguson et al. (2005) notes the importance in modelling environment-economy interactions of using a multisectoral framework, and of explicitly modelling energy inputs and pollution generation.

In order to address these points Ferguson et al. (2005) adopt a 25 sector disaggregation of the Scottish economy, and link each of the 6 pollutants studied to sectoral output and household consumption. This necessitates the use of a Leontief production function for intermediate input use in AMOSENVI. The simulation strategy is, in the first case, a 2.5% increase in government expenditure and, in the second case, a 7% increase in personal income tax that results in no increase in government expenditure[35].

Ferguson et al. (2005) find that, in the long run, a 2.5% increase in government expenditure increases the various GHGs in Scotland by between over 0.3% to nearly 0.8%. A 7% increase in personal income tax, without a corresponding increase in government expenditure, leads to a long-run decrease in the GHG emissions of between 1.5% and nearly 2%. Ferguson et al. (2005) also consider two, somewhat stark, economic policy changes to achieve a 2.5% decrease in CO_2 emissions.

Ferguson et al. (2005) find that in order to obtain a 2.5%[36] decrease in Scottish CO_2 emissions through expenditure or taxation changes, requires in the long run; either an 8.8% decrease in government expenditure, or a 9.73% increase in the average rate of personal income tax. In order to make these emission reductions in 10 years, Ferguson et al. (2005) find that these expenditure cuts must be increased to 15%, with increases in personal income taxation of 18.15%.

These are stark, and frankly unrealistic, means of obtaining such an emissions cut, however they are offered as illustrative of the sustainability estimates that AMOSENVI can produce. What Ferguson et al. (2005) demonstrate is the potential usefulness of AMOSENVI in assessing the environmental impacts of economic policy. This is one of the papers that we build upon in the analysis in this chapter.

The second environmental application of AMOS we note is a report carried out for the Scottish Government (Allan et al. 2008). This report used the AMOSENVI model to look at the impact on the Scottish economy of a series of supply-side economic changes which might help reduce Scotland's GHG

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[35] Ferguson et al. (2005) note that the most plausible 'real world' explanation for this simulation is an increase in income tax through a mechanism similar to the 'Scottish Variable Rate' that offsets a contraction in the block grant that is provided to the Scottish Government by the UK Parliament under the devolution settlement.

[36] Ferguson et al. (2005) take a 2.5% decrease in Scottish CO_2 emissions as an illustrative case, based on a share of the UK's target of a 20% reduction in CO_2 emissions by 2010.

emissions. These were:

1. Energy efficiency improvements in production
2. Labour productivity improvement
3. Population and demographic change
4. Reductions in household income
5. Switching the balance of energy supply towards renewable sources

It is easy to see how some of these simulations shed light on the potential impact on the economy of policies to reduce GHG emissions; energy efficiency improvements, for instance. However, with an energy efficiency improvement there can be a complication known as the 'rebound' effect, which affects the relationship between energy efficiency improvements and energy demand. For a given improvement in energy efficiency, because agents can do more with less energy input, the implicit price of the energy input will decrease.

This will lead to increased demand for energy by this agent. There are a number of general equilibrium effects that can reinforce or work against this increase in demand for energy. These include, for instance, increased spending on other goods and services which have a high embodied energy content. This can mean that the initial improvement in energy efficiency can lead to a less than expected decrease in energy demand (rebound), or even an increase in energy demand (backfire). For more on the impact of the rebound effect on sustainability and environmental balances, see Hanley et al. (2009).

The reason why a labour productivity improvement would impact upon environmental outcomes, such as GHG emissions, is because improvement in labour productivity would be expected to impact upon firm's input decisions (i.e. between energy and non-energy inputs). If labour becomes more productive, the price of labour in efficiency units will fall, making production less intermediate intensive. What Allan et al. (2008) find is that improvements in labour efficiency lead to an absolute increase in GHG emissions for most sectors.

However, importantly they also find that the emissions intensity of sectoral output decreases in most cases. This is because the labour efficiency improvement increases sectoral output and hence emissions in most sectors in the long run, but sectoral output grows at a greater rate in most cases than GHG emissions. This leads to a reduction in the emissions intensity of sectoral output in most sectors in the long run.

The economic impacts of population and demographic changes, for instance a tightening of the labour market and increases in labour costs, reduce GDP and hence emissions. Allan et al. (2008) find that the 'central case' estimate of a 1.7% lower population by 2050, with a 14.9% decrease in the working age population, and with the labour market characterised by regional wage bargaining; results in GDP falling by 9.3%, demand decreasing by 11.09% for electrical and 8.63% for non-electricity energy, and GHG emissions down by 8.7% by 2050. These simulations are useful in demonstrating the impact of population projections on economic and thus environmental totals. Unlike switching from non-renewable to renewable energy sources, demographic and population changes only affect the environment via their impact on economic activity.

Reductions in household income are introduced into the CGE model in Allan et al. (2008) to simulate increases in the price of energy to households. This could, for instance, stem from the introduction of a household energy levy which increased the price of energy. In order to examine this kind of issue, Allan et al. (2008) introduced a 1% decrease in household income. In the long run they found that this reduced GDP by 1.63%, electrical energy demand by 2.20% and non-electrical energy demand by 1.80%. CO_2 generation decreased in the long run by 1.81%. Again here, this reduction in household income reduces GDP and hence emissions.

The final simulation carried out by Allan et al. (2008) was a change in the balance of energy generation from non-renewable to renewable energy in Scotland. In order to utilise a fuller disaggregation of the energy/electricity sector an input-output approach is used, alongside a more sectorally aggregated

CGE model approach, for this final simulation. The purpose of the CGE analysis is to determine the combination of tax and subsidy that could be applied to the non-renewable and renewable sector respectively, to achieve a rebalancing of Scotland's electricity generation towards increased renewable use.

The authors note that, due to modelling constraints, the exact rebalancing implied by Scottish Government policies was unable to be precisely realised. Overall though, the 'central case' was a taxation in the non-renewable sector equivalent to 36.9% of value added, with a subsidy to the renewable sector of 94.1% of value added. This led to a fall in GDP in the long run of 1.15%, an increase in the price of the non-renewable sector of 28.54%, and a fall in total employment of 1.35%, and an increase in the output of the renewable sector of 92.8% (all results referring to the long-run case). In terms of CO_2 emissions, these simulations imply a reduction of 4.15% in these emissions in the long run.

The extended discussion of this report is given for a number of reasons. Principally it covers a similar area to the work presented in this chapter. Further, the analysis in Allan et al. (2008) uses the AMOSENVI model which is used in this chapter. Given the energy policy focus of Allan et al. (2008), they adopt a sectoral aggregation which makes a distinction between renewable and non-renewable electricity generation. In our analysis, where we focus on the environmental impacts of economic policy, rather than of energy policy, we adopt a sectoral aggregation which reflects both a sensible aggregation of industrial sectors, and a disaggregation of the energy (electricity and non-electricity) sector which allows a sensible linkage of emissions to fuel input use.

The AMOS model has been used with SAMs for other regions, notably Wales (De-Fence et al. 2010) and Jersey (Learmonth et al. 2007), in addition to applications to the Republic of Ireland, the UK, and the Western Isles of Scotland. One environmental application of the AMOS model was De-Fence et al. (2010) who used the AMOS model calibrated on a SAM for Wales in 2003 (the model is referred to in De-Fence et al. (2010) as AMOW (A Micro-macro model Of Wales)). In De-Fence et al. (2010) the analysis is of the environmental impact of a proposed economic change to the Welsh economy using the 'AMOW' CGE model to recreate the input-output database, this is similar to our approach in this Chapter.

To give some background to the analysis using the Welsh CGE model, proposals had been brought forward to expand the Welsh Steel sector. In order to further explore the impact of the proposed £185m investment in this sector, an exogenous final demand shock to the iron and steel sector was introduced. The model was then used to update the input-output database each period following the introduction of the 'shock'. This allowed De-Fence et al. (2010) to calculate, in each period, emissions totals for Wales using the territorial and consumption accounting principles (TAP and CAP).

Wales is an interesting case, as Turner et al. (2011b) show, because unlike studies for the UK or other parts of the UK (for instance the work contained in Chapter 2 of this thesis, or in Druckman et al. (2008)) the estimated consumption based emissions total is lower than the territorial based emissions total. Wales has a very high level of per capita territorial emissions generation. The reason for this is that Wales operates some heavy industry which largely serves external demand.

The proposed investment was to expand an industry which was export intensive. Therefore, while the expansion of this sector would be expected to create certain economic benefits in Wales and therefore impact on Welsh consumption emissions, it was also the case that it was expected to boost domestic production and hence territorial emissions. In the long run, therefore, we would expect both TAP and CAP emissions in Wales to increase. The degree to which the territorial emissions increase compared to the consumption emissions will depend, in the long run, where the results from a CGE model with a demand shock and no supply constraints resembles an input-output result (see McGregor et al. (1996)), on the relative emissions intensity of imports.

De-Fence et al. (2010) carry out a more focused (and arguably more realistic) analysis than we do here, in the sense that they examine the impact of a proposed investment in a particular sector, whereas we examine the impact of general growth in export demand. Our analysis, however, is more elaborate than that carried out by De-Fence et al. (2010) in the sense that we adopt a more flexible production structure, unlike De-Fence et al. (2010) who rely on Leontief production structures because, for data reasons, they needed to link emissions to output and therefore could not change the intermediate input mix. We link most emissions to fuel use, and therefore can adopt the more flexible CES production function for intermediate inputs.

De-Fence et al. (2010) find that the impact of this proposed investment is to increase the Welsh TAP emissions total more than the Welsh CAP emissions total. This raises important issues about the jurisdiction and responsibility for GHG emissions. For instance, the owners of the plants which are expanding are not Welsh, this investment is Foreign Direct Investment (FDI). The emissions are not being generated in Wales to satisfy Welsh consumption, yet, the Welsh Government have responsibility for sustainability -defined in terms of territorial emissions- in Wales.

A further use of the AMOS model is Learmonth et al. (2007), this time calibrated on a SAM for the State of Jersey[37] (and hence renamed JEMENVI in the paper). In contrast to Ferguson et al. (2005), Learmonth et al. (2007) does not have as disaggregated and elaborate a treatment of energy. In Learmonth et al. (2007), the focus is again on the impact of changes in the economy on sustainability indicators, for instance GHG emissions. The main economic 'sustainability' issue for the State of Jersey (hereafter Jersey) is population.

On the one hand, a stable population with strong economic growth might increase wages and hence reduce economic activity (and hence emissions) elsewhere in the economy. On the other hand, increases in population to meet any increase in labour demand stemming from increased economic demand would be expected to impact on wages as well as on environmental outcomes, such

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[37] Jersey is what is known as a Crown Dependency of the United Kingdom, and to all intents and purposes operates with full fiscal autonomy while remaining in a monetary union with the UK.

as GHG emissions. The principle purpose of Learmonth et al. (2007) therefore is to examine the impact of demographic and labour market change on GHG emissions.

JEMENVI uses the economic CGE model to simulate the impact of changes in the labour market, before linking GHG emissions to the output of each sector. Linking emissions to output in this way necessitates, in the CGE model context, the use of intermediate demand characterised by a Leontief production function. The alternative specification would be to link emissions to input use, which would allow the use of a more flexible production function, such as the CES function outlined earlier.

Two sets of simulations were carried out in Learmonth et al. (2007), each under two different specifications of migration. The first set of simulations considered no changes in final demand[38], the second a permanent increase in the export demand of the Finance sector of 50%. In each case two migration specifications were considered, in the first case zero net migration, and in the second case there is net in-migration of 200 people per year between 2001-2011.

Learmonth et al.'s (2007) main findings are that having a more open labour market stimulates economic activity in Jersey, but at the 'cost' of falling wages. When in-migration is combined with a stimulus to the Finance sectors' export demand Learmonth et al. (2007) find that certain sectoral employment tensions arise, as workers in other sectors are drawn into expanding industries/sectors. To the extent therefore that in-migration can help ease the shortages of labour in other sectors, they would be anticipated to be particularly beneficial. Learmonth et al. (2007) also find that increases in the population, through net in-migration, will increase congestion and pollution.

The AMOS model has also existed in an interregional variant as AMOSRUK which is a two region CGE model of Scotland and the rest of the UK (RUK). This model was used by Turner et al. (2012) in an analysis of interregional

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[38] This is not strictly speaking true, as there is an adjustment that is made to keep government expenditure per capita constant, although this is fairly minor in terms of total final demand.

trade balances between Scotland and the RUK. This paper takes the interregional CGE model, calibrated on an interregional SAM for 1999, to examine the pattern of emissions generation, in terms of which type of final demand supports what volume of emissions in the interregional system. Turner et al. (2012) simulate a 10% increase in Rest of the World (ROW) demand for RUK manufacturing.

In order to examine the sensitivity of these results to different labour market specifications, Turner et al. (2012) examine the impacts of this exogenous shock under three different labour market closures: a fixed real wage with no migration, real wage bargaining with no migration, and regional wage bargaining with flow migration. The model is specified with 3 sectors in each region (Manufacturing, Utilities, Services) and the shock is introduced into the model in each specification as a 'step change' in the first period before the model converges to its long-run equilibrium which is enforced at period 75.

Using AMOSRUK Turner et al. (2012) find that, depending upon the labour market specification used, the range of impacts in terms of CO_2 generation in Scotland of this shock is +1.2% (fixed real wage) to -0.65% (real wage bargaining with flow migration). In the RUK the range of impacts is +3.16 (fixed real wage) to +1.22 (real wage bargaining without migration). Turner et al. (2012) conclude that environmentally extended input-output models are the appropriate framework for environmental *accounting* work, but for *modelling* the impact of economic change on the economy and the environment a CGE framework is more appropriate than the input-output framework.

A follow up piece by Cui et al. (2011) used AMOSRUK to look at the implications for emissions in Scotland and the RUK of a permanent improvement in technological progress in Scottish production sectors. The purpose of the study was several fold. In addition to examining the economic impacts of improvements in technological progress, they also wanted to examine the spillover effects in terms of CO_2 emissions between the regions (including issues related to carbon leakage), and also the impact of this productivity improvement on the emissions intensity of production (CO_2 / GDP). In their study Cui et al. (2011) link some emissions to sectoral fuel use, and others (principally emissions related to imports) to sectoral output.

A collection of papers have also used the AMOSENVI model to look at issues related to energy efficiency improvements, and the potential implications for energy efficiency of the so-called ‘rebound’ and ‘backfire’ effects. These papers include Hanley et al. (2006) who looked at the implications for energy demand in Scotland of an improvement in energy efficiency; finding that energy consumption would increase in the face of a uniform 5% improvement in energy efficiency in all sectors, generating further pollution in Scotland. In their analysis Hanley et al. (2006) link emissions generation to the use of fuels at the sectoral level for CO_2 but retain the link between sectoral output and pollution for other pollutants.

Allan et al. (2007) carried out a similar analysis to Hanley et al. (2006), this time looking at the whole of the UK using the UK version of AMOSENVI (UKENVI). They find evidence of a ‘rebound’ effect for energy efficiency improvements of between 30-50%, but no evidence of ‘backfire’, in contrast to Hanley et al. (2006). In other words increases in energy efficiency lead to an overall reduction in energy consumption in the UK, although this reduction is less than would be expected given the implied improvement in energy efficiency. However, it is worth noting though that Allan et al. (2007) admit that their results are sensitive to their model specification.

Turner (2009) followed up the work reported in Allan et al. (2007) by looking at the implications for these rebound effects of disinvestment occurring in the energy sector as a result of the improvements in energy efficiency. For a particular improvement in energy efficiency, papers like Allan et al. (2007) had shown that rebound effects were present and are important in explaining why energy efficiency improvements do not lead to the expected reductions in energy consumption.

What Turner (2009) demonstrated was that the rebound effect can be greater in the short run than in the long run, contrary to the existing literature. In the short run, a fall in demand for energy reduces the price of energy in physical units, which cushions that reduction in demand. However, reduced profitability in the energy supply sectors, due to the falling prices and demand, reduces the return to capital investment in these sectors. This leads to a reduction in the capital stock and therefore capacity in these sectors. The price of energy in physical units then rises, rendering energy demand lower than in the short-run.

Ha et al. (2012) attempts to address one of the biggest weaknesses of the environmental CGE modelling through the econometric estimation of key production elasticities of substitution. These estimates are then used in the UKENVI model to evaluate their implications for the estimated impacts from improvements in energy efficiency. The authors note however that: "...we are most concerned about how much confidence we can have in the econometric estimations presented here..." Ha et al. (2012, p21). This is still work in progress, and the data and estimation issues that are raised in attempting to obtain econometric estimates of these parameters are not insignificant. This in part explains why this type of econometric estimation is not routinely undertaken. Nonetheless, the incorporation of econometrically estimated parameters into CGE models should be welcomed, and is an important area of current research.

4.8 Outline of AMOSENVI model

There are two critical issues to be addressed in extending the AMOS CGE model framework, first outlined in Harrigan et al. (1991), to an environmental analysis; these are how we model energy inputs, and how we specify pollution generation (Ferguson et al. 2005, p107). As Wendner (1999) notes: an"...applied model is useful only to the extent that its structure is appropriate to study the problem in question" (Wendner 1999). With this in mind, the following section will firstly outline how we will ensure the appropriate treatment of energy inputs in our CGE model, before discussing how we will link energy use to emissions generation. In the section that follows, when we outline the simulation strategy that we adopt, we deal in more detail with the other aspects of the model, i.e. the specification of the capital, labour and external markets.

4.8.1 Model overview

We discuss how we model the energy sectors in the next section, and how we link energy use to emissions generation in the following section. In this section we give an overview of the key features of the AMOSENVI model which we use here. This discussion begins with the AMOS model (Harrigan et al. 1991) itself, because as was explained earlier the principle extension between AMOS and AMOSENVI has been the disaggregation of the energy sectors in the production function. Outside of the production function all of the key components of AMOS remain.

Firstly we note that AMOS was conceived as a 'framework' (Harrigan et al. 1991) in the sense that key closures and parameters could be easily varied and changed to examine the impact of different approaches. AMOS as it was conceived was a comparative static model, although this is no longer the case. AMOS and AMOSENVI are now configured to allow for recursive dynamic and fully dynamic analyses.

Product markets are taken to be perfectly competitive in this model (although this need not be the case (Harrigan et al. 1991)). This means that price equals marginal cost in all markets. As we noted earlier in our discussion of the 'duality' problem, CGE models can either solve for cost minimisation (as we do here) or profit maximisation; these are theoretically equivalent.

Factor markets are handled differently. The labour market is linked to the external world through a flow migration relationship. In the labour market different specifications are possible. These include real wage bargaining, fixed real wage, and exogenous nominal wage (this can also be thought of in a regional context as national wage bargaining).

Exports are taken to be imperfectly competitive using the Armington (1969) assumption. This means that Scottish exports are taken to be price sensitive, thus increases in domestic output prices would be expected to choke off export demand. Imports are treated in the same manner, and thus increases in domestic output prices would be expected to lead to an increase in imported goods and services.

4.8.2 Detailed model overview

We begin by outlining the equations which determine prices in the model. $PM_{i,t}$ is the import price of good or service i at time t. This is equal to the exchange rate at time t, ε_t, times the world price of import, PWM_i, multiplied by 1 plus the rate of import tax $MTAX_i$.

$$PM_{i,t} = \varepsilon_t \cdot PWM_{i,t} \cdot (1 + MTAX_i) \tag{4.18}$$

The export price of good i at time t, $PE_{i,t}$ is equal to the exchange rate at time t, ε_t, multiplied by the world price of export i at time t (PWE_i), multiplied by 1 minus the rate of tax/subsidy on exports of good or service i.

$$PE_{i,t} = \varepsilon_t \cdot PWE_i \cdot (1 - TE_i) \tag{4.19}$$

Output price for good or service i at time t, $PX_{i,t}$, is given by the following equation, where $PR_{i,t}$ is the regional price, $PM_{i,t}$ is the price of imports of i at time t, $R_{i,t}$ is the regional supply of good i at time t, and $M_{i,t}$ is the imports of good i at time t.

$$PX_{i,t} = \frac{PR_{i,t} \cdot R_{i,t} + PM_{i,t} \cdot M_{i,t}}{R_{i,t} + M_{i,t}} \tag{4.20}$$

National commodity prices (i.e. Scotland and RUK), $PIR_{j,t}$, are a function of regional intermediate inputs, $VR_{i,j,t}$, the price of regional output, $PR_{i,t}$, RUK intermediate inputs, $VI_{i,j,t}$, and $\overline{PI}_j$, which is the price of RUK output. The final component her is $\sum_i VIR_{i,j,t}$ which is the sum of national intermediate inputs (i.e. Scottish and RUK).

$$PIR_{j,t} = \frac{\sum_i VR_{i,j,t} \cdot PR_{j,t} + \sum_i VI_{i,j,t} \cdot \overline{PI}_j}{\sum_i VIR_{i,j,t}} \tag{4.21}$$

Here we have the price of value added, $PY_{j,t}$, multiplied by the share of value added in production, a_j^Y. This is equal to the price of output, $PX_{j,t}$, multiplied by 1 minus business tax, $btax_j$, minus the rate of production subsidy, sub_j. $\sum_i a_{i,j}^V PX_{j,t}$ here is comprised of the input output coefficient $a_{i,j}^V$ and the commodity price, $PX_{j,t}$.

$$PY_{j,t} \cdot a_j^Y = (PX_{j,t} \cdot (1 - btax_j - sub_j) - \sum_i a_{i,j}^V PX_{i,t}) \tag{4.22}$$

The user cost of capital, UCK_t, is calculated using the capital good price, Pk_t, the interest rate r, and δ the rate of depreciation.

$$UCK_t = Pk_t \cdot (r + \delta) \tag{4.23}$$

Aggregate household consumption price, PC_t is calculated using the share parameter in the household demand function, $\delta_{j,h}^f$, commodity price, $PX_{j,t}$, and the elasticity of substitution between commodities in household consumption σ. Here 'j' indexes sectors and 'h' indexes households by type.

$$PC_t^{1-\sigma^c} = \sum_j \sum_h \delta_{j,h}^f \cdot PX_{j,t}^{1-\sigma^c} \tag{4.24}$$

The aggregate price of government consumption goods, $Pgov_t^{1-\sigma^g}$ is calculated as follows, where δ_j^g is the share parameter in the CES function for government consumption.

$$Pgov_t^{1-\sigma^g} = \sum_j \delta_j^g \cdot PX_{j,t}^{1-\sigma^g} \tag{4.25}$$

We now turn to the equations which determine wages in the model. The first is the calculation of the after tax wage, w_t^b, which is a function of the unified nominal wage w_t, the rate of social security paid by employees ($ssce$), the rate of social security paid by employers ($sscer$), and the rate of income tax ire.

$$w_t = \frac{w_t}{(1 + ssce + sscer) \cdot (1 + ire)} \tag{4.26}$$

There are three labour market specifications which are enabled in this model. These are regional wage bargaining, fixed real wage and national wage bargaining (fixed nominal wage). Regional wage bargaining is based on the work of Blanchflower & Oswald (1995), and models the real wage as a function of β, a calibrated parameter, ε the unemployment elasticity of wage income, and the regional unemployment rate u_t. Intuitively, this makes the real wage an inverse function of the regional unemployment rate. The fixed real wage specification is simply the maintenance in each period of the base period regional real wage through an adjustment in the nominal wage. National wage bargaining can be thought of as an exogenous and fixed nominal wage. The intuition here is that wage bargaining happens at the national level, and regional wages are given as a result of this national bargaining process, and therefore are unresponsive to changes in regional prices.

$$\text{Wage setting} \begin{cases} ln\left[\frac{w_t}{cpi_t}\right] = \beta - \varepsilon \quad ln(u_t) \text{ (Regional wage bargaining)} \\ \frac{w_t}{cpi_t} = \frac{w_{t=0}}{cpi_{t=0}} \quad \text{(Fixed real wage)} \\ w_t = w_{t=0} \quad \text{(Fixed nominal wage)} \end{cases} \tag{4.27}$$

The migration function in our model, following Harris & Todaro (1970), increases migration into the region in response to a real wage and/or unemployment differential between the region being modelled and the migrants' home region/country. The Harris & Todaro (1970) function is parameterised using the work of Jackman et al. (1991). This means that the Jackman et al. (1991)

function takes the form, in our case, of:

$$\ln\left[\frac{m^S}{L^S}\right] = \delta - 0.08.\left[\ln u^S - \ln u^R\right] + 0.06.[\ln\left[\frac{w^S}{cpi^S}\right] - \ln\left[\frac{w^R}{cpi^R}\right]] \tag{4.28}$$

In Equation 4.28 m represents net in-migration to Scotland, L^S is Scotland's population, u is the unemployment rate, and δ is calibrated such that there is zero net migration in equilibrium. The superscripts S and R refer to Scotland and the Rest of the UK (RUK). Equation 4.28 means that net in-migration to Scotland take place where there is an imbalance between the unemployment rates and/or real wages in the two regions.

The rate of return to capital is determined as follows, where $PY_{j,t}$ is the price of value added in sector j, δ_j^k the capital share in the value added function, $A(\xi_{j,t})$ is exogenous technical change in sector j, ϱj is the elasticity of substitution between labour and capital in sector j, and $Y_{j,t}$ is the value added in sector j while $K_{j,t}$ is capital demand in sector j.

$$rk_{j,t} = PY_{j,t} \cdot \delta_j^k \cdot A(\xi_{j,t})^{\varrho j} \cdot \left(\frac{Y_{j,t}}{K_{j,t}}\right)^{1-\varrho j} \tag{4.29}$$

Pk_t, the capital good price, is a function of $PX_{j,t}$, the price of commodity j at time t, and $KM_{i,j}$ the physical capital matrix[39].

$$Pk_t = \frac{\sum_j PX_{j,t} \cdot \sum_i KM_{i,j}}{\sum_i \sum_j KM_{i,j}} \tag{4.30}$$

The next stage is to specify the production technology in use in the model.

The total output of sector i at time t, $X_{i,t}$, is determined as a CES function of value added $Y_{i,t}$ and intermediate inputs $V_{j,t}$. $Y_{i,t}$ is determined- where AY^{ϱ} and AV^{ϱ} are efficiency parameters in the CES functions for value added and

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[39] This is constructed using a cross entropy estimation method.

intermediate inputs respectively- as:

$$Y_{i,t} = \left(AY^{\varrho}.a_i^Y.\frac{PX_{i,t}}{PY_{i,t}} \right)^{\frac{1}{1-\varrho_i}}.X_i \tag{4.31}$$

$V_{j,t}$ is determined as:

$$V_{j,t} = \left(AV_j^{\varrho}.a_j^v.\frac{PX_{j,t}}{PINT_t} \right)^{\frac{1}{1-\varrho_i}}.X_{j,t} \tag{4.32}$$

Where the price of intermediates is:

$$PINT_t^{\varrho} = \sum_i \sum_j a_{i,j}^v.PX_{i,t}^{1-\varrho_i} \tag{4.33}$$

Labour and capital are combined using a CES function to produce value added:

$$Y_{i,t} = A(\xi_{i,t}) \cdot [\delta_i^k \cdot K_{i,t}^{\varrho i} + \delta_i^l \cdot L_{i,t}^{\varrho i}]^{\frac{1}{\varrho i}} \tag{4.34}$$

Labour demand in sector j is determined by:

$$L_{j,t} = \left(A(\xi_{j,t})^{\varrho i} \cdot \delta_j^l \cdot \frac{PY_{j,t}}{w_t} \right)^{\frac{1}{1-\varrho j}} \cdot Y_{j,t} \tag{4.35}$$

Here, $A(\xi_{j,t})$ is as above, δ_j^l is the labour share in the value added function, and $PY_{j,t}$ is the price of value added. We then specify how trade is incorporated in to the model. The following four equations provide the cost minimisation problem which is used to determine the demand function for regional and imported output. Total intermediate inputs, $VV_{i,j,t}$ are determined by:

$$VV_{i,j,t} = \gamma_{i,j}^{vv} \cdot \left[\delta_{i,j}^{vm} VM_{i,t}^{\rho_i^A} + \delta_{i,j}^{vir} VIR_{i,t}^{\rho_i^A} \right]^{\frac{1}{\rho_i^A}} \tag{4.36}$$

Above, $\gamma_{i,j}^{vv}$ is a shift parameter, while $\delta_{i,j}^{vm}$ and $\delta_{i,j}^{vir}$ are share parameters in the CES function for intermediate goods, and ρ_i^A is the elasticity of substitution. ROW intermediate inputs ($VM_{i,j}$), national intermediate inputs (i.e. RUK and

Scot) ($VIR_{i,j}$), and their prices ($PIR_{i,t}$, $PM_{i,t}$) are as defined above.

$$\frac{VM_{i,j,t}}{VIR_{i,j,t}} = \left[\left(\frac{\delta^{vm}_{i,j}}{\delta^{vir}_{i.j}} \right) \cdot \left(\frac{PIR_{i,t}}{PM_{i,t}} \right) \right]^{\frac{1}{1-\rho^A_i}} \tag{4.37}$$

$$VIR_{i,j,t} = \gamma^{vir}_{i,j} \cdot \left[\delta^{vi}_{i,j} VI^{\rho^A_i}_{i,t} + \delta^{vr}_{i,j} VR^{\rho^A_i}_{i,t} \right]^{\frac{1}{\rho^A_i}} \tag{4.38}$$

$$\frac{VR_{i,j,t}}{VI_{i,j,t}} = \left[\left(\frac{\delta^{vr}_{i,j}}{\delta^{vi}_{i.j}} \right) \cdot \left(\frac{PI_{i,t}}{PR_{i,t}} \right) \right]^{\frac{1}{1-\rho^A_i}} \tag{4.39}$$

Total exports, $E_{i,t}$, is defined using an export demand function as follows, where $PE_{i,t}$ and $PR_{i,t}$ are export and regional prices and σ^x_i is the elasticity of export demand with respect to the terms of trade.

$$E_{i,t} = \bar{E}_i \cdot \left(\frac{PE_{i,t}}{PR_{i,t}} \right)^{\sigma^x_i} \tag{4.40}$$

We then specify regional demand (comprised of domestic households, institutions and external demands). Here, $VR_{i,j,t}$ is regional intermediate inputs, $QHR_{i,h,t}$ is regional consumption in sector of origin i for consumption group h, $QVR_{i,t}$ is regional investment by sector i, and $QGR_{i,t}$ is is regional government expenditure.

$$R_{i,t} = \sum_j VR_{i,j,t} + \sum_h QHR_{i,h,t} + QVR_{i,t} + QGR_{i,t} \tag{4.41}$$

Total production is then determined as the sum of regional and export demand.

$$X_{i,t} = R_{i,t} + E_{i,t} \tag{4.42}$$

Household and other domestic institutions behaviour is determined by the following utility function:

$$U = \sum_{t=0}^{\infty} (1+\rho)^{-t} \frac{C_t^{1-\sigma} - 1}{1-\sigma} \tag{4.43}$$

ρ is the rate of consumer time preference, C_t is aggregate household consumption at time t, and σ is the elasticity of marginal utility. In the equation below, PC_t is the price of aggregate consumption at time t, and r is the interest rate. Equation 4.44 gives the optimal path of consumption. This is then distributed among different types of consumption according to the CES function in Equation 4.51.

$$\frac{C_t}{C_{t+1}} = \left[\frac{PC_t \cdot (1+\rho)}{PC_{t+1} \cdot (1+r)} \right]^{-(\frac{1}{\sigma})} \tag{4.44}$$

Total household wealth is given by the following equation.

$$W_t = NFW_t + FW_t \tag{4.45}$$

Non financial wealth (NFW) in period t is a function of NFW in the previous period, dtr_h[40], social security paid by employees (ssce), the income tax rate (ire), labour demand ($L_{j,t}$), the unified nominal wage (w_t), transfers among non governmental institutions ($dnginsp$), government transfers to households (TRG), and household net remittances (REM).

$$\begin{aligned} NFW_t(1+r_t) = NFW_{t+1} + \sum_h dtr_h \cdot (ssce + ire) \cdot \sum_j L_{j,t} \cdot w_t \\ + \sum_h \sum_{dnginsp} TRSF_{h,dnginsp,t} + \sum_h TRG_h \cdot PC_t + \sum_h REM_h \\ \cdot \epsilon_t - \sum_{dnginsp} \sum_h TRSF_{dnginsp,h,t} \end{aligned} \tag{4.46}$$

FW at time t is similarly a function of FW in the previous period, the rate of return to capital ($rk_{i,t}$), physical capital demand in sector i, and SAV_h is

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[40] This is the share of household income in total household income for each household type.

household savings. Note that $d^{K}_{dngins} \cdot rk_{i,t} \cdot \sum_i K_i$ here is capital income.

$$FW_t(1 + r_t) = FW_{t+1} + d^{K}_{dngins} \cdot rk_{i,t} \cdot \sum_i K_i - \sum_h SAV_h \tag{4.47}$$

Domestic non-government income, $YNG_{dngins,t}$, is determined as follows:

$$\begin{aligned} YNG_{dngins,t} &= d^{L}_{dngins} \cdot w_t \cdot \sum_i L_i + d^{K}_{dngins} \cdot rk_{i,t} \sum_i K_i \\ &+ \sum_{dnginsp} TRSF_{dngins,dnginsp,t} + PC_t \cdot TRG_{dngins} + \varepsilon_t \cdot REM_{dngins} \end{aligned} \tag{4.48}$$

Here, d^{L}_{dngins} and d^{K}_{dngins} are share parameters, w_t is the unified nominal wage, L_i is labour demand, $TRSF_{dngins,dnginsp,t}$ is transfers among non-governmental organisations, PC_t is aggregate consumption price, TRG_{dngins} is domestic non government transfers, REM_{dngins} is remittance for *dngins*.

Transfers among non-governmental organisations is determined as follows (the bar above a variable indicates that the variable is fixed), and fixed in real terms.

$$TRSF_{dngins,dnginsp,t} = PC_t \cdot \overline{TRSF}_{dngins,dnginsp} \tag{4.49}$$

Above, PC_t is aggregate consumption price and $\overline{TRSF}_{dngins,dnginsp}$ is transfers between domestic non-governmental institutions. Domestic non-government saving is given by the following equation where: mps_{dngins} (a calibrated parameter) is the rate of saving in institutions and $YNG_{dngins,t}$ is domestic non-government income. Taken together Equations 4.50 and 4.47 do not imply a binding balance of payments constraint. See Lecca et al. (2011a) for a discussion of the balance of payments treatment in AMOS.

$$SAV_{dngins,t} = mps_{dngins} \cdot YNG_{dngins,t} \tag{4.50}$$

Total household consumption for sector i for h ($QH_{i,h,t}$) is given by:

$$QH_{i,h,t} = \delta^{f}_{i,h}{}^{\rho^c_i} \cdot \left(\frac{PC_{i,t}}{PX_{i,t}}\right)^{\rho^c_i} \cdot C_t \tag{4.51}$$

$\delta^f_{i,h}$ is the share parameter in the CES function for household consumption goods, PC_t is the price of consumption good i at time t, PX_{it} is commodity price i at time t, and ρ^c_i is the elasticity of substitution for household consumption.

Total household consumption for sector i for h ($QH_{i,h,t}$) is split between domestic and imported goods according to Equations 4.52 and 4.53.

$$QH_{i,h,t} = \gamma^f_{i,h} \cdot \left[\delta^{hr}_{i,h} \cdot QHR^{\rho^A_i}_{i,h,t} + \delta^{hm}_{i,h} \cdot QHM^{\rho^A_i}_{i,h,t}\right]^{\frac{1}{\rho^A_i}} \tag{4.52}$$

$\gamma^f_{i,h}$ is the shift parameter in the CES function for household consumption goods. $\delta^{hr}_{i,h}$ and $\delta^{hm}_{i,h}$ are the share parameters in the CES function for household consumption goods for regional and imported goods respectively. $QHR^{\rho^A_i}_{i,h,t}$ is regional consumption in sector i for group h. $QHM^{\rho^A_i}_{i,h,t}$ is import consumption in sector i for group h. In both cases, ρ^A_i is the elasticity of substitution. The ratio of regional consumption in sector i for group h to imported consumption in sector i for group h is given by:

$$\frac{QHR_{i,h,t}}{QHM_{i,h,t}} = \left[\left(\frac{\delta^{hr}_{i,h}}{\delta^{hm}_{i,h}}\right) \cdot \left(\frac{PM_{i,t}}{PR_{i,t}}\right)\right]^{\frac{1}{1-\rho^A_i}} \tag{4.53}$$

The fiscal deficit (FD) is given by:

$$\begin{aligned} FD_t = (G_t + I_{(g),t}) \cdot Pgov_t + \overline{GSAV} + \sum_{dngins} TRG_{dngins,t} \cdot PC_t \\ -(d^k_g \cdot \sum_i rk_{i,t} \cdot K_{i,t} + d^h_g \cdot \sum_i rh_{i,t} \cdot H_{i,t} \sum_i IMT_{i,t} + \sum_h dtr_h \\ \cdot (ssce + ire_t) \cdot \sum_j L_{j,t} \cdot w_t + \overline{FE} \cdot \epsilon_t) \end{aligned} \tag{4.54}$$

Government demand is specified as:

$$G_t = \overline{G} \tag{4.55}$$

Here $QG_{i,t}$ is government expenditure on commodity i at time t, $PX_{i,t}$ is the price of commodity i at time t, and $\overline{GSAV}$ is government saving (recall that the bar above a variable indicates that the variable is fixed). Government expenditure on commodity i at time t, $QG_{i,t}$, is then given as:

$$QG_{i,t} = \gamma_i^g \left[\delta_i^{gr} \cdot QGR_{i,t}^{\rho_i^A} + \delta_i^{gm} \cdot QGM_{i,t}^{\rho_i^A}\right]^{\frac{1}{\rho_i^A}} \tag{4.56}$$

γ_i^g is the shift parameter in the CES function for government consumption, δ_i^{gr} and δ_i^{gm} are a share parameter in the CES function for government consumption (regional and import). $QGR_{i,t}^{\rho_i^A}$ is regional government expenditure and $QGM_{i,t}^{\rho_i^A}$ is government import expenditure (i.e. expenditure in RUK and ROW). Again ρ_i^A is the elasticity of substitution. The ratio of regional government expenditure to imported government expenditure is given by the ratio of relative prices as:

$$\frac{QGR_{i,t}}{QGM_{i,t}} = \left[\left(\frac{\delta_i^{gr}}{\delta_i^{gm}}\right) \cdot \left(\frac{PM_{i,t}}{PR_{i,t}}\right)\right]^{\frac{1}{1-\rho_i^A}} \tag{4.57}$$

Investment is modeled according to the following equations. Total investment by sector of origin i, $QV_{i,t}$, is comprised of domestic goods and imports as follows:

$$QV_{i,t} = \gamma_i^v \cdot \left[\delta_i^{qvm} \cdot QVM_{i,t}^{\rho_i^A} + \delta_i^{qvir} \cdot QVIR_{i,t}^{\rho_i^A}\right]^{\frac{1}{\rho_i^A}} \tag{4.58}$$

γ_i^v is a shift parameter in the investment demand function, δ_i^{qvm} and δ_i^{qvir} are the share parameters in the CES function for investment goods. $QVM_{i,t}^{\rho_i^A}$ and $QVIR_{i,t}^{\rho_i^A}$ are ROW investment demand and national (RUK and Scottish) investment demand respectively. The ratio of ROW investment demand to national investment demand is given by:

$$\frac{QVM_{i,t}}{QVIR_{i,t}} = \left[\left(\frac{\delta_i^{qvm}}{\delta_i^{qvir}}\right) \cdot \left(\frac{PIR_{i,t}}{PM_{i,t}}\right)\right]^{\frac{1}{1-\rho_i^A}} \tag{4.59}$$

National investment, $QVIR_{i,t}$ is given by:

$$QVIR_{i,t} = \gamma_i^{vir} \cdot \left[\delta_i^{qvi} \cdot QVI_{i,t}^{\rho_i^A} + \delta_i^{qvr} \cdot QVR_{i,t}^{\rho_i^A}\right]^{\frac{1}{\rho_i^A}} \tag{4.60}$$

γ_i^{vir} is the shift parameter in the CES function for intermediate goods. δ_i^{qvi} and δ_i^{qvr} are share parameters in the CES function for investment goods. The ratio of Scottish investment demand by sector of origin i to RUK investment demand by sector of origin i is given by:

$$\frac{QVR_{i,t}}{QVI_{i,t}} = \left[\left(\frac{\delta_i^{qvr}}{\delta_i^{qvi}}\right) \cdot \left(\frac{PI_{i,t}}{PR_{i,t}}\right)\right]^{\frac{1}{1-\rho_i^A}} \tag{4.61}$$

Here $PR_{i,t}$ and $PI_{i,t}$ are the regional (Scottish) and rest of the nation (RUK here) price of i at time t. The time path of investment in AMOSENVI is specified as follows, where $J_{j,t}$ is investment by destination j with quadratic adjustment costs, to see this look at Equations 4.65 and 4.66, following the approach of Hayashi (1982).

$$J_{i,t} = I_{i,t}\left(1 - bb - tk + \frac{\beta}{2}\frac{\left(\frac{I_{i,t}}{K_{i,t}} - \alpha\right)^2}{\frac{I_{i,t}}{K_{i,t}}}\right) \tag{4.62}$$

$I_{i,t}$ is investment by sector of destination i without quadratic adjustment costs. bb is the rate of distortion or incentive to invest, tk is the rate of corporation tax, β and α are parameters in the adjustment cost function (see Equation 4.65), and $\frac{I_{i,t}}{K_{i,t}}$ is the ratio of investment by sector of destination i to physical capital demand (see Equation 4.66). $\lambda_{i,t}$ is the shadow price of capital and Pk_t is the price of the capital good.

$$\frac{I_t}{K_t} = \alpha + \frac{1}{\beta} \cdot \left[\frac{\lambda_{i,t}}{Pk_t} - (1 - bb - tk)\right] \tag{4.63}$$

The evolution of the shadow price of capital $\lambda_{i,t}$ is given by the co-state equation for Equation 4.62 as:

$$\dot{\lambda_{i,t}} = \lambda_{i,t}(r_t + \delta) - R^k_{i,t} \tag{4.64}$$

r_t is the interest rate and δ is the rate of depreciation. $R^k_{i,t}$ is the marginal net revenue of capital.

$$\theta(x_t) = \frac{\beta}{2}\frac{(x_t - \alpha)^2}{x_t} \tag{4.65}$$

x_t is defined below, and θ is an adjustment cost parameter.

$$x_t = \frac{I_t}{K_t} \tag{4.66}$$

The marginal net revenue of capital, $R^k_{i,t}$, is given by the following equation where, rk_t is the rate of return to capital, and Pk_t is the capital good price.

$$R^k_{i,t} = rk_t - Pk_t \left[\frac{I_{i,t}}{K_{i,t}}\right]^2 \theta'_t(I/K) \tag{4.67}$$

Capital accumulation is determined by the following equations, where $KS_{i,t}$ is the capital stock at time t, $KS_{i,t+1}$ is the capital stock at time t+1, δ is the rate of depreciation and $I_{i,t}$ is the investment by sector of destination i.

$$KS_{i,t+1} = (1 - \delta) \cdot KS_{i,t} + I_{i,t} \tag{4.68}$$

Labour supply, $LS_{i,t}$, evolves according to the following equation.

$$LS_{i,t+1} = \left(1 + \left(\zeta - v^u[ln(u_t) - ln(\bar{u}^N)] + v^w \left[ln\left(\frac{w_t}{cpi_t}\right) - ln\left(\frac{w^N}{cpi^N}\right)\right]\right)\right) \cdot LS_{i,t} \tag{4.69}$$

Here ζ is a calibrated parameter, v^u is the elasticity between unemployment in the region and the nation (equal to 0.06 for our purposes), u_t is the regional unemployment rate, $\bar{u}^N$ is the fixed national unemployment rate, v^w is the elasticity of the real wage, w_t is the unified nominal wage, w^N is the national wage, cpi_t and cpi_N are the regional and national consumer price indexes. Physical capital demand in this model is equal to physical capital stock.

$$K_{i,t} = KS_{i,t} \tag{4.70}$$

Total labour supply at time t, LS_t, multiplied by the fraction of the labour force employed (i.e. 1 minus the unemployment rate) equals labour demand at time t, $L_{j,t}$.

$$LS_t \cdot (1 - u_t) = \sum_j L_{j,t} \tag{4.71}$$

Indirect taxes and subsidies are determined according to the following equations.

$$IBT_{i,t} = btax_i \cdot X_{i,t} \cdot PX_{i,t} \tag{4.72}$$

$btax_i$ is business tax, $X_{i,t}$ is total output, and $PX_{i,t}$ is the price of output at time t. $IBT_{i,t}$ is indirect taxes and subsidies. Below, $IMT_{j,t}$ is total import taxes, $MTAX_j$ is the import tax rate, $VM_{i,j,t}$ is intermediate input imports from ROW, and $PM_{i,t}$ is the price of imports.

$$IMT_{j,t} = \sum_i MTAX_j \cdot VM_{i,j,t} \cdot PM_{i,t} \tag{4.73}$$

Production subsidies, $SUBSY_{i,t}$, are determined using the following equation where SUB_i is the rate of production subsidies in sector i, $X_{i,t}$ is the output of sector i, and $PX_{i,t}$ is the price of output in sector i.

$$SUBSY_{i,t} = SUB_i \cdot X_{i,t} \cdot PX_{i,t} \tag{4.74}$$

Total demand for imports, $M_{i,t}$, is the sum of intermediate imports from the rest of the nation $VI_{i,j,t}$ (here RUK), intermediate imports from the rest of the world $VM_{i,j,t}$, import consumption in sector i for group h $QHM_{i,h,t}$, RUK investment demand $QVI_{i,t}$, and ROW investment demand $QVM_{i,t}$.

$$M_{i,t} = \sum_j VI_{i,j,t} + \sum_j VM_{i,j,t} + \sum_h QHM_{i,h,t} + QGM_{i,t} + QVI_{i,t} + QVM_{i,t} \tag{4.75}$$

The current account balance, TB_t is:

$$TB_t = \sum_i M_{i,t} \cdot PM_{i,t} - \sum_i E_{i,t} \cdot PE_{i,t} + \epsilon_t \cdot \left(\sum_{dngins} \overline{REM}_{dngins} + \overline{FE} \right) \tag{4.76}$$

Total imports here are $M_{i,t}$, the price of imports $PM_{i,t}$, total exports $E_{i,t}$, the price of exports $PE_{i,t}$, remittances for non government institutions $\overline{REM}_{dngins}$, and remittances for the government $\overline{FE}$.

Domestic private assets are determined as:

$$VF_{i,t} = \lambda_{i,t} \cdot K_{i,t} \tag{4.77}$$

$VF_{i,t}$ is the value of firms, $\lambda_{i,t}$ is the shadow price of capital and $K_{i,t}$ is physical capital demand. This follows from Hayashi (1982) result that where firms act as price takers, average and marginal q are the same. Foreign debt is D_t, r is the interest rate, and TB_t is the current account balance. This allows us to calculate the shadow price of capital as the ratio of $VF_{i,t}$ to $K_{i,t}$.

$$D_{t+1} = (1 + r - \tau) \cdot D_t + TB_t \tag{4.78}$$

τ here is a subvention that addresses the fact that in a regional context it can be ‘sustainable’ for a region to run a permanent trade deficit because of transfers from outside the region which are not related to the accumulation of assets within the region by an external agent. An example of this is transfers from the European Union to fund capital investment in the region. See Lecca et al. (2011a) for more on this.

$Pgov_{t+1}$ is the price index of government consumption, GD_{t+1} is government debt, r is as above, and FD_t is fiscal deficit.

$$Pgov_{t+1} \cdot GD_{t+1} = \left[1 + r - \tau g + \left(\frac{Pc_{t+1}}{Pc_t} - 1\right)\right] \cdot GD_t \cdot Pgov_t + FD_t \quad (4.79)$$

The model steady state conditions, specifying that the capital stock at time T by sector i equals investment by that sector at time T, that the marginal net revenue of capital at time T equals the shadow price of capital, that the fiscal deficit at time T is the negative of government debt at time T, and that the current account balance equals the negative of foreign debt; are as follows:

$$KS_{i,T}\delta = I_{i,T} \quad (4.80)$$

$$R^k_{i,T} = \lambda_{i,T}(r_T + \delta) \quad (4.81)$$

$$FD_T = -\left[r - \tau g + \left(\frac{Pc_{t+1}}{Pc_t} - 1\right)\right] \cdot Pgov_T \cdot GD_T \quad (4.82)$$

$$TB_T = -(r - \tau) \cdot D_t \quad (4.83)$$

$$\begin{aligned} NFW_T \cdot r_T = & \sum_h dtr_h \cdot (ssce + ire) \cdot \sum_j L_{j,T} \cdot w_T \\ & + \sum_h \sum_{dnginsp} TRSF_{h,dnginsp,T} + \sum_h TRG_h \cdot PC_T \\ & + \sum_h REM_h \cdot \epsilon_T - \sum_{dnginsp} \sum_h TRSF_{dnginsp,h,T} \end{aligned} \quad (4.84)$$

$$FW_t \cdot r_T = d^K_{dngins} \cdot rk_{i,t} \cdot \sum_i K_i - \sum_h SAV_{h,t} \tag{4.85}$$

Calculation of the short run results requires the imposition of the following constraints. These are that the capital stock, labour supply, government debt and fiscal deficit in the first period is the same as in the base period.

$$KS_{i,t=1} = KS_{i,t=0} \tag{4.86}$$

$$LS_{t=1} = LS_{t=0} \tag{4.87}$$

$$GD_{t=1} = GD_{t=0} \tag{4.88}$$

$$D_{t=1} = D_{t=0} \tag{4.89}$$

Total consumption in the myopic model is calculated as:

$$\begin{aligned} C_t = \sum_{dngins \in \langle H \rangle} YNG_{dngins,t} - \sum_{dngins \in \langle HH \rangle} SAV_{dngins,t} \qquad (4.90) \\ -HTAX_t - \sum_{dngins} \sum_h TRSF_{dgins,h,t} \qquad (4.91) \end{aligned}$$

Here, $YNG_{dngins,t}$ is domestic non-government income, $SAV_{dngins,t}$ is domestic non-government saving, $HTAX_t$ is total household tax, $TRSF_{dgins,h,t}$ is transfers among non government institutions. Investment in the myopic model is calculated as follows:

$$I_{i,t} = v \cdot [KS^*_{i,t} - KS_{i,t}] + \delta \cdot KS_{i,t} \tag{4.92}$$

Investment by sector of destination i at time t is $I_{i,t}$, v is the adjustment parameter in the investment function (controlling the speed of adjustment),

$KS^*_{i,t}$ is defined below, $KS_{i,t}$ is the capital stock in sector i at time t, and δ is the rate of depreciation. In the final equation of the model below $A(\xi_{j,t})$ is exogenous technical change, δ^k_j is the capital share in the value added function, $PY_{j,t}$ is the value added price, and uck_t is the user cost of capital.

$$KS^*_{i,j} = \left(A(\xi_{j,t})^{\rho i} \cdot \delta^k_j \cdot \frac{PY_{j,t}}{uck_t} \right)^{\frac{1}{1-\rho_j}} \cdot Y_{j,t} \tag{4.93}$$

4.8.3 Modelling energy sectors

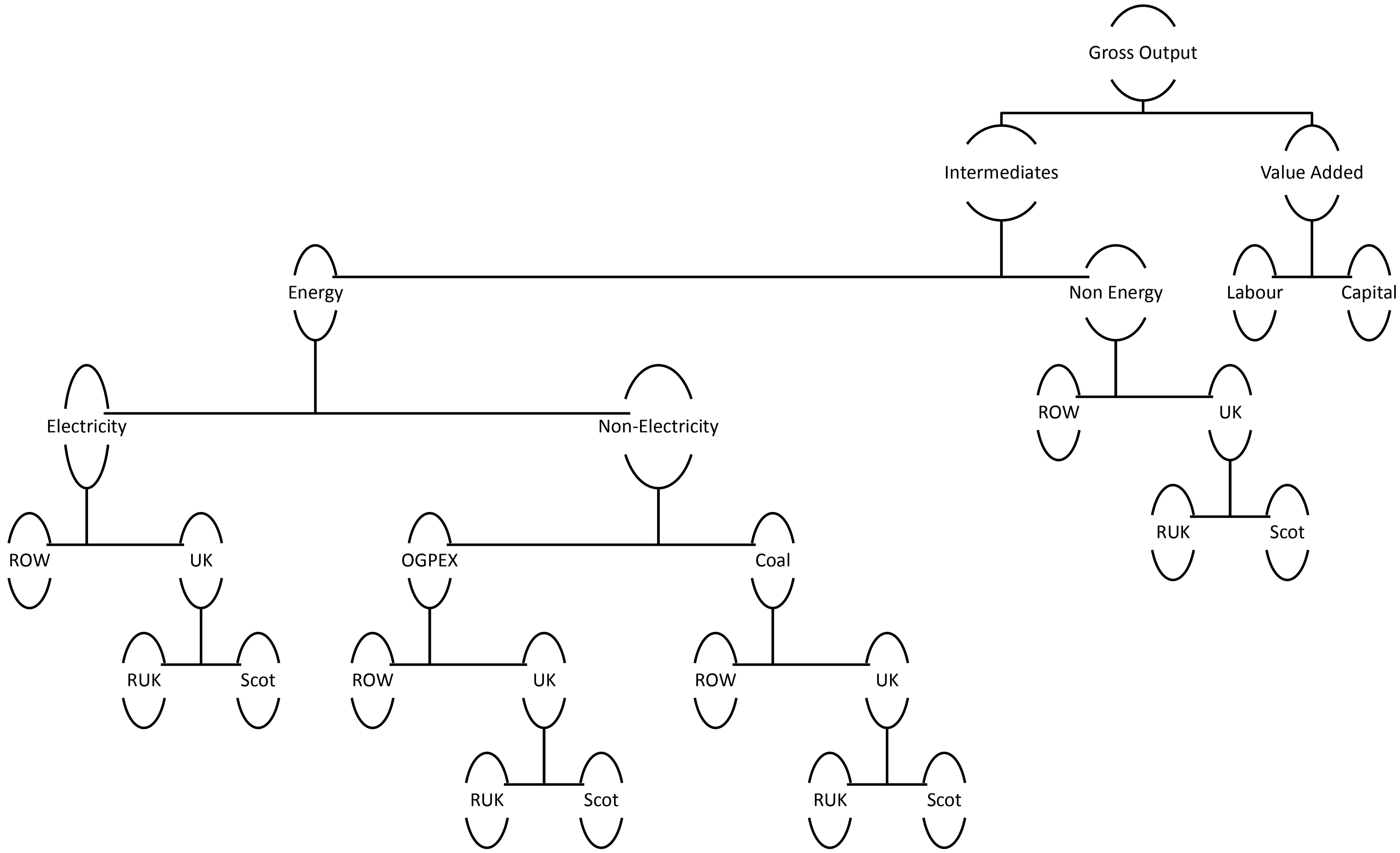
Ferguson et al. (2005) state that there are 3 key issues to be addressed in the specification of an energy sector in an environmental CGE model, these are:

1. Is energy an intermediate or a primary input?
2. How substitutable is energy for non-energy inputs?
3. How substitutable are different forms of energy input?

In Ferguson et al. (2005) energy is specified, although not separately identified, as an intermediate input, all of which are characterised by Leontief production technologies (i.e. there is no substitutability between these intermediate inputs). In reading this discussion of our modelling approach, the reader is directed to Figure 4.4, for a schematic of the production structure used in this study.

In our study, we use nested production functions to separately specify three energy sources as distinct intermediate inputs using CES production technologies, where we assume that energy inputs are imperfect substitutes for each other. Using nested CES production functions allows us to model output as a function of, firstly, primary and intermediate inputs. Then for intermediate inputs to be modelled as a function of a materials and an energy composite. The materials composite here is a CES function of domestically produced and imported materials using the Armington (1969) assumption.

Figure 4.4: Production structure of AMOSENVI model



OGPEX – OIL & GAS EXTRACTION AND DISTRIBUTION, AND COKE, PETROLEUM AND NUCLEAR FUEL

Energy is then modelled as a CES composite of electricity and non-electricity energy. We do not disaggregate the electricity market into renewable and non-renewable (or intermittent and non-intermittent) electricity generation. This may be a useful direction for future research. The non-electricity energy composite is again modelled using a CES function, this time as a combination of Coal and OGPEX[41]. At each level we distinguish between Scottish, RUK and ROW production using the Armington (1969) assumption[42].

This set up requires the following equations to be specified for each substitution pair, taking as our example the nest of energy (EN) and non energy (NE). For each of the other nesting pairs, for instance electricity (ELE) and non-electricity (NELE), EN and NE can be substituted for ELE and NELE, similarly for Coal and OGPED etc. In these equations $V_{j,t}$ is intermediate input purchases by j sectors, $EN_{j,t}$ is sectoral energy purchases, and $NE_{j,t}$ is sectoral materials (non-energy) purchases. $A^{EN,NE}$ are scale parameters in the CES function and $\delta^{EN,NE}$ are share parameters in the CES function.

$$V_{j,t} = CES(EN_{j,t}, NE_{j,t},, A^{EN,NE}) \tag{4.94}$$

$$V_{j,t} = [\delta_j^{EN}(A_j^{EN}EN_{j,t})^{\rho_j} + \delta_j^{NE}(A_j^{NE}NE_{j,t})^{\rho_j}]^{\frac{1}{\rho_j}} \tag{4.95}$$

$$EN_{j,t} = CES(PINT_t, PEN_t, A_j^{EN}, \rho_j) \tag{4.96}$$

$$EN_{j,t} = \left((A_j^{EN})^{\rho_j}\delta_j^{EN}\frac{PINT_t}{PEN_t}\right)^{\frac{1}{1-\rho_j}} \tag{4.97}$$

$$NE_{j,t} = CES(PINT_t, PNE_t, A_j^{NE}, \rho_j) \tag{4.98}$$

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[41] OGPEX stands for Oil and Gas extraction and distribution, Coke, Petroleum and Nuclear fuel.

[42] Following the work of Lecca et al. (2011b), we may in future work vary the production structure noted here to assess its impact on our results.

$$NE_{j,t} = \left((A_j^{NE})^{\rho_j} \delta_j^{NE} \frac{PINT_t}{PNE_t} \right)^{\frac{1}{1-\rho_j}} \tag{4.99}$$

4.8.4 Linking emissions to energy use

There are two main ways of thinking about linking pollution to economic activity, either as being linked to sectoral production, or to sectoral fuel use. Ferguson et al. (2005) note that: "...pollution is most commonly assumed to be generated by means of fixed coefficients linking pollution production to each sector's output level" (Ferguson et al. 2005, p107). This is the approach that we took in Chapter 2 of this thesis, where we had a Leontief production function for intermediate input demands.

In this Chapter, in order to relax the assumption that intermediate inputs are non-substitutable, i.e. to relax the Leontief intermediate technology assumption, we link some emissions to sectoral fuel use, and others to sectoral output. Where we have some reason to believe that emissions are related to factors other than the volume of fuel use, we model emissions as deriving from both fuel use and sectoral output- consistent with the approach of Bergman (1991)[43].

There are two approaches that we considered to estimating the emissions embodied in fuel combustion by each sector. The first is to calculate a national average emissions/fuel use intensity (i.e. emissions per £m (or tonne of oil equivalent) of fuel use by dividing total emissions generated from the use of each fuel type by the total value of purchases of that fuel). This factor, once estimated, can then be applied to purchases of individual fuels (if calculated as emissions per £m of a particular fuel), at the sectoral level to produce an estimate of the emissions associated with each sector's use of that fuel.

The alternative approach, is to estimate sectoral level emissions/fuel use intensities. Where data are available on sectoral fuel use, sectoral fuel purchases (taken e.g. from the input-output database) and sectoral emissions generation,

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[43] Refer to Table 4.3 for details on which sectors had what volume of emissions related to their use of Coal and OGPED, and their production of output.

it is possible to estimate the emissions embodied in each sectors *actual* use of each fuel. This is a distinct from the first approach which estimates the emissions embodied in the *national/regional average* use of that fuel.

There are a number of reasons, ex-ante, to believe that the emissions from each sector's use of a particular fuel are different. The most obvious of these is that sectors may be purchasing a different type of, say, coal. Another reason could be that there is a different degree of abatement technology in place in different sectors. Some sectors may, for instance, have 'scrubbers' fitted to their chimneys which 'clean' some of the emissions prior to their release, reducing the emissions released per £1m of fuel use.

Regardless of the reason, it seems pointless to ignore the richness of the sectoral variation in the raw data by taking the second approach and using a single national/regional fuel use intensity. It is nonetheless true, as we discussed in Chapter 2, that we have concerns about some of the environmental and energy data that the Scottish Government have made available as 'experimental' data. That being said, it seems reasonable to expect that the data on air emissions and fuel use that the Scottish Government have released will be compatible with each other, and since what this study is doing is linking fuel use to emissions it seems only proper to use the same data source for both.[44]

In order to carry out the type of pollution attribution work that we did in Chapter 2 of this thesis, having introduced an export demand shock into the CGE model, we require to construct emissions-output intensities (emissions per £m of sectoral output). We link most emissions to fuel use and some to sectoral output. It may be helpful at this stage to outline how we will go from the post shock CGE results through to an updated output-emissions intensity.

The basic approach is to estimate in the base case, the emissions associated with each sector's use of £1m of each fuel type (Coal and OGPEX). Having done so, we will apply these intensities to the inflation adjusted (i.e. real terms)

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[44] In addition, following from the work of Turner (2006) who showed that using national level pollution intensities in an analysis of the States of Jersey could provide misleading results, we have at least some reason to believe that using region specific data may improve the precision of our pollution totals.

purchases of each of these fuels by each sector, both domestically and through imports. This will allow us to determine the total volume of emissions generated through sectoral fuel use in each period[45]. A similar approach is taken where there are sectors with emissions linked to sectoral activity (i.e. output) as opposed to fuel consumption.

In these sectors, a contribution to total sectoral emissions is also included where an initial emissions intensity- calculated for the base period- is applied to sectoral output in each period in real terms. The alternative approach would have been to adjust the sectoral fuel input (and output) intensities of each sector to keep these in real terms. The approaches are equivalent, but the approach taken here is more straightforward. In our study, this gives us the following equation to characterise sector emissions generation in each period t ($Poll_{i,t}$).

$$\begin{aligned} Poll_{i,t} = {} & OGPED_{i,t} \cdot P_{OGPED,t} \cdot EI_{OGPED_i} + COAL_{i,t} \cdot P_{COAL,t} \cdot EI_{COAL_i} \\ & + X_{i,t} \cdot P_{X_i,t} \cdot EI_{X_i} \end{aligned} \tag{4.100}$$

In Equation 4.100 sectoral pollution at time t, is the sum of real term purchases of OGPED by sector i at time t ($OGPED_{i,t} \cdot P_{OGPED,t}$) multiplied by the emissions intensity of sector i's use of OGPED EI_{OGPED_i}, plus the sum of real term purchases of COAL by sector i at time t ($COAL_{i,t} \cdot P_{COAL,t}$) multiplied by the emissions intensity of sector i's use of COAL EI_{COAL_i}, plus the real value of sector i's output at time t ($X_{i,t} \cdot P_{X_i,t}$) multiplied by the emissions intensity of sector i output (EI_{X_i}).

These two emissions sources (one stemming from fuel input use, the other from sectoral activity) allow us to sum the emissions associated with each sector's activities in each period. This total can then be used to construct a new output-emissions intensity for each sector in each period, which can then be used, as in Chapter 2 of this thesis, as the basis for emissions attribution work. This includes the estimation of a range of different emissions totals according

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[45] Bergman (2005) notes that difficulties with the measurement of some pollutants sometimes require that these are estimated on the basis that: "they are proportional to the use of various types of fossil fuels" (Bergman 2005, p1286). While we are doing this for a different reason here, it nonetheless seems a reasonable way to proceed.

to different ‘principles’ and approaches. We will discuss later the recreation of the demand driven input-output system which is also required to give effect to an analysis of these different emissions totals in each of the 50 periods after the introduction of the permanent increase in export demand.

4.8.5 Simulation strategy

The stated purpose of this analysis is to investigate the environmental impact of export growth in Scotland. Focusing specifically on two main emissions totals, one calculated on the basis of the territorial (or production) accounting principle, the other based on the consumption accounting principle.

In specifying the production structure of the AMOSENVI model we have paid particular attention to the literature. Specifically, Bergman (2005, p1287) who notes the impact of different emissions intensities of different fuel inputs, and thus the importance of separately identifying these. In this model, ideally, we would like separately to specify each different type of fuel in the production function. The problem in practice with this comes from the difficulties posed by sectoral aggregation, specifically how the available sectoral definitions match up against the fuel use data.

Details of all elasticity values in the base case in this model are contained in Table 4.4. In line with the literature, as in most environmental CGE models (Bergman 2005, p1286), we make a distinction in the production function between electricity and non-electricity fuels. From Table 4.4 it is clear that at each nest in our model we use a CES technology. We use a “best guess” elasticity of substitution of 0.3; this follows from the work of Harris (1989), for all sectors except the energy sectors. High elasticities, also in line with the literature, are imposed between fuel types and electricity and non-electricity fuels (Bergman 2005, p1286); in our case these are set to 2. Having formalised the production structure we move to the determination of the other aspects of the model, specifically the labour market, capital market, migration function, model dynamics and trade relationships.

Following from the work of Blanchflower & Oswald (1995) (updated in Blanchflower & Oswald (2005) and discussed and expanded in Bell et al. (2002)) we characterise the labour market using a regional wage bargaining function. In this way the regional real wage is inversely related to the regional unemployment rate, our specification uses the econometric relationship parameterised by Jackman et al. (1991).

The migration function, following Harris & Todaro (1970), increases migration into the region in response to a real wage and/or unemployment differential between the region being modelled and the migrants' home region/country. Equation 4.28 presents the migration function used here, which models net in-migration to Scotland in response to an imbalance between the unemployment rates and/or real wages between Scotland and RUK.

The capital market is initially taken to be in equilibrium with actual and desired capital stock in each sector being equal. Given what we argued earlier about the implausibility of linking regional saving to regional investment, and the mobility of capital across regions, capital adjustment is specified as an updating function where investment equals a function of the difference between the actual and the desired capital stock (i.e. the difference between these two figures is multiplied by a speed of adjustment parameter).

The specifics of the capital market are that sectoral capital stock within each period of this analysis is fixed. Capital demand at the sectoral level constitutes aggregate investment demand. Investment in each period is therefore given by the depreciation of the current capital stock, plus a proportion (given by the speed of adjustment parameter) of the difference between the current and desired capital stock. The desired capital stock is determined at the sectoral level using a cost minimisation function where the price of capital is given by the user cost of capital.

In terms of trade, we specify all trade as being characterised by an Armington (1969) relationship using a CES function. This means that imports are taken to be imperfect substitutes for domestically produced goods. In the base case we specify an elasticity of 2 following Gibson (1990). We model Scotland as a price taker in foreign markets, but this does not imply the law of one price (i.e. we still have price sensitive export demand since the price of domestically produced goods can differ from the world price).

The model is specified with myopic agents, rather than forward looking agents. The impact of this decision is something which we will investigate in future work. Although, as has been noted earlier, there are only certain circumstances when we would expect that the specification of agents as being forward looking would be expected to have important implications for the results in an environmental CGE model environment. This would be the case, for example, if we were modelling the impact of a pollution permit system where agents could bank and borrow permits between periods.

One final issue which is worth noting, and which was also raised in Chapter 2, is that in our analysis here we do not include interregional feedback effects. While these effects may be small, the literature demonstrates that even if the *net* impact of these effects is small their distribution was shown to be sensitive to the nature of the interregional relationships (McGregor et al. 1999). This provides another avenue for future research.

The model simulation approach taken here is to introduce a permanent 5% increase in RUK and ROW export final demand in the AMOSENVI CGE model of Scotland for 2004. These results are then compared to the calibrated base case to calculate the % change in key variables. This is the standard means of calculating and evaluating CGE model results (Conrad 2002, p1061). In our model we calculate results for each period of a 50 period horizon. Each period is normally assumed to be represent a year (Partridge & Rickman 2010, p1317), although this is more a modelling convenience than a definitive reality (Gillespie et al. 2001, p128).

4.8.6 Calculating emissions totals for each period

Section 4.8.4 discussed how we would link emissions to economic activity, and adjust these to allow us to calculate emission generation totals for each sector in each period after the initial shock in the CGE model. The other crucial component underpinning the results presented here is the demand driven input-output system. Using the output of the CGE model, period by period, we can recreate the input-output database, and each of the import matrices (one for the rest of the UK and one for the rest of the world (ROW), for each period.

Using this database, we can recreate the environmentally extended input-output system outlined and implemented in Chapter 2. This will allow us to calculate in each period, the attribution of territorial and consumption emissions to final demand in each period. The consumption emissions presented here are calculated using the domestic technology assumption (DTA) approach outlined in Chapter 2.

While we could look to replicate some of the other approaches taken in Chapter 2, we restrict ourselves to the DTA approach, and instead explore another dimension, namely the issue of per capita emissions. In this chapter, having calculated the territorial and consumption emissions in each period, we compare the evolution of these emissions on a per capita basis in a case where we have no migration, and in the case where we have flow migration. This allows us to explore a new dimension of the evolution of Scottish territorial and consumption emissions.

4.9 Results

This results section is split into two sub-sections, one which contains a discussion of the economic results from this CGE model application, while the other discusses the main environmental results from the analysis in this chapter. In our discussion of these results, largely for convenience but also because the database we use in this model is annual (an argument made by (McGregor et al. 1996, 484)), we take each period of our model to represent a year.

4.9.1 Economic results

The key macroeconomic results are shown in Figures 4.5 - Figure 4.8. Summary results are contained in Table 4.1. We present two sets of results in this section, the first set are the results from a 5% increase in export final demand with flow migration- the MigON case (Figure 4.5 and Figure 4.7). The second set of results relate to the results from a 5% exogenous increase in export final demand with no migration- the MigOFF case (Figures 4.6 and 4.8).

The former case represents a pure demand shock (i.e. with no long-run supply constraints). The second case, where there is no migration, represents a demand shock with an active long-run supply constraint. The short run results are the same in Table 4.1 as there is no labour supply (migration) or capital adjustment in the short run case (i.e. the short run constraints are the same in both the MigON and MigOFF case).

The key conclusion of McGregor et al. (1996) was that in the presence of a demand shock, with no supply constraints, the CGE model results in the long run will be almost identical to the results from introducing a demand shock to a Type II input-output model (recall that Type II input-output models differ from the Type I models used in Chapter 2 in that households are endogenised and treated as a production sector). We briefly demonstrate that our results are in accordance with these findings.

Table 4.1 presents summary results from introducing a pure demand shock to our CGE model (the MigON case). From Table 4.1 we see that by Period 50 (which in our model represents the long-run case[46]) there is no change in the nominal gross wage or real gross wage. In other words, in the long run case there are no changes in the price of labour. Similarly, by Period 50 the unemployment rate has returned to its original level. This follows from the

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[46] The model may converge to the long run equilibrium prior to period 50, but the latest the model can converge is period 50.

Table 4.1: Summary economic results.

	MigON & MigOFF Short-run	MigON Long-run	MigOFF
GRP Income measure	0.0727	2.6016	0.4731
Consumer Price Index	1.0230	0.0000	0.8515
Unemployment Rate	-1.8005	0.0000	-5.4214
Total Employment	0.1149	2.4571	0.3460
Nominal Gross Wage	1.2307	0.0000	1.4893
Real Gross Wage	0.2056	0.0000	0.6325
Replacement cost of capital	0.9519	0.0000	0.7787
Labour supply	0.0000	2.4571	0.0000
Households Consumption	0.1702	1.5401	0.5345
Investment	0.7193	2.8799	0.7017
Capital Stock	0.0000	2.8530	0.6947
Export RUK	2.8828	5.0000	3.3196
Export ROW	2.9536	5.0000	3.2392

labour supply increasing through the migration function in our model so that in the long run, with no supply constraints, the real wage returns to its base level.

In Figures 4.6 and 4.8 and Table 4.1 we can see the results from introducing a 5% increase in export demand on macroeconomic variables where there is no migration, i.e. the population is fixed (MigOFF case). Figure 4.6 shows that this simulation increases the nominal gross wage, the real gross wage and total employment. With a fixed population, an increase in total employment necessarily implies a reduction in the unemployment rate, which is also shown in Figure 4.6. Intuitively, the increase in export demand, with a fixed labour supply, leads to increased demand for labour. With a fixed population, this leads to an increase in the real gross wage in the long run (from Table 4.1) of 0.6325%, and a reduction in the unemployment rate of 5.4214%.

Figure 4.7 and Table 4.1 show the impact on a number of other important macroeconomic variables of this simulation. The first thing to note from Table 4.1 is that in the short run case there is an increase in both RUK and ROW export demand of 2.88% and 2.95% respectively. By Period 50 (the long-run case) export demand from both RUK and ROW has increased by 5% in the

Figure 4.5: MigON Labour Market Impacts

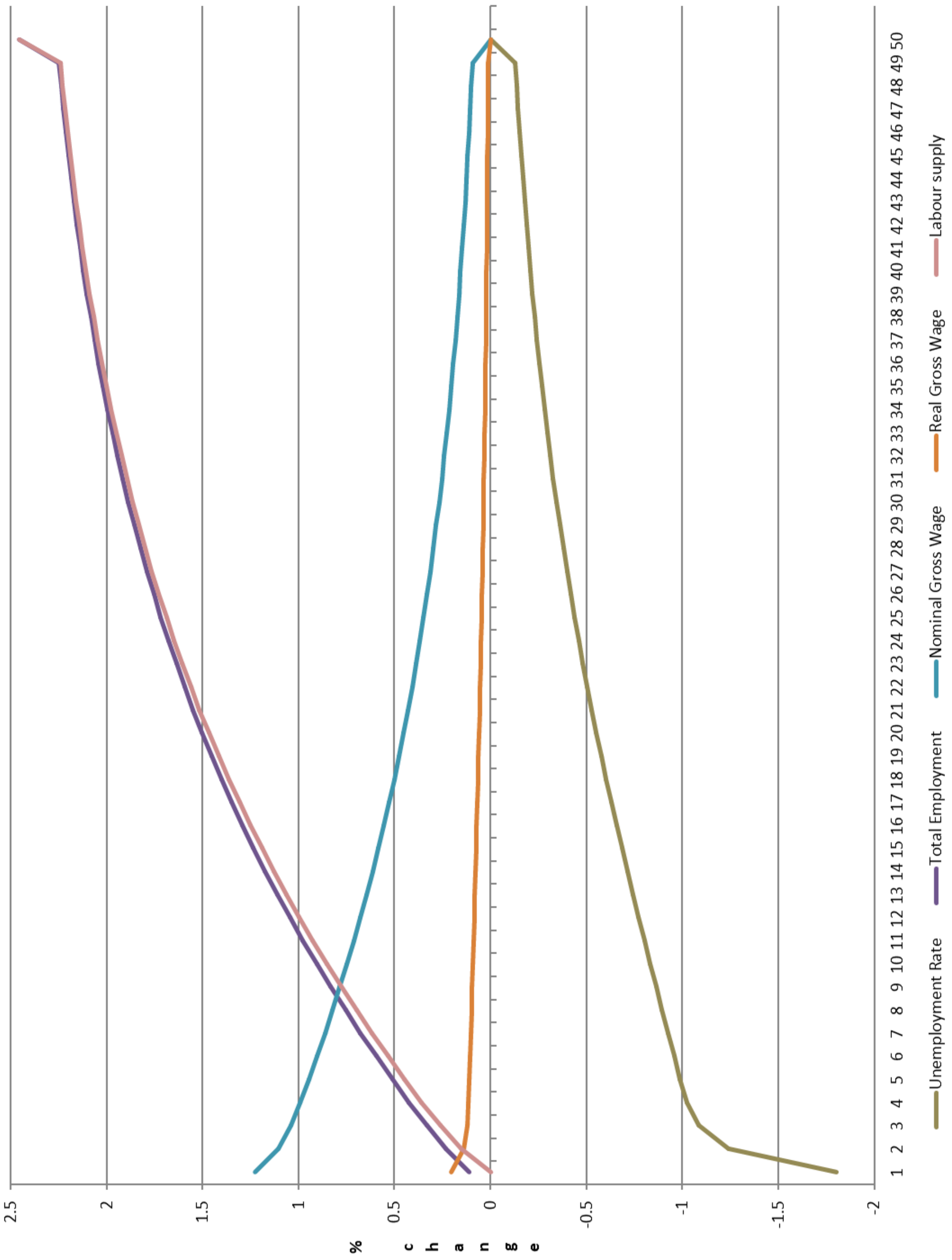


Figure 4.6: MigOFF Labour Market Impacts

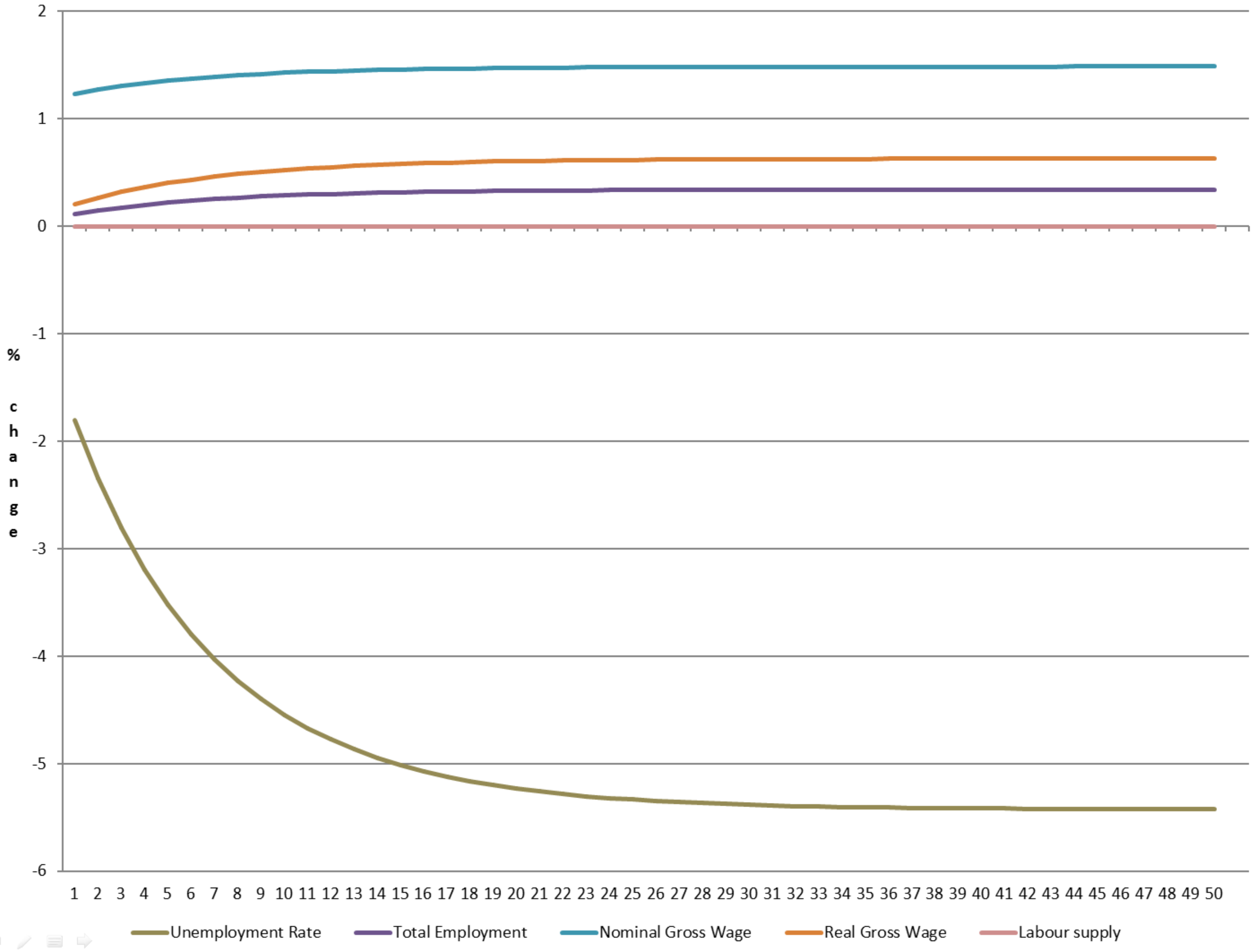


Figure 4.7: MigON Impacts on Key Macro Variables

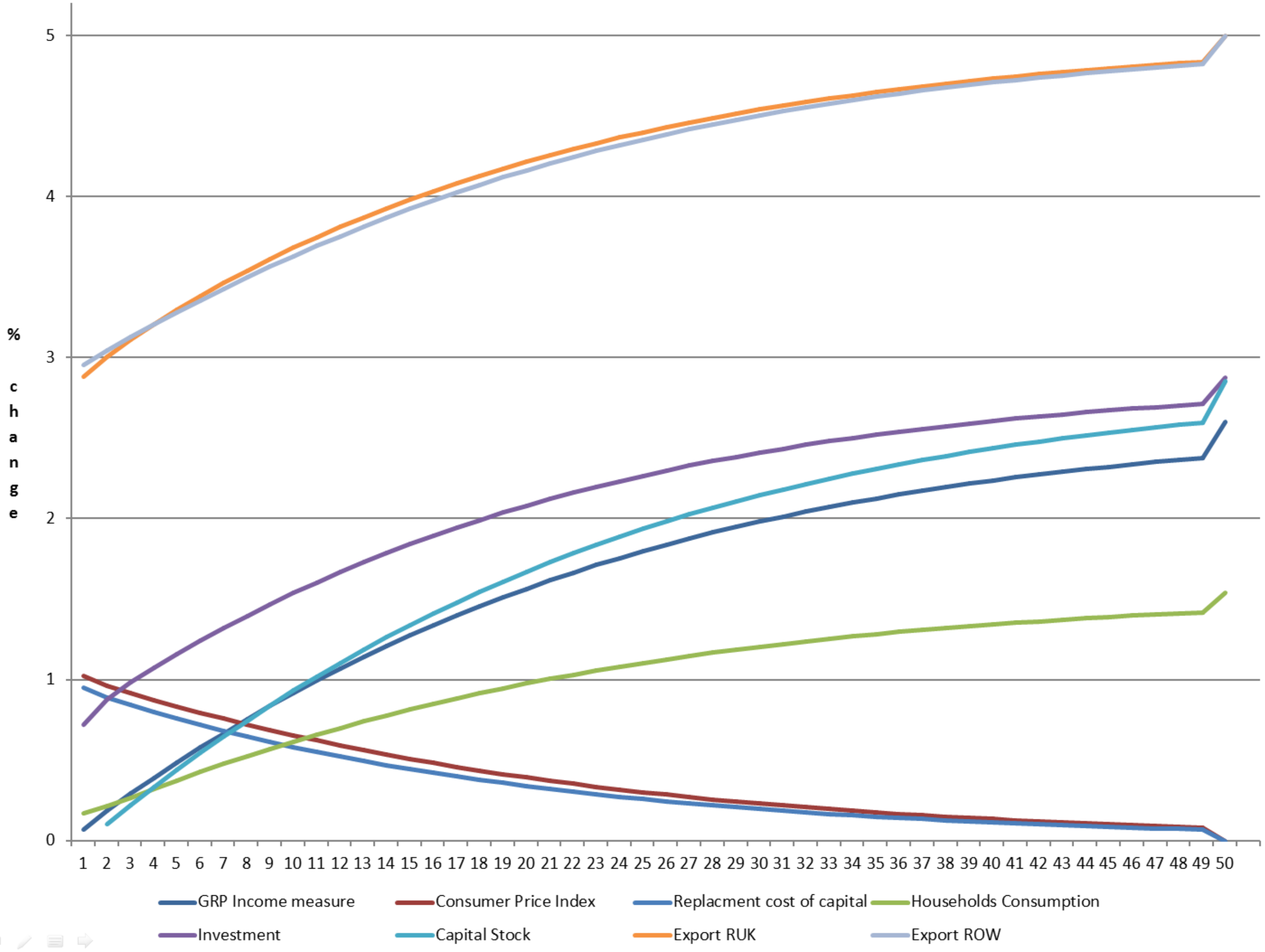
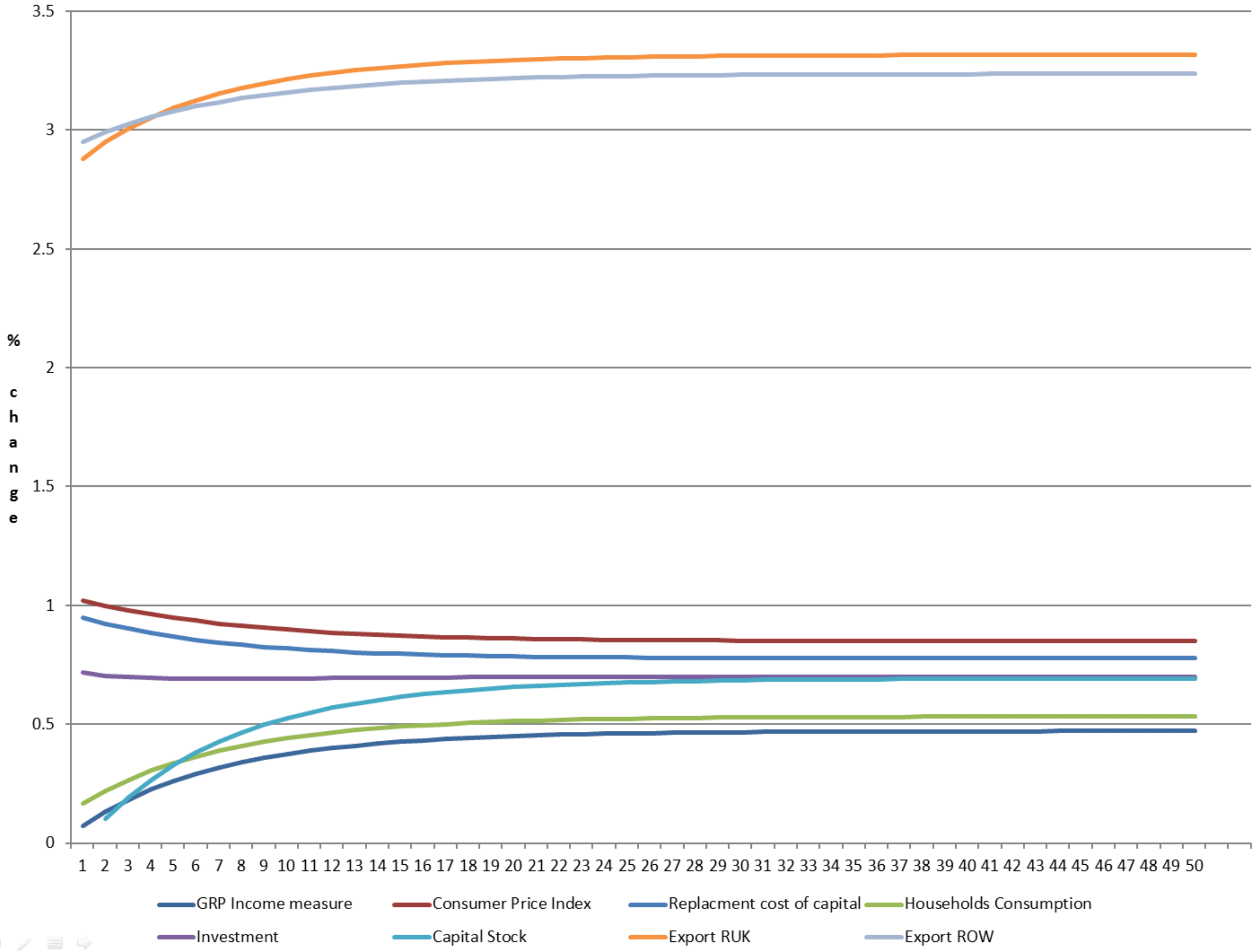


Figure 4.8: MigOFF Impacts on Key Macro Variables



MigON case. The fact that in the long run MigON case the full exogenous increase in export demand has been realised is in accordance with McGregor et al. (1996).

This is the same increase in export demand that would be obtained by introducing a 5% increase in export demand into the input-output model. However, in the MigOFF case, because in the long-run wages are higher, due to the fixed labour supply, this makes domestic production lose competitiveness. As a result, in the MigOFF case, exports do not increase by the full 5% exogenous shock. The sector by sector results are presented in Section 4.12. This illustrates the degree to which increases in wages due to the supply constraint impact differently on the competitiveness of sectoral output.

The total exports of the Health, Sewage and Sanitary services (HSS) sector increase in the long run by 2.53% despite receiving an exogenous 5% increase in export final demand. In response to the same stimuli, the Oil and Gas extraction and distribution sector (OGK) expands its exports by 4.46%. The reason for this difference lies in the impact of wage and capital costs, and the substitutibility of these, on sectoral output price and the consequential loss of competitiveness. To see this, note that the HSS sectors output price increases by the most of any sector by Period 50 at 1.2%, compared to a 0.26% increase in the output price of the OGK sector.

In Figure 4.7, and in Table 4.1, we can see that in the MigON case, the consumer price index and the replacement cost of capital both increase in the short-run by 1.023% and 0.9519% respectively, but in both cases return to their base level (i.e. the % change is zero) by Period 50 (the long-run case here). This is because in the long run where there are no supply constraints there are no changes in prices, as all factors can perfectly adjust.

In the MigOFF case, because in the long-run population is fixed, the consumer price index is higher than it was in the base period. This is due to the impact of increased wages on sectoral output. Similarly the fact that wages are higher in the long-run would lead to an increased demand for capital, leading to the replacement cost of capital in the long-run being higher than in the base period.

4.9.2 Environmental results

This section offers a brief overview of some of the main results from this analysis. To recap, territorial accounting principle (TAP) emissions include all the emissions generated within the territorial boundary of a particular area, in this work Scotland. Consumption accounting principle (CAP) emissions include the emissions embodied in Scottish consumption, regardless of where these consumption goods, and the emissions embodied within them, are produced. There is a common element to the TAP and CAP emissions totals, namely the emissions embodied in domestic consumption of domestically produced goods; while the TAP emissions total includes the emissions embodied in exports, whereas the CAP emissions total includes the emissions embodied in imports.

We focus here on three main measures, these are: the TAP (territorial) and CAP (consumption) emissions total, the % change in the TAP and CAP emissions total relative to the base period, and per capita TAP and CAP emissions. Given that we examine the impact of export growth on the TAP and CAP emissions total with a fixed population (MigOFF) and with flow migration (MigON), we can examine the impact of migration on per capita emissions in Scotland.

Figure 4.9 shows the impact, in absolute terms, on the TAP and CAP emissions total for a 5% permanent increase in export demand from RUK and ROW with both no migration, and flow migration. There is a clear difference between the results with no migration and with flow migration. It is also clear from Figure 4.9 that both emissions totals do increase. Figure 4.10 shows the percentage change in the variables shown in Figure 4.9. In both the MigON and MigOFF cases the TAP emissions total shows a greater % increase than the equivalent CAP total.

Figure 4.10 is useful, because it shows the much quicker growth of the TAP emissions total relative to the CAP emissions total in both the MigON and

Figure 4.9: TAP and CAP CO_2 emissions totals following 5% export shock

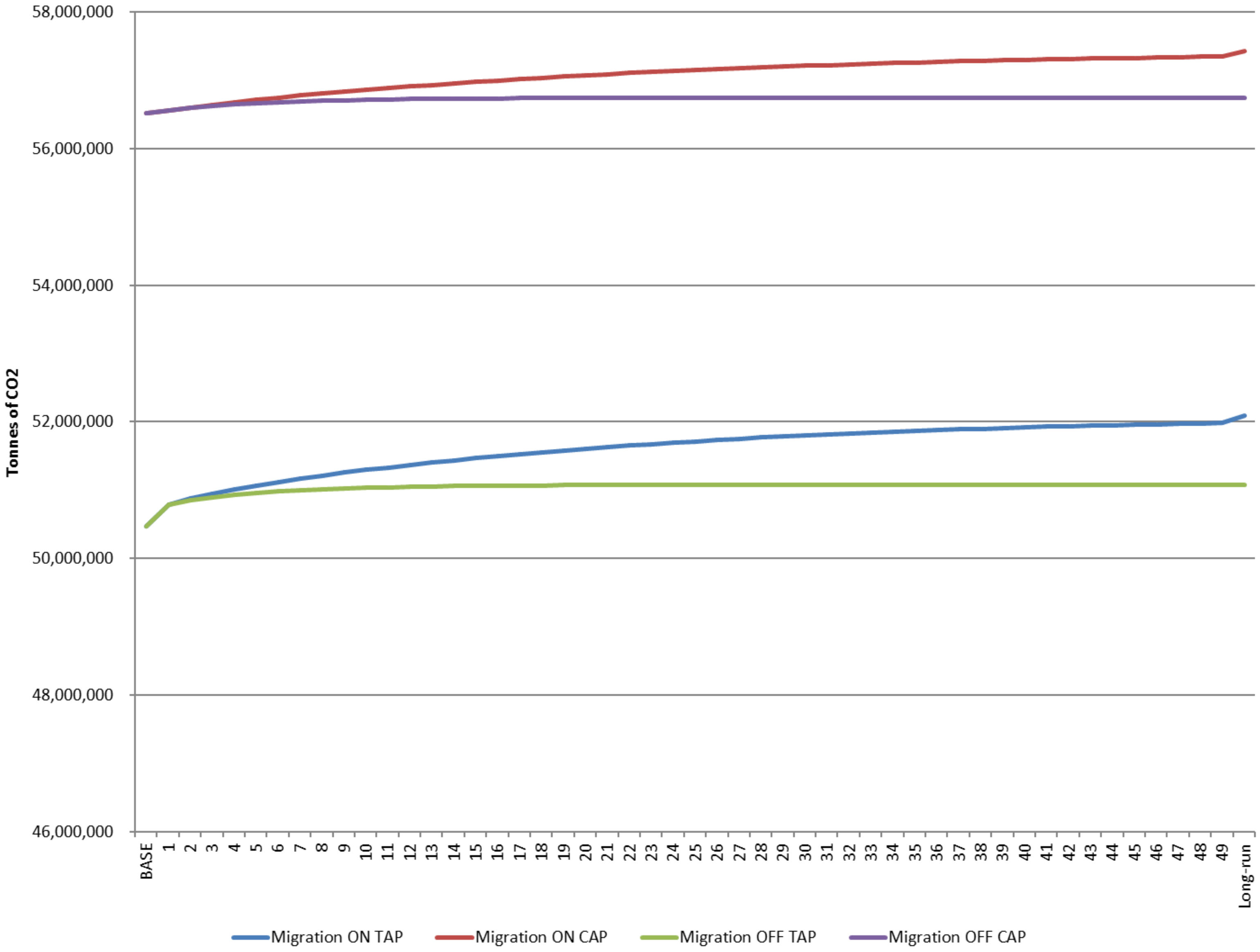
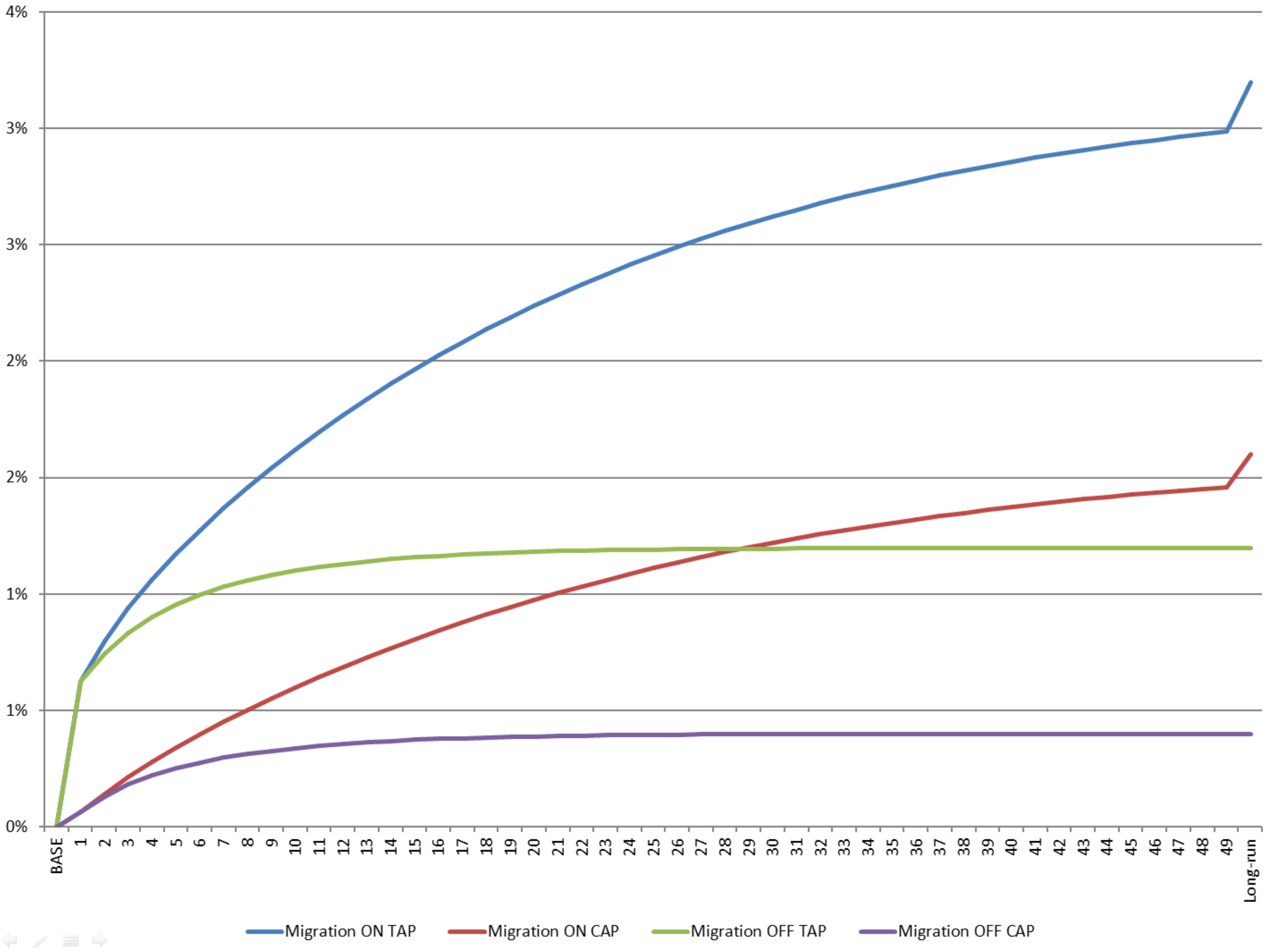


Figure 4.10: % change in TAP and CAP CO_2 emissions totals relative to base following 5% export shock



MigOFF cases. Indeed the initial % increase in the TAP emissions in the MigOFF case is more rapid than in the CAP case with Migration ON, even though the latter total ultimately shows a greater % increase. In the MigON case, given that in the long run we know from the literature that the CGE model results will be similar to input-output simulation results, we might expect that the TAP emissions total will increase more than the CAP emissions total.

The reason being that we expect that there will be a 5% increase in export demand (RUK and ROW), and a smaller increase in household and capital final demand, while government demand is fixed. In the long run the output multipliers do not change in this model and there is no distinction between the emissions intensities of domestic and imported commodities. Therefore in the MigON case, in order for the CAP emissions total to increase more than the TAP emissions total in the face of an export shock, there would need to be differences in the sectoral composition of export and household and capital final demand.

In other words, if export demand was concentrated in the least polluting sectors while household and capital final demand was concentrated in the most polluting sectors, you might find CAP emissions increasing more than TAP emissions. This is in addition to the case where the imports are concentrated in the most polluting sectors, this may also lead to a situation where the CAP emissions increase more than the TAP emissions in the face of a 5% export shock.

Figure 4.11 shows the difference between the CAP and the TAP emissions total as a % of the TAP emissions total. What is interesting here is that this difference decreases by far more in the case of flow migration than it does in the case of no migration. The difference between the CAP and TAP emissions total, recall, is that the former includes an estimate of the emissions embodied in imports, while the latter includes the emissions embodied in exports. The difference between the CAP and TAP emissions measure can therefore be thought of as the difference between the emissions embodied in imports *minus* the emissions embodied in exports.

The fact that this difference is decreasing much more in the flow migration case is interesting. It is driven by price effects, so where we have migration off, this favours imports over domestically produced goods due to a loss of competitiveness. This pushes up our imports (and thus the emissions embodied in imports), but at the same time penalising exports (and hence emissions embodied in exports) by making them less competitive. The added issue here is that the increase in export demand also leads to increases in other withdrawals (for instance savings, taxes, etc.). Looking at our results we see that in the long run the 5% increase in export demand in the MigON case leads to an increase in sectoral imports of between 1.59% and 4.33% and in the MigOFF case of between 1.72% and 2.86%.

Figures 4.12 and 4.13 detail the TAP and CAP emissions per capita following the 5% shock to RUK and ROW exports both in absolute (Figures 4.12) and relative terms (Figure 4.13). Figure 4.12 shows that TAP emissions per capita in both cases do not diverge greatly in absolute terms, although from Figure 4.13 we see that they do diverge a little in % terms with TAP emissions per capita increasing slightly more in % terms in the MigOFF case. CAP emissions per capita in both the MigON and MigOFF cases (from Figure 4.12) behave quite differently.

In the MigON case, CAP emissions per capita fall in the long run. This makes sense given what was said earlier about the output multipliers being the same in the long-run as in the base case, as well as the fact that consumption increases less than population in the MigON case (1.5401% compared to 2.4571%). In addition, public expenditure per head is falling with increased population. In the MigOFF case they increase in the long run, this is because the increase in export demand, with a fixed population, causes prices and wages to rise in the long run.

Consumer demand increases, and hence so do the emissions embodied in consumer consumption, while the population remains fixed, leading to an increase

Figure 4.11: Difference between TAP and CAP CO_2 emissions totals as a % of TAP emission total following 5% export shock

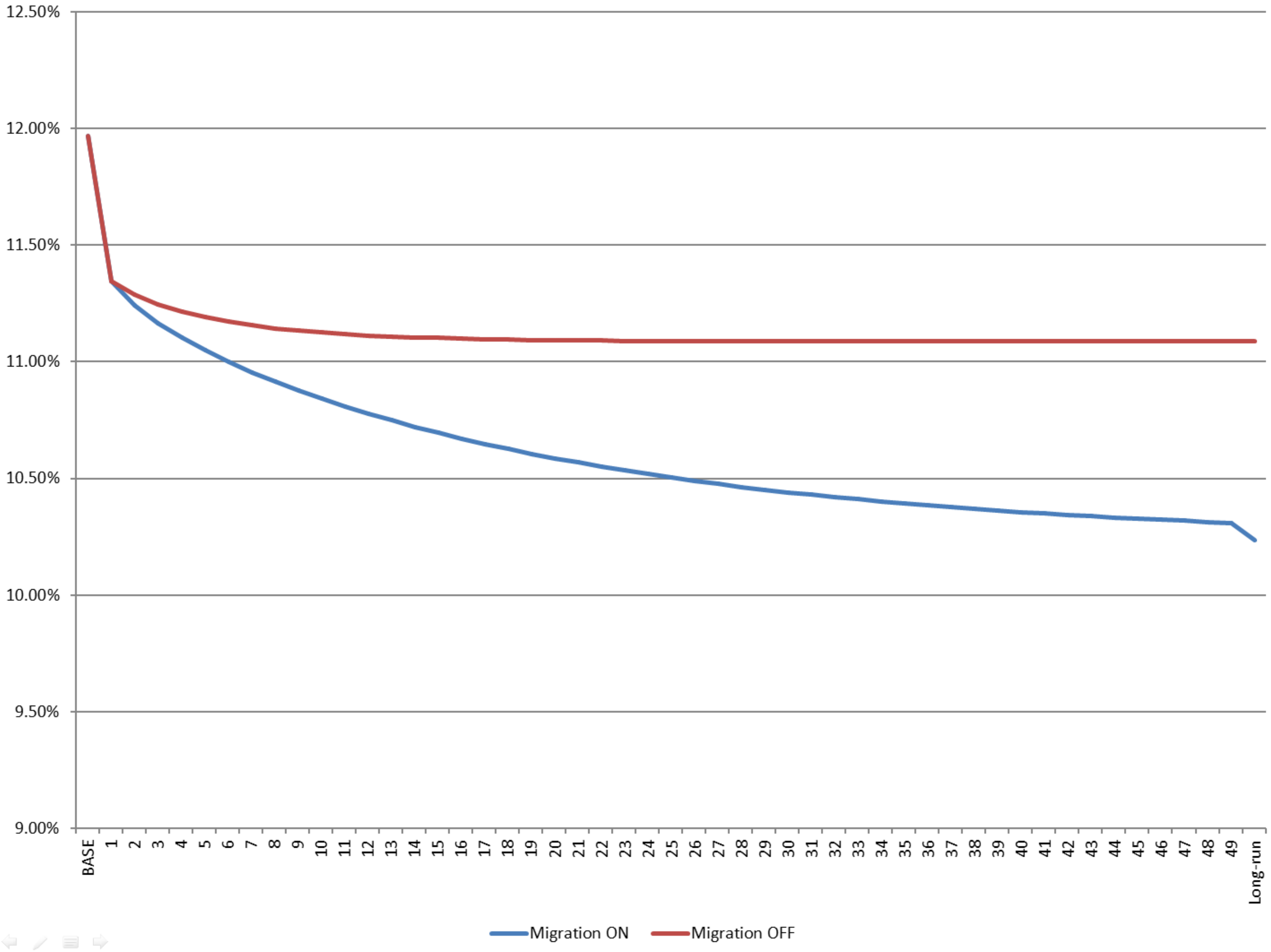


Figure 4.12: TAP and CAP CO_2 emissions per capita following 5% export shock

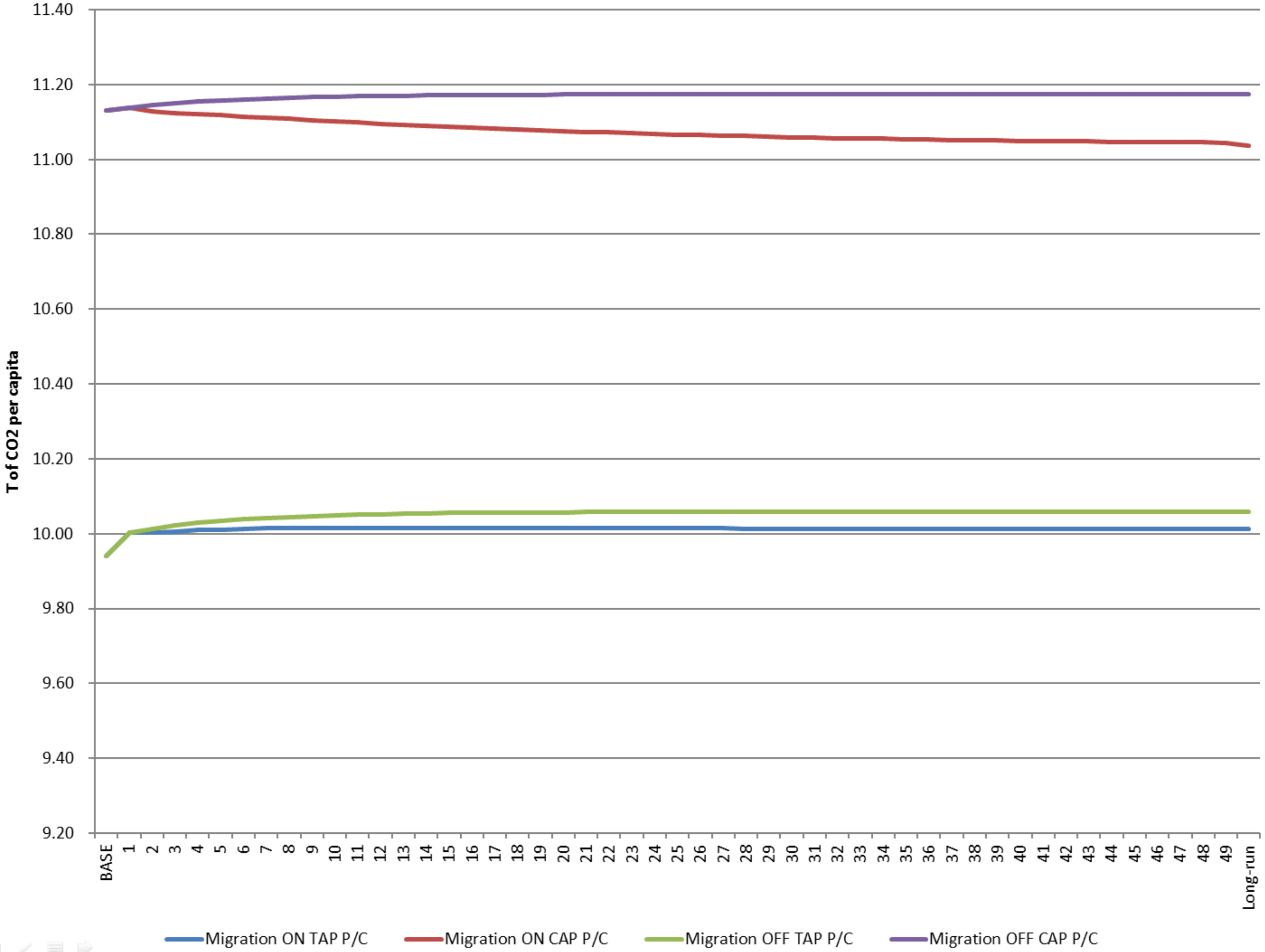
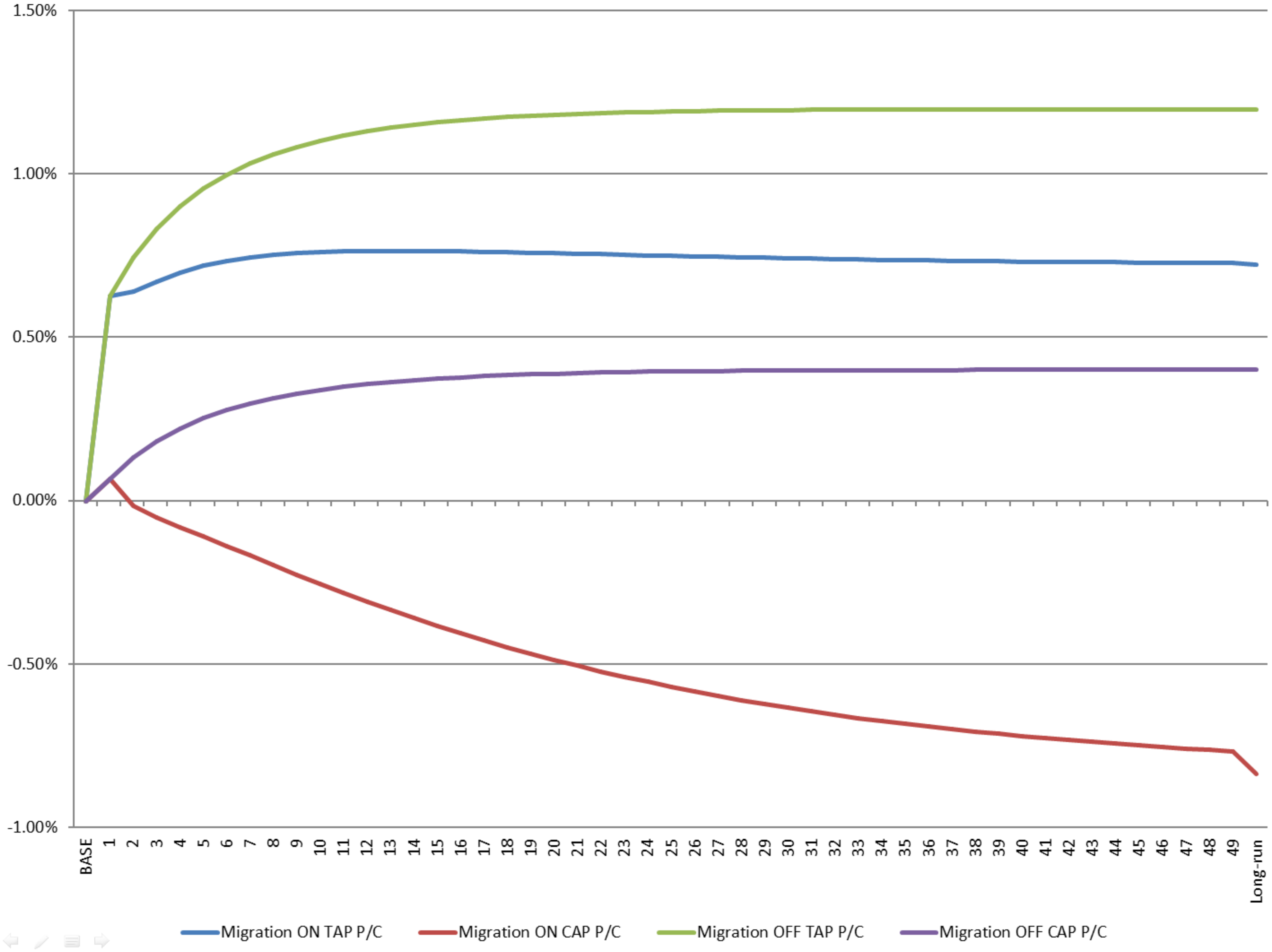


Figure 4.13: % change in CO_2 emissions per capita following 5% export shock



in the CAP emissions per capita. To see the magnitude of these changes, Figure 4.13 shows them in % terms. Here is is clear that in the MigON case there is a % decrease in per capita emissions of over 0.5% compared to an increase in the MigOFF case of around 0.3%. Figure 4.14 and Figure 4.15 delve into these aggregate results in more detail.

Figure 4.14 shows that in the MigON case, CAP emissions are increasing by a smaller % than the population is increasing. This explains why in Figure 4.12 CAP emissions per capita fall. In the case of the MigOFF simulations in Figure 4.15 we can see that since population is fixed, CAP emissions per capita increase at the same percentage rate that total CAP emissions increase.

The fact that in the MigON case the CGE results replicate input-output results may make it seems that there is no advantage in using the CGE framework in this case. There are two (related) reasons why it is advantageous to use a CGE framework in this case. The first is that there are important insights to be gained from consideration of the adjustment to the long-run equilibrium. In other words how the model expects that the economy move from point a to point b. This is a point which will be particularly obvious when we look at the sensitivity analysis in the next section.

The second and related reason why this simulation is of interest is the argument of (Partridge & Rickman 2010, 1316) that: “The long-run period required for convergence, however, is too long to be relevant for most policy analyses’ Partridge & Rickman (2010, p1316). If the long run period is indeed too long for most policy analyses, then the advantage of the CGE modelling environment compared to the input-output environment is that we can consider the period by period impact of this change. This allows us to consider impacts in between the short run and long run cases.

Figure 4.14: MigON CAP Emissions, CAP P/C, and Population % Change

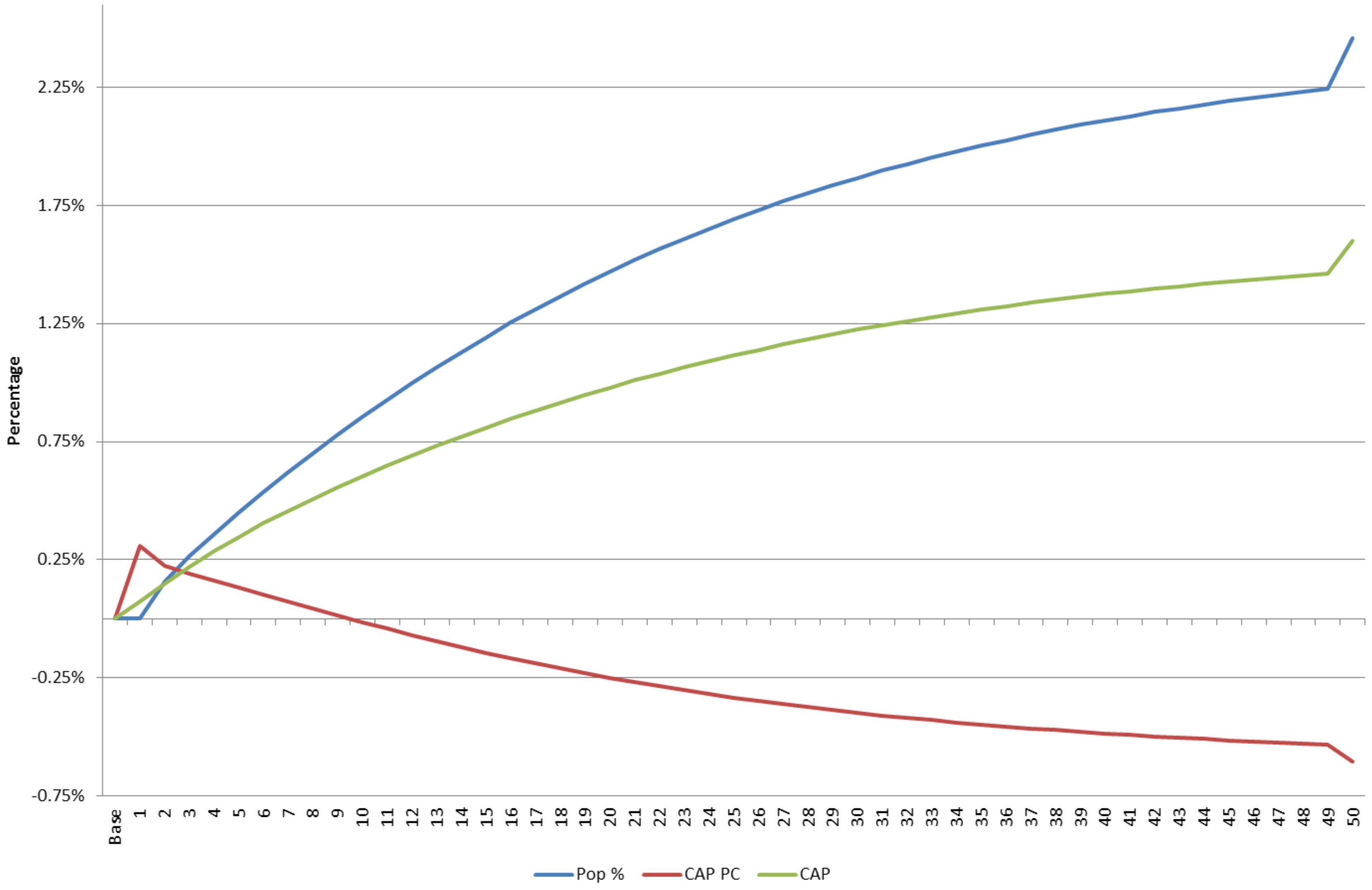
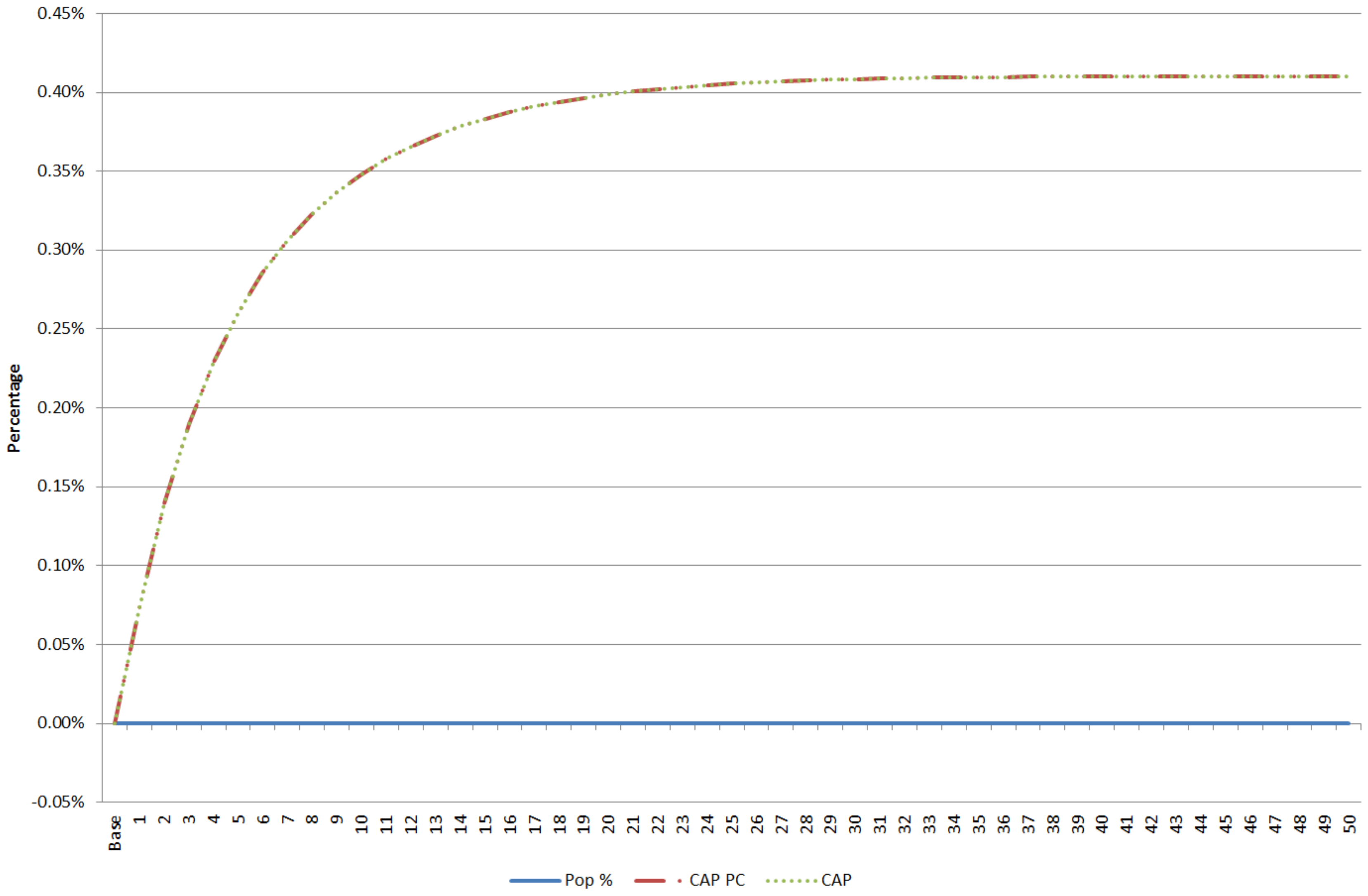


Figure 4.15: MigOFF CAP Emissions, CAP P/C, and Population % Change



4.10 Sensitivity analysis

For this analysis we have focussed on the sensitivity of our two environmental totals to three key elasticities of substitution which we have imposed. For reference purposes the base case elasticities are presented in Table 4.4. The three elasticities we focus on in the sensitivity analysis are: the elasticity of substitution between electricity and non-electricity (ELEC/NELEC), the elasticity of substitution between the oil, gas and petroleum extraction and distribution (OGPED) and Coal (OGPED/COAL), and the elasticity of substitution between energy and non-energy (ENER/NENER) intermediate inputs.

In the first two cases ELEC/NELEC and OGPED/COAL the central case elasticity of substitution is equal to 2. In our sensitivity analysis we vary this by 0.5 in each direction, considering alternative elasticities of substitution of 1.5 and 2.5. In the final case ENER/NENER we assume a central case elasticity of 0.3, and vary this to 0.2 and 0.4 in our sensitivity analysis. For each of these sensitivity analyses we consider the impact of varying these elasticities in both the MigON and MigOFF cases.

Table 4.5 presents the results from varying the ELEC/NELEC elasticity of substitution in the MigON case and Table 4.6 presents the results from the MigOFF case. The first thing to note from Table 4.5 is that by period 50 the results are identical across elasticity estimates. That is, by period 50 in the MigON case, all emissions totals increase by the same %. This follows from the fact that with a pure demand shock (as we have here), following McGregor et al. (1996), in the long run (represented here as period 50) in the absence of any supply constraints the CGE results will replicate input-output results.

Another thing to notice is that the emissions totals do not vary by much at any point, in other words it appears that neither the TAP nor the CAP emissions totals are particularly sensitive to the elasticity of substitution between electricity and non-electricity. In addition, we can see that the TAP emissions total adjusts to the long run level more rapidly the higher is the elasticity of substitution between electricity and non-electricity. This is the reverse of the position with the CAP emissions total. The higher the elasticity of substitution between electricity and non-electricity the lower the initial increase in the CAP emissions total.

In Table 4.6 the same range of estimates for the elasticity of substitution between electricity and non-electricity are considered as in Table 4.5, but in this case there is no migration. This means that contrary to the results in Table 4.5 in the long run (period 50) in this case the % increases in the emissions totals for different elasticities of substitution between electricity and non-electricity need not be the same. For TAP emissions, the higher the elasticity of substitution between electricity and non-electricity the greater the % increase in TAP emissions.

For CAP emissions, for all three values of the elasticity of substitution between electricity and non-electricity, the same % increase in CAP emissions is realised; however the greater the elasticity of substitution between electricity and non-electricity the quicker the adjustment to the long run level. In both cases again (Table 4.6), the difference in the emissions totals is relatively small as we alter the elasticities of substitution between electricity and non-electricity, suggesting our results are not particularly sensitive to this elasticity.

Turning to Table 4.7 and Table 4.8 we see the impact of varying the elasticity of substitution between OGPED and COAL in the MigON and the MigOFF cases. As before, in the MigON case both TAP and CAP emissions totals converge across elasticity values to the same number. This again is a reflection of the fact that, as McGregor et al. (1996) showed, in the long run with a pure demand shock and no supply constraint CGE results converge to input-output results. For TAP emissions Table 4.7 shows that the higher the elasticity of substitution between OGPED and COAL the slower the adjustment to the long run emissions total. For CAP emissions the reverse is true. The higher the elasticity of substitution between OGPED and COAL the quicker the CAP emissions total adjusts to its long run value.

In the MigOFF case in Table 4.8 the higher the elasticity of substitution between OGPED and COAL the lower the TAP emissions total in the long run. However for CAP emissions the reverse is true in the MigOFF case. The higher the elasticity of substitution between OGPED and COAL the greater the CAP emissions total in the long run. As before the results in both the MigON case (Table 4.7) and MigOFF case (Table 4.8) show little sensitivity to a change in the imposed elasticity.

The final elasticity of substitution where we undertake sensitivity analysis is the elasticity of substitution between energy and non-energy. In this case we vary the central case elasticity from 0.3 to 0.2 and 0.4. The results of this sensitivity analysis are contained in Table 4.9 and Table 4.10. The MigON results for both TAP and CAP emissions both converge to the same long run value for each elasticity estimate. For both the TAP and CAP total the greater this elasticity the quicker the results converge to the long-run level.

In the MigOFF case in Table 4.10 the greater the elasticity of substitution between energy and non-energy the greater the increase in both the TAP and CAP emissions totals. The variation in this elasticity of substitution results in the greatest change in the TAP and CAP emissions estimates of all the sensitivity analyses we undertake. Since emissions are mainly linked to energy inputs, increasing the substitutability between energy and non-energy must lead to substitution towards energy use, but this only happens if the increase in the price of energy is less than the change in the price of non-energy.

What this sensitivity analysis has shown is that the two main environmental totals we focus on (the TAP and CAP emissions totals) do not respond significantly to changes in the elasticity of substitution between electricity and non-electricity or in the elasticity of substitution between Coal and OGPED. The elasticity of substitution between energy and non-energy is the one which shows the greatest impact on the TAP and CAP emissions totals.

In the MigON case this is reflected in the more rapid adjustment of the TAP and CAP emissions totals to their long run levels the higher the elasticity of substitution. In the MigOFF case this is reflected in the greater increase in the TAP and CAP emissions totals in the long-run the greater the elasticity of substitution between energy and non-energy inputs.

4.11 Conclusions

This chapter has presented an analysis of the environmental impacts of export growth in Scotland. It used an environmental CGE model to better understand the general equilibrium consequences of export demand growth on different CO_2 emissions totals. This analysis builds on the analyses presented in previous chapters of this thesis, most notably the CO_2 attribution and accounting work presented in Chapter 2, and the export weighted linkage measures presented in Chapter 3.

The results presented here provide a number of interesting conclusions. These include the evolution of the TAP and CAP emissions totals following an export shock. In addition, the % change in each emissions total relative to the base period, highlights the relative growth of different emissions measures. The comparison of an export shock with flow migration, with the case where we have no migration, provided additional insights into the impact of a permanent increase in export demand in Scotland's CO_2 emissions totals.

To return to where this paper started, Scotland has both a desire to increase its exports and to reduce both its consumption and territorial CO_2 emissions. What this analysis has shown is that, in contrast to the current lack of attention to the impact of export growth on the environment, a growth in export demand in Scotland is likely to have very big implications for both TAP and CAP CO_2 emissions in Scotland.

We also saw that the impact of migration is likely to play an important role in the evolution of both of these emissions totals in the face of export demand growth. In both cases, where population was fixed (MigOFF) the emissions total increased substantially less with export demand growth than it did in the MigON case. Future work will explore different aspects of this analysis, including the impact of different exogenous parameters on the results presented here, and the importance, following Lecca et al. (2011b), of the chosen production structure for energy.

In setting economic and environmental policy in Scotland, a broader recognition of the feedback between the two is likely to be important in helping to understand how related policy goals can be met. The relationship between the environment and the economy is not one way. While the growth of ‘green’ industries, and the further development of renewable energy, will have a role in determining the evolution of CO_2 emissions totals in Scotland, so too will the path of economic growth.

4.12 Tables

Table 4.2: 25 Sector aggregation scheme

25 Sector Aggregation Code	67 Sector Aggregation Code	Environmental Accounts Code	Sector Name
1	1	1	Agriculture
1	2	2	Forestry
1	3	3	Fishing
2	6	6-7	Metal ores extraction, Other mining and quarrying
3	7	8	Food and drink
3	8	9	Tobacco
4	9	10	Textiles
4	10	11	Wearing apparel
4	11	12	Leather products
5	12	13	Wood products
5	13	14-15	Pulp and paper; printing and publishing
6	15	19	Industrial gases and dyes
6	16	20-21	Inorganic chemicals, Organic chemicals
6	17	22-24	Fertilisers, Plastics & Synthetic resins etc, Pesticides
6	18	25	Paints, varnishes, etc
7	19	26	Pharmaceuticals
7	20	27	Soap and detergents
7	21	28-29	Other Chemical products, Man-made fibres
8	22	30	Rubber products
8	23	31	Plastic products
8	24	32	Glass, glass products
8	25	33	Ceramic goods
9	26	34-35	Structural clay products, Cement, lime and plaster
9	27	36	Articles of concrete, stone etc
10	28	37-40	Iron and steel, Non-ferrous metals, Metal castings
10	29	41	Metal products
11	30	42	Machinery and equipment
11	31	43	Office machinery
11	32	44	Electrical machinery
11	33	45	Radio, television, communications
11	34	46	Medical and precision instruments
11	35	47	Motor vehicles
11	36	48	Other transport equipment
11	37	49-50	Other manufacturing and recycling
11	42	59	Motor vehicle sales, repair & fuel
11	56	77	Renting of machinery
12	48	69	Water transport
12	49	70	Air transport
13	40	57	Water supply
14	41	58	Construction
15	43	60	Wholesale distribution
16	46	63	Railway transport
16	47	64-68	Other land transport
16	50	71	Ancillary transport services
17	51	72	Post and telecommunications
17	52	73	Banking and finance
17	53	74	Insurance & pension funds
17	54	75	Auxiliary financial services
17	58	79	Research and development
18	57	78	Computer services
18	59	80	Other business activities
19	60	81-82	Public administration and defence
19	61	83	Education
20	55	76	Real estate activities
20	64	88	Membership organisations
20	65	89	Recreational services
20	66	90	Other service activities
20	67	91	Private Households with employed persons
21	62	84	Health & social work
21	63	85-87	Sewage & refuse services
22	44	61	Retail distribution
22	45	62	Hotels, catering, pubs etc
23	38	51-55	Electricity production & distribution
24	5	5	Oil and gas extraction
24	14	16-18	Coke, refined petroleum & nuclear fuel
24	39	56	Gas distribution
25	4	4	Coal extraction

Table 4.3: Linking production emissions to sectoral fuel use and output production (Tonnes of CO_2).

Sector	Abbreviation	Coal emissions	OGPED emissions	Output emissions
Agriculture, forestry and fishing	(AGR)	2,828	1,088,407	-
Metal ores extraction, Other mining and quarrying	(EXT)	2,812	313,414	-
Food and drinks	(FOO)	33,567	1,343,395	-
Clothing, and leather goods	(CLG)	49,336	212,915	-
Wood, wood products and paper	(WWP)	71,507	703,337	-
Industrial chemicals, fertilizers and paints.	(CHE)	-	514,820	-
Pharmaceuticals and toiletries.	(PHA)	36,843	146,929	97,348
Rubber, plastic, glass and ceramic manufactures	(RUB)	85,296	385,571	282,246
Articles of concrete etc	(CEM)	237,660	82,134	435,801
Iron, Steel and metal products	(IRO)	8,086	275,528	177,400
Equipment manufactures (inc. vehicles)	(MEQ)	33,122	984,585	-
Air and water transport	(AIR)	-	3,415,892	-
Water Supply	(WAT)	-	138,178	-
Construction	(CON)	-	923,747	-
Wholesale distribution	(DIS)	-	486,021	-
Railway, other and ancillary transport services	(TRA)	-	2,540,860	-
Comms, banking, finance, pensions, insurance services	(COM)	-	273,017	-
Professional services	(PRS)	-	235,447	-
Public administration, inc. education	(PHE)	23,854	1,159,891	-
Recreational and other services	(OTH)	1,661	339,144	-
Health, Sewage & sanitary services	(HSS)	13,646	470,173	-
Retail distribution inc. hotels.	(RET)	-	688,148	-
Electricity production and distribution	(ELE)	12,113,288	3,771,859	-
Oil & gas ext & dist, Coke, refined petroleum & nuclear fuel	(OGK)	-	2,989,182	2,872,034
Coal extraction and distribution	(COAL)	-	1,146	-
Total	12,713,505	23,483,740	3,864,829	
Grand total	40,062,074			

Table 4.4: Base case elasticities of substitution AMOSENVI

Activity	Armington Elasticity: Elasticity of substitution between imports and domestic output in domestic demand	CET Elasticity: Elasticity of transformation between exports and domestic supplies in domestic marketed output	Elasticity of substitution between factor: CAPITAL AND LABOUR	Elasticity of substitution between INTERMEDIATE AND VALUE ADDED	ENERGY AND NON-ENERGY	ELECTRICITY AND NON-ELECTRICITY	COAL AND NON-COAL	BETWEEN NON ENERGY
SECTOR	SIGMAV	SIGMAX	SIGMAF	SIGMAZ	SIGMAINT	SIGMAENE	SIGMANELE	SIGMANENE
AGR	2	2	0.3	0.3	0.3	2	2	0.3
EXT	2	2	0.3	0.3	0.3	2	2	0.3
FOO	2	2	0.3	0.3	0.3	2	2	0.3
CLG	2	2	0.3	0.3	0.3	2	2	0.3
WWP	2	2	0.3	0.3	0.3	2	2	0.3
CHE	2	2	0.3	0.3	0.3	2	2	0.3
PHA	2	2	0.3	0.3	0.3	2	2	0.3
RUB	2	2	0.3	0.3	0.3	2	2	0.3
CEM	2	2	0.3	0.3	0.3	2	2	0.3
IRO	2	2	0.3	0.3	0.3	2	2	0.3
MEQ	2	2	0.3	0.3	0.3	2	2	0.3
AIR	2	2	0.3	0.3	0.3	2	2	0.3
WAT	2	2	0.3	0.3	0.3	2	2	0.3
CON	2	2	0.3	0.3	0.3	2	2	0.3
DIS	2	2	0.3	0.3	0.3	2	2	0.3
TRA	2	2	0.3	0.3	0.3	2	2	0.3
COM	2	2	0.3	0.3	0.3	2	2	0.3
PRS	2	2	0.3	0.3	0.3	2	2	0.3
PHE	2	2	0.3	0.3	0.3	2	2	0.3
OTH	2	2	0.3	0.3	0.3	2	2	0.3
HSS	2	2	0.3	0.3	0.3	2	2	0.3
RET	2	2	0.3	0.3	0.3	2	2	0.3
ELE	2	2	0.3	0.3	0.3	2	2	0.3
OGK	2	2	0.3	0.3	0.3	2	2	0.3
COAL	2	2	0.3	0.3	0.3	2	2	0.3

Table 4.5: Sensitivity of TAP and CAP emissions totals to the elasticity of substitution between Electricity and non-Electricity energy sources MigON

	Territorial Accounting Principle			Consumption Accounting Principle		
Period	Elasticity=1.5	Elasticity=2	Elasticity=2.5	Elasticity=1.5	Elasticity=2	Elasticity=2.5
Base	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1	0.64%	0.65%	0.67%	0.08%	0.07%	0.07%
2	0.81%	0.83%	0.85%	0.16%	0.15%	0.15%
3	0.96%	0.97%	0.99%	0.23%	0.22%	0.22%
4	1.09%	1.10%	1.12%	0.30%	0.29%	0.29%
5	1.20%	1.22%	1.24%	0.36%	0.35%	0.35%
6	1.30%	1.32%	1.34%	0.41%	0.40%	0.41%
7	1.40%	1.42%	1.44%	0.46%	0.46%	0.46%
8	1.49%	1.51%	1.53%	0.52%	0.51%	0.51%
9	1.58%	1.60%	1.62%	0.56%	0.56%	0.56%
10	1.66%	1.68%	1.70%	0.61%	0.60%	0.61%
11	1.74%	1.76%	1.78%	0.65%	0.65%	0.65%
12	1.82%	1.83%	1.85%	0.70%	0.69%	0.70%
13	1.89%	1.90%	1.92%	0.74%	0.73%	0.74%
14	1.95%	1.97%	1.99%	0.78%	0.77%	0.78%
15	2.02%	2.03%	2.05%	0.82%	0.81%	0.82%
16	2.08%	2.10%	2.11%	0.85%	0.85%	0.85%
17	2.14%	2.15%	2.17%	0.89%	0.88%	0.89%
18	2.20%	2.21%	2.23%	0.92%	0.92%	0.92%
19	2.25%	2.26%	2.28%	0.95%	0.95%	0.95%
20	2.30%	2.31%	2.33%	0.98%	0.98%	0.98%
21	2.35%	2.36%	2.38%	1.01%	1.01%	1.01%
22	2.40%	2.41%	2.43%	1.04%	1.04%	1.04%
23	2.44%	2.45%	2.47%	1.07%	1.07%	1.07%
24	2.48%	2.50%	2.51%	1.09%	1.09%	1.10%
25	2.53%	2.54%	2.55%	1.12%	1.12%	1.12%
26	2.56%	2.57%	2.59%	1.14%	1.14%	1.14%
27	2.60%	2.61%	2.63%	1.16%	1.16%	1.17%
28	2.64%	2.65%	2.66%	1.19%	1.18%	1.19%
29	2.67%	2.68%	2.69%	1.21%	1.20%	1.21%
30	2.70%	2.71%	2.72%	1.23%	1.22%	1.23%
31	2.73%	2.74%	2.75%	1.25%	1.24%	1.25%
32	2.76%	2.77%	2.78%	1.26%	1.26%	1.26%
33	2.79%	2.80%	2.81%	1.28%	1.28%	1.28%
34	2.81%	2.82%	2.83%	1.30%	1.29%	1.30%
35	2.84%	2.85%	2.86%	1.31%	1.31%	1.31%
36	2.86%	2.87%	2.88%	1.33%	1.32%	1.33%
37	2.89%	2.89%	2.90%	1.34%	1.34%	1.34%
38	2.91%	2.91%	2.92%	1.35%	1.35%	1.36%
39	2.93%	2.93%	2.94%	1.37%	1.36%	1.37%
40	2.95%	2.95%	2.96%	1.38%	1.38%	1.38%
41	2.97%	2.97%	2.98%	1.39%	1.39%	1.39%
42	2.98%	2.99%	3.00%	1.40%	1.40%	1.40%
43	3.00%	3.01%	3.01%	1.41%	1.41%	1.41%
44	3.01%	3.02%	3.03%	1.42%	1.42%	1.42%
45	3.03%	3.04%	3.04%	1.43%	1.43%	1.43%
46	3.04%	3.05%	3.06%	1.44%	1.44%	1.44%
47	3.06%	3.06%	3.07%	1.45%	1.45%	1.45%
48	3.07%	3.08%	3.08%	1.45%	1.45%	1.46%
49	3.08%	3.09%	3.09%	1.46%	1.46%	1.46%
50	3.31%	3.31%	3.31%	1.60%	1.60%	1.60%

Table 4.6: Sensitivity of TAP and CAP emissions totals to the elasticity of substitution between Electricity and non-Electricity energy sources MigOFF

	Territorial Accounting Principle			Consumption Accounting Principle		
Period	Elasticity=1.5	Elasticity=2	Elasticity=2.5	Elasticity=1.5	Elasticity=2	Elasticity=2.5
Base	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %
1	0.63 %	0.65 %	0.67 %	0.07 %	0.07 %	0.07 %
2	0.75 %	0.77 %	0.79 %	0.14 %	0.14 %	0.14 %
3	0.84 %	0.86 %	0.88 %	0.19 %	0.19 %	0.19 %
4	0.91 %	0.93 %	0.95 %	0.23 %	0.23 %	0.23 %
5	0.96 %	0.98 %	1.00 %	0.26 %	0.26 %	0.26 %
6	1.01 %	1.03 %	1.04 %	0.28 %	0.29 %	0.29 %
7	1.04 %	1.06 %	1.08 %	0.30 %	0.31 %	0.31 %
8	1.07 %	1.09 %	1.11 %	0.32 %	0.32 %	0.32 %
9	1.09 %	1.11 %	1.13 %	0.33 %	0.34 %	0.34 %
10	1.11 %	1.13 %	1.15 %	0.35 %	0.35 %	0.35 %
11	1.13 %	1.15 %	1.16 %	0.36 %	0.36 %	0.36 %
12	1.14 %	1.16 %	1.18 %	0.36 %	0.37 %	0.37 %
13	1.16 %	1.17 %	1.19 %	0.37 %	0.37 %	0.37 %
14	1.17 %	1.18 %	1.20 %	0.38 %	0.38 %	0.38 %
15	1.17 %	1.19 %	1.20 %	0.38 %	0.38 %	0.38 %
16	1.18 %	1.20 %	1.21 %	0.39 %	0.39 %	0.39 %
17	1.19 %	1.20 %	1.22 %	0.39 %	0.39 %	0.39 %
18	1.19 %	1.21 %	1.22 %	0.39 %	0.39 %	0.40 %
19	1.19 %	1.21 %	1.22 %	0.39 %	0.40 %	0.40 %
20	1.20 %	1.21 %	1.23 %	0.40 %	0.40 %	0.40 %
21	1.20 %	1.22 %	1.23 %	0.40 %	0.40 %	0.40 %
22	1.20 %	1.22 %	1.23 %	0.40 %	0.40 %	0.40 %
23	1.21 %	1.22 %	1.23 %	0.40 %	0.40 %	0.40 %
24	1.21 %	1.22 %	1.24 %	0.40 %	0.40 %	0.41 %
25	1.21 %	1.22 %	1.24 %	0.40 %	0.41 %	0.41 %
26	1.21 %	1.23 %	1.24 %	0.40 %	0.41 %	0.41 %
27	1.21 %	1.23 %	1.24 %	0.41 %	0.41 %	0.41 %
28	1.21 %	1.23 %	1.24 %	0.41 %	0.41 %	0.41 %
29	1.21 %	1.23 %	1.24 %	0.41 %	0.41 %	0.41 %
30	1.21 %	1.23 %	1.24 %	0.41 %	0.41 %	0.41 %
31	1.21 %	1.23 %	1.24 %	0.41 %	0.41 %	0.41 %
32	1.21 %	1.23 %	1.24 %	0.41 %	0.41 %	0.41 %
33	1.21 %	1.23 %	1.24 %	0.41 %	0.41 %	0.41 %
34	1.21 %	1.23 %	1.24 %	0.41 %	0.41 %	0.41 %
35	1.21 %	1.23 %	1.24 %	0.41 %	0.41 %	0.41 %
36	1.21 %	1.23 %	1.24 %	0.41 %	0.41 %	0.41 %
37	1.21 %	1.23 %	1.24 %	0.41 %	0.41 %	0.41 %
38	1.21 %	1.23 %	1.24 %	0.41 %	0.41 %	0.41 %
39	1.21 %	1.23 %	1.24 %	0.41 %	0.41 %	0.41 %
40	1.21 %	1.23 %	1.24 %	0.41 %	0.41 %	0.41 %
41	1.21 %	1.23 %	1.24 %	0.41 %	0.41 %	0.41 %
42	1.21 %	1.23 %	1.24 %	0.41 %	0.41 %	0.41 %
43	1.21 %	1.23 %	1.24 %	0.41 %	0.41 %	0.41 %
44	1.21 %	1.23 %	1.24 %	0.41 %	0.41 %	0.41 %
45	1.21 %	1.23 %	1.24 %	0.41 %	0.41 %	0.41 %
46	1.21 %	1.23 %	1.24 %	0.41 %	0.41 %	0.41 %
47	1.21 %	1.23 %	1.24 %	0.41 %	0.41 %	0.41 %
48	1.21 %	1.23 %	1.24 %	0.41 %	0.41 %	0.41 %
49	1.21 %	1.23 %	1.24 %	0.41 %	0.41 %	0.41 %
50	1.21 %	1.23 %	1.24 %	0.41 %	0.41 %	0.41 %

Table 4.7: Sensitivity of TAP and CAP totals to the elasticity of substitution between OGPED and Coal MigON

	Territorial Accounting Principle			Consumption Accounting Principle		
Period	Elasticity=1.5	Elasticity=2	Elasticity=2.5	Elasticity=1.5	Elasticity=2	Elasticity=2.5
Base	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %
1	0.65 %	0.65 %	0.65 %	0.08 %	0.07 %	0.07 %
2	0.83 %	0.83 %	0.83 %	0.15 %	0.15 %	0.15 %
3	0.97 %	0.97 %	0.97 %	0.22 %	0.22 %	0.22 %
4	1.10 %	1.10 %	1.10 %	0.28 %	0.29 %	0.29 %
5	1.22 %	1.22 %	1.21 %	0.34 %	0.35 %	0.35 %
6	1.32 %	1.32 %	1.32 %	0.40 %	0.40 %	0.41 %
7	1.42 %	1.42 %	1.42 %	0.45 %	0.46 %	0.46 %
8	1.51 %	1.51 %	1.51 %	0.50 %	0.51 %	0.51 %
9	1.60 %	1.60 %	1.59 %	0.55 %	0.56 %	0.56 %
10	1.68 %	1.68 %	1.67 %	0.60 %	0.60 %	0.61 %
11	1.76 %	1.76 %	1.75 %	0.64 %	0.65 %	0.65 %
12	1.84 %	1.83 %	1.83 %	0.69 %	0.69 %	0.70 %
13	1.91 %	1.90 %	1.90 %	0.73 %	0.73 %	0.74 %
14	1.98 %	1.97 %	1.96 %	0.77 %	0.77 %	0.78 %
15	2.04 %	2.03 %	2.03 %	0.81 %	0.81 %	0.81 %
16	2.10 %	2.10 %	2.09 %	0.84 %	0.85 %	0.85 %
17	2.16 %	2.15 %	2.15 %	0.88 %	0.88 %	0.89 %
18	2.22 %	2.21 %	2.20 %	0.91 %	0.92 %	0.92 %
19	2.27 %	2.26 %	2.26 %	0.95 %	0.95 %	0.95 %
20	2.32 %	2.31 %	2.31 %	0.98 %	0.98 %	0.98 %
21	2.37 %	2.36 %	2.36 %	1.01 %	1.01 %	1.01 %
22	2.42 %	2.41 %	2.40 %	1.04 %	1.04 %	1.04 %
23	2.46 %	2.45 %	2.45 %	1.06 %	1.07 %	1.07 %
24	2.51 %	2.50 %	2.49 %	1.09 %	1.09 %	1.09 %
25	2.55 %	2.54 %	2.53 %	1.12 %	1.12 %	1.12 %
26	2.58 %	2.57 %	2.57 %	1.14 %	1.14 %	1.14 %
27	2.62 %	2.61 %	2.60 %	1.16 %	1.16 %	1.16 %
28	2.66 %	2.65 %	2.64 %	1.18 %	1.18 %	1.18 %
29	2.69 %	2.68 %	2.67 %	1.20 %	1.20 %	1.20 %
30	2.72 %	2.71 %	2.70 %	1.22 %	1.22 %	1.22 %
31	2.75 %	2.74 %	2.73 %	1.24 %	1.24 %	1.24 %
32	2.78 %	2.77 %	2.76 %	1.26 %	1.26 %	1.26 %
33	2.81 %	2.80 %	2.79 %	1.28 %	1.28 %	1.28 %
34	2.83 %	2.82 %	2.82 %	1.29 %	1.29 %	1.29 %
35	2.86 %	2.85 %	2.84 %	1.31 %	1.31 %	1.31 %
36	2.88 %	2.87 %	2.86 %	1.33 %	1.32 %	1.32 %
37	2.90 %	2.89 %	2.89 %	1.34 %	1.34 %	1.34 %
38	2.92 %	2.91 %	2.91 %	1.35 %	1.35 %	1.35 %
39	2.94 %	2.93 %	2.93 %	1.37 %	1.36 %	1.36 %
40	2.96 %	2.95 %	2.95 %	1.38 %	1.38 %	1.38 %
41	2.98 %	2.97 %	2.97 %	1.39 %	1.39 %	1.39 %
42	3.00 %	2.99 %	2.98 %	1.40 %	1.40 %	1.40 %
43	3.01 %	3.01 %	3.00 %	1.41 %	1.41 %	1.41 %
44	3.03 %	3.02 %	3.02 %	1.42 %	1.42 %	1.42 %
45	3.04 %	3.04 %	3.03 %	1.43 %	1.43 %	1.43 %
46	3.06 %	3.05 %	3.04 %	1.44 %	1.44 %	1.44 %
47	3.07 %	3.06 %	3.06 %	1.45 %	1.45 %	1.44 %
48	3.08 %	3.08 %	3.07 %	1.45 %	1.45 %	1.45 %
49	3.09 %	3.09 %	3.08 %	1.46 %	1.46 %	1.46 %
50	3.31 %	3.31 %	3.31 %	1.60 %	1.60 %	1.60 %

Table 4.8: Sensitivity of TAP and CAP emissions totals to the elasticity of substitution between OGPED and Coal MigOFF

	Territorial Accounting Principle			Consumption Accounting Principle		
Period	Elasticity=1.5	Elasticity=2	Elasticity=2.5	Elasticity=1.5	Elasticity=2	Elasticity=2.5
Base	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %
1	0.65 %	0.65 %	0.65 %	0.08 %	0.07 %	0.07 %
2	0.77 %	0.77 %	0.77 %	0.14 %	0.14 %	0.14 %
3	0.86 %	0.86 %	0.86 %	0.19 %	0.19 %	0.19 %
4	0.93 %	0.93 %	0.93 %	0.22 %	0.23 %	0.23 %
5	0.99 %	0.98 %	0.98 %	0.25 %	0.26 %	0.27 %
6	1.03 %	1.03 %	1.03 %	0.28 %	0.29 %	0.29 %
7	1.07 %	1.06 %	1.06 %	0.30 %	0.31 %	0.31 %
8	1.10 %	1.09 %	1.09 %	0.32 %	0.32 %	0.33 %
9	1.12 %	1.11 %	1.11 %	0.33 %	0.34 %	0.34 %
10	1.14 %	1.13 %	1.13 %	0.34 %	0.35 %	0.35 %
11	1.16 %	1.15 %	1.14 %	0.35 %	0.36 %	0.36 %
12	1.17 %	1.16 %	1.16 %	0.36 %	0.37 %	0.37 %
13	1.18 %	1.17 %	1.17 %	0.36 %	0.37 %	0.38 %
14	1.19 %	1.18 %	1.18 %	0.37 %	0.38 %	0.39 %
15	1.20 %	1.19 %	1.18 %	0.37 %	0.38 %	0.39 %
16	1.21 %	1.20 %	1.19 %	0.38 %	0.39 %	0.39 %
17	1.21 %	1.20 %	1.20 %	0.38 %	0.39 %	0.40 %
18	1.22 %	1.21 %	1.20 %	0.39 %	0.39 %	0.40 %
19	1.22 %	1.21 %	1.20 %	0.39 %	0.40 %	0.40 %
20	1.22 %	1.21 %	1.21 %	0.39 %	0.40 %	0.41 %
21	1.23 %	1.22 %	1.21 %	0.39 %	0.40 %	0.41 %
22	1.23 %	1.22 %	1.21 %	0.39 %	0.40 %	0.41 %
23	1.23 %	1.22 %	1.21 %	0.39 %	0.40 %	0.41 %
24	1.23 %	1.22 %	1.22 %	0.40 %	0.40 %	0.41 %
25	1.23 %	1.22 %	1.22 %	0.40 %	0.41 %	0.41 %
26	1.23 %	1.23 %	1.22 %	0.40 %	0.41 %	0.41 %
27	1.24 %	1.23 %	1.22 %	0.40 %	0.41 %	0.41 %
28	1.24 %	1.23 %	1.22 %	0.40 %	0.41 %	0.41 %
29	1.24 %	1.23 %	1.22 %	0.40 %	0.41 %	0.41 %
30	1.24 %	1.23 %	1.22 %	0.40 %	0.41 %	0.42 %
31	1.24 %	1.23 %	1.22 %	0.40 %	0.41 %	0.42 %
32	1.24 %	1.23 %	1.22 %	0.40 %	0.41 %	0.42 %
33	1.24 %	1.23 %	1.22 %	0.40 %	0.41 %	0.42 %
34	1.24 %	1.23 %	1.22 %	0.40 %	0.41 %	0.42 %
35	1.24 %	1.23 %	1.22 %	0.40 %	0.41 %	0.42 %
36	1.24 %	1.23 %	1.22 %	0.40 %	0.41 %	0.42 %
37	1.24 %	1.23 %	1.22 %	0.40 %	0.41 %	0.42 %
38	1.24 %	1.23 %	1.22 %	0.40 %	0.41 %	0.42 %
39	1.24 %	1.23 %	1.22 %	0.40 %	0.41 %	0.42 %
40	1.24 %	1.23 %	1.22 %	0.40 %	0.41 %	0.42 %
41	1.24 %	1.23 %	1.22 %	0.40 %	0.41 %	0.42 %
42	1.24 %	1.23 %	1.22 %	0.40 %	0.41 %	0.42 %
43	1.24 %	1.23 %	1.22 %	0.40 %	0.41 %	0.42 %
44	1.24 %	1.23 %	1.22 %	0.40 %	0.41 %	0.42 %
45	1.24 %	1.23 %	1.22 %	0.40 %	0.41 %	0.42 %
46	1.24 %	1.23 %	1.22 %	0.40 %	0.41 %	0.42 %
47	1.24 %	1.23 %	1.22 %	0.40 %	0.41 %	0.42 %
48	1.24 %	1.23 %	1.22 %	0.40 %	0.41 %	0.42 %
49	1.24 %	1.23 %	1.22 %	0.40 %	0.41 %	0.42 %
50	1.24 %	1.23 %	1.22 %	0.40 %	0.41 %	0.42 %

Table 4.9: Sensitivity of TAP and CAP emissions totals to the elasticity of substitution between Energy and Non-Energy intermediate inputs MigON

	Territorial Accounting Principle			Consumption Accounting Principle		
Period	Elasticity=0.2	Elasticity=0.3	Elasticity=0.4	Elasticity=0.2	Elasticity=0.3	Elasticity=0.4
Base	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1	0.63%	0.65%	0.67%	0.05%	0.07%	0.09%
2	0.81%	0.83%	0.85%	0.13%	0.15%	0.17%
3	0.95%	0.97%	0.99%	0.20%	0.22%	0.25%
4	1.08%	1.10%	1.12%	0.26%	0.29%	0.31%
5	1.19%	1.22%	1.24%	0.32%	0.35%	0.37%
6	1.30%	1.32%	1.34%	0.38%	0.40%	0.43%
7	1.40%	1.42%	1.44%	0.43%	0.46%	0.48%
8	1.49%	1.51%	1.53%	0.48%	0.51%	0.53%
9	1.57%	1.60%	1.62%	0.53%	0.56%	0.58%
10	1.66%	1.68%	1.70%	0.58%	0.60%	0.63%
11	1.74%	1.76%	1.78%	0.63%	0.65%	0.67%
12	1.81%	1.83%	1.85%	0.67%	0.69%	0.71%
13	1.88%	1.90%	1.92%	0.71%	0.73%	0.75%
14	1.95%	1.97%	1.99%	0.75%	0.77%	0.79%
15	2.02%	2.03%	2.05%	0.79%	0.81%	0.83%
16	2.08%	2.10%	2.11%	0.83%	0.85%	0.87%
17	2.14%	2.15%	2.17%	0.86%	0.88%	0.90%
18	2.19%	2.21%	2.23%	0.90%	0.92%	0.93%
19	2.25%	2.26%	2.28%	0.93%	0.95%	0.97%
20	2.30%	2.31%	2.33%	0.96%	0.98%	1.00%
21	2.35%	2.36%	2.38%	0.99%	1.01%	1.02%
22	2.40%	2.41%	2.42%	1.02%	1.04%	1.05%
23	2.44%	2.45%	2.47%	1.05%	1.07%	1.08%
24	2.48%	2.50%	2.51%	1.08%	1.09%	1.10%
25	2.52%	2.54%	2.55%	1.10%	1.12%	1.13%
26	2.56%	2.57%	2.59%	1.13%	1.14%	1.15%
27	2.60%	2.61%	2.62%	1.15%	1.16%	1.17%
28	2.64%	2.65%	2.66%	1.17%	1.18%	1.19%
29	2.67%	2.68%	2.69%	1.19%	1.20%	1.21%
30	2.70%	2.71%	2.72%	1.21%	1.22%	1.23%
31	2.73%	2.74%	2.75%	1.23%	1.24%	1.25%
32	2.76%	2.77%	2.78%	1.25%	1.26%	1.27%
33	2.79%	2.80%	2.80%	1.27%	1.28%	1.29%
34	2.82%	2.82%	2.83%	1.29%	1.29%	1.30%
35	2.84%	2.85%	2.85%	1.30%	1.31%	1.32%
36	2.86%	2.87%	2.88%	1.32%	1.32%	1.33%
37	2.89%	2.89%	2.90%	1.33%	1.34%	1.35%
38	2.91%	2.91%	2.92%	1.34%	1.35%	1.36%
39	2.93%	2.93%	2.94%	1.36%	1.36%	1.37%
40	2.95%	2.95%	2.96%	1.37%	1.38%	1.38%
41	2.97%	2.97%	2.98%	1.38%	1.39%	1.39%
42	2.98%	2.99%	2.99%	1.39%	1.40%	1.40%
43	3.00%	3.01%	3.01%	1.40%	1.41%	1.41%
44	3.02%	3.02%	3.03%	1.41%	1.42%	1.42%
45	3.03%	3.04%	3.04%	1.42%	1.43%	1.43%
46	3.05%	3.05%	3.05%	1.43%	1.44%	1.44%
47	3.06%	3.06%	3.07%	1.44%	1.45%	1.45%
48	3.07%	3.08%	3.08%	1.45%	1.45%	1.46%
49	3.08%	3.09%	3.09%	1.46%	1.46%	1.46%
50	3.31%	3.31%	3.31%	1.60%	1.60%	1.60%

Table 4.10: Sensitivity of TAP and CAP emissions totals to the elasticity of substitution between Energy and Non-Energy intermediate inputs MigOFF

	Territorial Accounting Principle			Consumption Accounting Principle		
Period	Elasticity=0.2	Elasticity=0.3	Elasticity=0.4	Elasticity=0.2	Elasticity=0.3	Elasticity=0.4
Base	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1	0.63%	0.65%	0.67%	0.05%	0.07%	0.09%
2	0.75%	0.77%	0.79%	0.11%	0.14%	0.16%
3	0.84%	0.86%	0.88%	0.16%	0.19%	0.22%
4	0.91%	0.93%	0.95%	0.20%	0.23%	0.26%
5	0.96%	0.98%	1.01%	0.23%	0.26%	0.29%
6	1.00%	1.03%	1.05%	0.26%	0.29%	0.31%
7	1.04%	1.06%	1.09%	0.28%	0.31%	0.33%
8	1.07%	1.09%	1.12%	0.29%	0.32%	0.35%
9	1.09%	1.11%	1.14%	0.31%	0.34%	0.37%
10	1.11%	1.13%	1.16%	0.32%	0.35%	0.38%
11	1.12%	1.15%	1.18%	0.33%	0.36%	0.39%
12	1.14%	1.16%	1.19%	0.34%	0.37%	0.40%
13	1.15%	1.17%	1.20%	0.34%	0.37%	0.40%
14	1.16%	1.18%	1.21%	0.35%	0.38%	0.41%
15	1.17%	1.19%	1.22%	0.35%	0.38%	0.41%
16	1.17%	1.20%	1.22%	0.36%	0.39%	0.42%
17	1.18%	1.20%	1.23%	0.36%	0.39%	0.42%
18	1.18%	1.21%	1.23%	0.36%	0.39%	0.42%
19	1.19%	1.21%	1.24%	0.37%	0.40%	0.43%
20	1.19%	1.21%	1.24%	0.37%	0.40%	0.43%
21	1.19%	1.22%	1.24%	0.37%	0.40%	0.43%
22	1.19%	1.22%	1.25%	0.37%	0.40%	0.43%
23	1.20%	1.22%	1.25%	0.37%	0.40%	0.43%
24	1.20%	1.22%	1.25%	0.38%	0.40%	0.43%
25	1.20%	1.22%	1.25%	0.38%	0.41%	0.43%
26	1.20%	1.23%	1.25%	0.38%	0.41%	0.44%
27	1.20%	1.23%	1.25%	0.38%	0.41%	0.44%
28	1.20%	1.23%	1.25%	0.38%	0.41%	0.44%
29	1.20%	1.23%	1.25%	0.38%	0.41%	0.44%
30	1.20%	1.23%	1.25%	0.38%	0.41%	0.44%
31	1.20%	1.23%	1.25%	0.38%	0.41%	0.44%
32	1.20%	1.23%	1.25%	0.38%	0.41%	0.44%
33	1.20%	1.23%	1.26%	0.38%	0.41%	0.44%
34	1.20%	1.23%	1.26%	0.38%	0.41%	0.44%
35	1.20%	1.23%	1.26%	0.38%	0.41%	0.44%
36	1.20%	1.23%	1.26%	0.38%	0.41%	0.44%
37	1.20%	1.23%	1.26%	0.38%	0.41%	0.44%
38	1.20%	1.23%	1.26%	0.38%	0.41%	0.44%
39	1.20%	1.23%	1.26%	0.38%	0.41%	0.44%
40	1.21%	1.23%	1.26%	0.38%	0.41%	0.44%
41	1.21%	1.23%	1.26%	0.38%	0.41%	0.44%
42	1.21%	1.23%	1.26%	0.38%	0.41%	0.44%
43	1.21%	1.23%	1.26%	0.38%	0.41%	0.44%
44	1.21%	1.23%	1.26%	0.38%	0.41%	0.44%
45	1.21%	1.23%	1.26%	0.38%	0.41%	0.44%
46	1.21%	1.23%	1.26%	0.38%	0.41%	0.44%
47	1.21%	1.23%	1.26%	0.38%	0.41%	0.44%
48	1.21%	1.23%	1.26%	0.38%	0.41%	0.44%
49	1.21%	1.23%	1.26%	0.38%	0.41%	0.44%
50	1.20%	1.23%	1.26%	0.38%	0.41%	0.44%

Full CGE Model Output MigON Case

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
GRP Income measure	0.07	0.19	0.29	0.39	0.49	0.58	0.67	0.75	0.84	0.92	0.99	1.07	1.14	1.21	1.28	1.34	1.40	1.46	1.51	1.57	1.62	1.67	1.71	1.76	1.80
Consumer Price Index	1.02	0.96	0.92	0.88	0.84	0.80	0.76	0.72	0.69	0.66	0.62	0.59	0.56	0.54	0.51	0.48	0.46	0.44	0.41	0.39	0.37	0.35	0.34	0.32	0.30
Unemployment Rate	- 1.80	- 1.23	- 1.08	- 1.02	- 0.99	- 0.95	- 0.92	- 0.89	- 0.86	- 0.83	- 0.80	- 0.77	- 0.74	- 0.71	- 0.68	- 0.65	- 0.63	- 0.60	- 0.57	- 0.55	- 0.52	- 0.50	- 0.48	- 0.46	- 0.44
Total Employment	0.11	0.24	0.33	0.43	0.51	0.60	0.68	0.76	0.83	0.91	0.98	1.05	1.11	1.18	1.24	1.30	1.35	1.41	1.46	1.51	1.55	1.60	1.64	1.68	1.72
Nominal Gross Wage	1.23	1.11	1.04	0.99	0.95	0.91	0.86	0.83	0.79	0.75	0.72	0.68	0.65	0.62	0.59	0.56	0.53	0.50	0.48	0.46	0.43	0.41	0.39	0.37	0.35
Real Gross Wage	0.21	0.14	0.12	0.12	0.11	0.11	0.10	0.10	0.10	0.09	0.09	0.09	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.05	0.05	0.05
Replacment cost of capital	0.95	0.89	0.84	0.80	0.76	0.72	0.68	0.65	0.61	0.58	0.55	0.52	0.50	0.47	0.45	0.42	0.40	0.38	0.36	0.34	0.32	0.31	0.29	0.27	0.26
Labour supply	- 0.00	0.16	0.27	0.36	0.45	0.54	0.62	0.70	0.78	0.85	0.93	1.00	1.07	1.13	1.19	1.25	1.31	1.37	1.42	1.47	1.52	1.56	1.61	1.65	1.69
Households Consumption	0.17	0.22	0.27	0.32	0.38	0.43	0.48	0.53	0.57	0.62	0.66	0.70	0.74	0.78	0.82	0.85	0.89	0.92	0.95	0.98	1.01	1.03	1.06	1.08	1.11
Investment	0.72	0.88	0.98	1.08	1.16	1.24	1.32	1.40	1.47	1.54	1.61	1.67	1.73	1.79	1.84	1.90	1.95	1.99	2.04	2.08	2.12	2.16	2.20	2.23	2.27
Capital Stock		0.11	0.22	0.33	0.44	0.55	0.65	0.75	0.84	0.93	1.02	1.11	1.19	1.27	1.34	1.41	1.48	1.55	1.61	1.67	1.73	1.79	1.84	1.89	1.94
Export RUK	2.88	3.01	3.11	3.21	3.30	3.38	3.46	3.54	3.61	3.68	3.75	3.81	3.87	3.93	3.98	4.04	4.08	4.13	4.18	4.22	4.26	4.30	4.33	4.37	4.40
Export ROW	2.95	3.05	3.13	3.21	3.28	3.36	3.43	3.50	3.57	3.63	3.69	3.76	3.81	3.87	3.93	3.98	4.03	4.08	4.12	4.16	4.21	4.25	4.28	4.32	4.36

	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	LR
GRP Income measure	1.84	1.88	1.91	1.95	1.98	2.01	2.04	2.07	2.10	2.13	2.15	2.17	2.20	2.22	2.24	2.26	2.28	2.29	2.31	2.32	2.34	2.35	2.37	2.38	2.60
Consumer Price Index	0.29	0.27	0.26	0.24	0.23	0.22	0.21	0.20	0.19	0.18	0.17	0.16	0.15	0.14	0.14	0.13	0.12	0.11	0.11	0.10	0.10	0.09	0.09	0.08	- 0.00
Unemployment Rate	- 0.41	- 0.40	- 0.38	- 0.36	- 0.34	- 0.32	- 0.31	- 0.29	- 0.28	- 0.26	- 0.25	- 0.24	- 0.23	- 0.22	- 0.20	- 0.19	- 0.18	- 0.17	- 0.17	- 0.16	- 0.15	- 0.14	- 0.13	- 0.13	0.00
Total Employment	1.76	1.79	1.83	1.86	1.89	1.92	1.95	1.97	2.00	2.02	2.04	2.07	2.09	2.11	2.12	2.14	2.16	2.17	2.19	2.20	2.22	2.23	2.24	2.25	2.46
Nominal Gross Wage	0.33	0.32	0.30	0.29	0.27	0.26	0.24	0.23	0.22	0.21	0.20	0.19	0.18	0.17	0.16	0.15	0.14	0.13	0.13	0.12	0.11	0.11	0.10	0.10	- 0.00
Real Gross Wage	0.05	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	- 0.00
Replacment cost of capital	0.25	0.23	0.22	0.21	0.20	0.19	0.18	0.17	0.16	0.15	0.14	0.14	0.13	0.12	0.12	0.11	0.10	0.10	0.09	0.09	0.08	0.08	0.07	0.07	- 0.00
Labour supply	1.73	1.77	1.80	1.84	1.87	1.90	1.93	1.95	1.98	2.00	2.03	2.05	2.07	2.09	2.11	2.13	2.15	2.16	2.18	2.19	2.21	2.22	2.23	2.24	2.46
Households Consumption	1.13	1.15	1.17	1.19	1.21	1.22	1.24	1.25	1.27	1.28	1.30	1.31	1.32	1.33	1.34	1.35	1.36	1.37	1.38	1.39	1.40	1.41	1.41	1.42	1.54
Investment	2.30	2.33	2.36	2.39	2.41	2.44	2.46	2.48	2.50	2.52	2.54	2.56	2.58	2.59	2.61	2.62	2.64	2.65	2.66	2.67	2.68	2.69	2.70	2.71	2.88
Capital Stock	1.98	2.03	2.07	2.11	2.15	2.18	2.22	2.25	2.28	2.31	2.34	2.37	2.39	2.41	2.44	2.46	2.48	2.50	2.52	2.54	2.55	2.57	2.58	2.60	2.85
Export RUK	4.43	4.46	4.49	4.52	4.54	4.57	4.59	4.61	4.63	4.65	4.67	4.69	4.70	4.72	4.73	4.75	4.76	4.77	4.79	4.80	4.81	4.82	4.83	4.84	5.00
Export ROW	4.39	4.42	4.45	4.48	4.50	4.53	4.55	4.58	4.60	4.62	4.64	4.66	4.68	4.69	4.71	4.73	4.74	4.75	4.77	4.78	4.79	4.80	4.81	4.82	5.00

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	LR
Households Consumption	AGR	0.17	0.22	0.29	0.35	0.41	0.46	0.51	0.56	0.61	0.66	0.70	0.74	0.78	0.82	0.86	0.89	0.92	0.96	0.99	1.01	1.04	1.07	1.09	1.11	1.14	1.16	1.18	1.20	1.21	1.23	1.25	1.26	1.28	1.29	1.30	1.32	1.33	1.34	1.35	1.36	1.37	1.38	1.39	1.39	1.40	1.41	1.42	1.42	1.43	1.54
Households Consumption	EXT	0.17	0.23	0.30	0.37	0.43	0.49	0.54	0.59	0.64	0.68	0.73	0.77	0.81	0.84	0.88	0.91	0.94	0.97	1.00	1.03	1.06	1.08	1.10	1.13	1.15	1.17	1.19	1.21	1.22	1.24	1.26	1.27	1.28	1.30	1.31	1.32	1.33	1.34	1.36	1.36	1.37	1.38	1.39	1.40	1.41	1.41	1.42	1.43	1.43	1.54
Households Consumption	FOO	0.11	0.15	0.21	0.26	0.32	0.37	0.43	0.48	0.53	0.58	0.62	0.66	0.71	0.75	0.79	0.82	0.86	0.89	0.92	0.96	0.99	1.01	1.04	1.07	1.09	1.11	1.13	1.16	1.18	1.19	1.21	1.23	1.25	1.26	1.28	1.29	1.30	1.32	1.33	1.34	1.35	1.36	1.37	1.38	1.39	1.39	1.40	1.41	1.42	1.54
Households Consumption	CLG	0.25	0.28	0.33	0.38	0.43	0.48	0.53	0.57	0.62	0.66	0.70	0.74	0.78	0.82	0.85	0.89	0.92	0.95	0.98	1.01	1.03	1.06	1.08	1.11	1.13	1.15	1.17	1.19	1.21	1.22	1.24	1.26	1.27	1.28	1.30	1.31	1.32	1.33	1.35	1.36	1.37	1.37	1.38	1.39	1.40	1.41	1.41	1.42	1.43	1.54
Households Consumption	WWP	0.13	0.17	0.22	0.28	0.33	0.38	0.44	0.49	0.53	0.58	0.62	0.67	0.71	0.75	0.79	0.82	0.86	0.89	0.93	0.96	0.99	1.01	1.04	1.07	1.09	1.11	1.13	1.16	1.17	1.19	1.21	1.23	1.24	1.26	1.27	1.29	1.30	1.31	1.33	1.34	1.35	1.36	1.37	1.38	1.39	1.39	1.40	1.41	1.42	1.54
Households Consumption	CHE	0.11	0.16	0.22	0.29	0.34	0.40	0.45	0.51	0.56	0.60	0.65	0.69	0.73	0.77	0.81	0.85	0.88	0.91	0.95	0.98	1.00	1.03	1.06	1.08	1.11	1.13	1.15	1.17	1.19	1.21	1.22	1.24	1.26	1.27	1.28	1.30	1.31	1.32	1.33	1.35	1.36	1.37	1.37	1.38	1.39	1.40	1.41	1.41	1.42	1.54
Households Consumption	PHA	0.15	0.19	0.25	0.31	0.37	0.42	0.47	0.52	0.57	0.62	0.66	0.71	0.75	0.79	0.82	0.86	0.89	0.92	0.95	0.98	1.01	1.04	1.06	1.09	1.11	1.13	1.15	1.17	1.19	1.21	1.23	1.24	1.26	1.27	1.29	1.30	1.31	1.33	1.34	1.35	1.36	1.37	1.38	1.39	1.39	1.40	1.41	1.42	1.42	1.54
Households Consumption	RUB	0.14	0.19	0.25	0.31	0.37	0.42	0.47	0.52	0.57	0.62	0.66	0.70	0.74	0.78	0.82	0.86	0.89	0.92	0.95	0.98	1.01	1.04	1.06	1.09	1.11	1.13	1.15	1.17	1.19	1.21	1.23	1.24	1.26	1.27	1.29	1.30	1.31	1.33	1.34	1.35	1.36	1.37	1.38	1.38	1.39	1.40	1.41	1.42	1.42	1.54
Households Consumption	CEM	0.19	0.22	0.26	0.31	0.36	0.42	0.47	0.51	0.56	0.61	0.65	0.69	0.74	0.77	0.81	0.85	0.88	0.92	0.95	0.98	1.01	1.03	1.06	1.08	1.11	1.13	1.15	1.17	1.19	1.21	1.22	1.24	1.26	1.27	1.29	1.30	1.31	1.32	1.33	1.35	1.36	1.37	1.37	1.38	1.39	1.40	1.41	1.41	1.42	1.54
Households Consumption	IRO	0.16	0.20	0.25	0.31	0.36	0.41	0.46	0.51	0.56	0.61	0.65	0.69	0.73	0.77	0.81	0.85	0.88	0.91	0.94	0.97	1.00	1.03	1.05	1.08	1.10	1.13	1.15	1.17	1.19	1.20	1.22	1.24	1.25	1.27	1.28	1.30	1.31	1.32	1.33	1.34	1.35	1.36	1.37	1.38	1.39	1.40	1.41	1.41	1.42	1.54
Households Consumption	MEQ	0.24	0.27	0.31	0.35	0.39	0.44	0.48	0.52	0.56	0.61	0.65	0.68	0.72	0.76	0.79	0.83	0.86	0.89	0.92	0.95	0.98	1.01	1.04	1.06	1.08	1.11	1.13	1.15	1.17	1.19	1.21	1.22	1.24	1.25	1.27	1.28	1.30	1.31	1.32	1.33	1.34	1.35	1.36	1.37	1.38	1.39	1.40	1.41	1.41	1.54
Households Consumption	AIR	0.35	0.37	0.40	0.44	0.48	0.52	0.56	0.60	0.63	0.67	0.71	0.74	0.78	0.81	0.84	0.87	0.90	0.93	0.96	0.98	1.01	1.04	1.06	1.08	1.10	1.12	1.14	1.16	1.18	1.20	1.22	1.23	1.25	1.26	1.28	1.29	1.30	1.31	1.33	1.34	1.35	1.36	1.37	1.37	1.38	1.39	1.40	1.41	1.41	1.54
Households Consumption	WAT	0.29	0.29	0.32	0.35	0.39	0.43	0.47	0.51	0.56	0.60	0.64	0.68	0.72	0.76	0.80	0.83	0.87	0.90	0.93	0.96	0.99	1.02	1.05	1.07	1.09	1.12	1.14	1.16	1.18	1.20	1.22	1.23	1.25	1.26	1.28	1.29	1.30	1.32	1.33	1.34	1.35	1.36	1.37	1.38	1.39	1.40	1.40	1.41	1.42	1.54
Households Consumption	CON	0.23	0.28	0.34	0.39	0.45	0.50	0.55	0.60	0.65	0.69	0.73	0.77	0.81	0.84	0.88	0.91	0.94	0.97	1.00	1.03	1.05	1.08	1.10	1.12	1.15	1.17	1.19	1.20	1.22	1.24	1.25	1.27	1.28	1.30	1.31	1.32	1.33	1.34	1.35	1.36	1.37	1.38	1.39	1.40	1.41	1.41	1.42	1.43	1.43	1.54
Households Consumption	DIS	0.17	0.21	0.27	0.32	0.37	0.43	0.48	0.53	0.57	0.62	0.66	0.70	0.74	0.78	0.82	0.85	0.89	0.92	0.95	0.98	1.01	1.03	1.06	1.08	1.11	1.13	1.15	1.17	1.19	1.21	1.22	1.24	1.26	1.27	1.28	1.30	1.31	1.32	1.33	1.35	1.36	1.37	1.37	1.38	1.39	1.40	1.41	1.41	1.42	1.54
Households Consumption	TRA	0.22	0.28	0.35	0.41	0.47	0.52	0.57	0.62	0.67	0.71	0.75	0.79	0.83	0.87	0.90	0.93	0.96	0.99	1.02	1.05	1.07	1.10	1.12	1.14	1.16	1.18	1.20	1.22	1.23	1.25	1.26	1.28	1.29	1.31	1.32	1.33	1.34	1.35	1.36	1.37	1.38	1.39	1.40	1.40	1.41	1.42	1.42	1.43	1.44	1.54
Households Consumption	COM	0.12	0.17	0.24	0.30	0.36	0.41	0.47	0.52	0.57	0.61	0.66	0.70	0.74	0.78	0.82	0.85	0.89	0.92	0.95	0.98	1.01	1.04	1.06	1.09	1.11	1.13	1.15	1.17	1.19	1.21	1.23	1.24	1.26	1.27	1.29	1.30	1.31	1.32	1.34	1.35	1.36	1.37	1.38	1.38	1.39	1.40	1.41	1.41	1.42	1.54
Households Consumption	PRS	0.15	0.20	0.25	0.31	0.37	0.42	0.47	0.52	0.57	0.61	0.66	0.70	0.74	0.78	0.82	0.85	0.88	0.92	0.95	0.98	1.01	1.03	1.06	1.08	1.11	1.13	1.15	1.17	1.19	1.21	1.22	1.24	1.26	1.27	1.28	1.30	1.31	1.32	1.33	1.34	1.35	1.36	1.37	1.38	1.39	1.40	1.41	1.41	1.42	1.54
Households Consumption	PHE	0.18	0.24	0.29	0.35	0.40	0.45	0.50	0.55	0.59	0.64	0.68	0.72	0.76	0.80	0.83	0.87	0.90	0.93	0.96	0.99	1.02	1.04	1.07	1.09	1.12	1.14	1.16	1.18	1.20	1.21	1.23	1.25	1.26	1.28	1.29	1.30	1.32	1.33	1.34	1.35	1.36	1.37	1.38	1.39	1.39	1.40	1.41	1.42	1.42	1.54
Households Consumption	OTH	0.12	0.17	0.22	0.27	0.33	0.38	0.43	0.48	0.53	0.58	0.62	0.66	0.71	0.75	0.78	0.82	0.86	0.89	0.92	0.95	0.98	1.01	1.04	1.06	1.09	1.11	1.13	1.15	1.17	1.19	1.21	1.23	1.24	1.26	1.27	1.29	1.30	1.31	1.32	1.34	1.35	1.36	1.37	1.37	1.38	1.39	1.40	1.41	1.41	1.54
Households Consumption	HSS	0.14	0.20	0.26	0.32	0.38	0.43	0.48	0.53	0.57	0.62	0.66	0.70	0.74	0.78	0.82	0.85	0.89	0.92	0.95	0.98	1.01	1.03	1.06	1.08	1.11	1.13	1.15	1.17	1.19	1.21	1.22	1.24	1.26	1.27	1.28	1.30	1.31	1.32	1.33	1.34	1.35	1.36	1.37	1.38	1.39	1.40	1.41	1.41	1.42	1.54
Households Consumption	RET	0.16	0.20	0.26	0.32	0.37	0.42	0.47	0.52	0.57	0.61	0.66	0.70	0.74	0.78	0.81	0.85	0.88	0.92	0.95	0.98	1.00	1.03	1.06	1.08	1.10	1.13	1.15	1.17	1.19	1.21	1.22	1.24	1.25	1.27	1.28	1.30	1.31	1.32	1.33	1.34	1.35	1.36	1.37	1.38	1.39	1.40	1.41	1.41	1.42	1.54
Households Consumption	ELE	0.22	0.27	0.33	0.39	0.45	0.50	0.55	0.60	0.65	0.69	0.73	0.77	0.81	0.84	0.88	0.91	0.94	0.97	1.00	1.03	1.05	1.08	1.10	1.12	1.14	1.17	1.18	1.20	1.22	1.24	1.25	1.27	1.28	1.30	1.31	1.32	1.33	1.34	1.35	1.36	1.37	1.38	1.39	1.40	1.41	1.41	1.42	1.43	1.43	1.54
Households Consumption	OGK	0.30	0.36	0.42	0.48	0.54	0.59	0.64	0.69	0.73	0.77	0.81	0.85	0.88	0.91	0.95	0.98	1.01	1.03	1.06	1.08	1.11	1.13	1.15	1.17	1.19	1.21	1.23	1.24	1.26	1.27	1.29	1.30	1.31	1.32	1.34	1.35	1.36	1.37	1.38	1.38	1.39	1.40	1.41	1.42	1.42	1.43	1.43	1.44	1.45	1.54
Households Consumption	COAL	0.31	0.36	0.42	0.47	0.52	0.57	0.61	0.66	0.70	0.74	0.78	0.81	0.85	0.88	0.91	0.94	0.97	1.00	1.03	1.06	1.08	1.10	1.13	1.15	1.17	1.19	1.20	1.22	1.24	1.25	1.27	1.28	1.30	1.31	1.32	1.33	1.34	1.35	1.36	1.37	1.38	1.39	1.40	1.41	1.41	1.42	1.43	1.43	1.44	1.54
Capital Stock	AGR	Eps	0.24	0.47	0.69	0.89	1.07	1.25	1.41	1.56	1.69	1.82	1.95	2.06	2.17	2.27	2.36	2.45	2.53	2.61	2.68	2.75	2.82	2.88	2.94	2.99	3.04	3.09	3.14	3.18	3.22	3.26	3.30	3.33	3.36	3.40	3.43	3.45	3.48	3.50	3.53	3.55	3.57	3.59	3.61	3.63	3.64	3.66	3.68	3.69	3.94
Capital Stock	EXT	Eps	0.39	0.75	1.05	1.30	1.52	1.72	1.89	2.04	2.17	2.30	2.41	2.51	2.60	2.69	2.77	2.85	2.92	2.98	3.04	3.10	3.15	3.20	3.25	3.30	3.34	3.38	3.42	3.45	3.48	3.51	3.54	3.57	3.60	3.62	3.65	3.67	3.69	3.71	3.73	3.75	3.76	3.78	3.79	3.81	3.82	3.83	3.84	3.86	4.05
Capital Stock	FOO	Eps	0.13	0.28	0.45	0.62	0.78	0.95	1.12	1.28	1.44	1.59	1.74	1.88	2.01	2.14	2.27	2.38	2.50	2.60	2.71	2.80	2.90	2.99	3.07	3.15	3.22	3.30	3.36	3.43	3.49	3.55	3.60	3.65	3.70	3.75	3.79	3.84	3.88	3.91	3.95	3.98	4.01	4.04	4.07	4.10	4.13	4.15	4.17	4.20	4.58
Capital Stock	CLG	Eps	- 0.03	0.05	0.17	0.31	0.47	0.63	0.79	0.95	1.12	1.27	1.43	1.57	1.72	1.85	1.99	2.11	2.23	2.35	2.46	2.56	2.66	2.76	2.85	2.93	3.02	3.09	3.17	3.24	3.30	3.37	3.43	3.48	3.54	3.59	3.64	3.68	3.73	3.77	3.81	3.85	3.88	3.91	3.95	3.98	4.00	4.03	4.06	4.08	4.51
Capital Stock	WWP	Eps	0.07	0.18	0.32	0.46	0.60	0.75	0.89	1.04	1.18	1.31	1.45	1.57	1.70	1.82	1.93	2.04	2.15	2.25	2.34	2.43	2.52	2.60	2.68	2.76	2.83	2.90	2.96	3.02	3.08	3.14	3.19	3.24	3.29	3.33	3.38	3.42	3.46	3.49	3.53	3.56	3.59	3.62	3.65	3.68	3.70	3.72	3.75	3.77	4.15
Capital Stock	CHE	Eps	0.24	0.49	0.73	0.96	1.18	1.38	1.57	1.75	1.92	2.08	2.23	2.38	2.51	2.64	2.76	2.87	2.98	3.08	3.17	3.26	3.35	3.43	3.50	3.58	3.65	3.71	3.77	3.83	3.88	3.94	3.99	4.03	4.08	4.12	4.16	4.20	4.23	4.27	4.30	4.33	4.36	4.38	4.41	4.43	4.46	4.48	4.50	4.52	4.87
Capital Stock	PHA	Eps	0.18	0.40	0.62	0.83	1.03	1.23	1.41	1.58	1.74	1.90	2.04	2.18	2.31	2.43	2.55	2.66	2.76	2.86	2.95	3.04	3.12	3.20	3.27	3.35	3.41	3.48	3.54	3.59	3.65	3.70	3.75	3.79	3.84	3.88	3.92	3.95	3.99	4.02	4.05	4.08	4.11	4.14	4.16	4.19	4.21	4.23	4.25	4.27	4.61
Capital Stock	RUB	Eps	0.16	0.36	0.57	0.77	0.96	1.15	1.32	1.49	1.65	1.80	1.95	2.08	2.21	2.33	2.45	2.56	2.67	2.77	2.86	2.95	3.03	3.11	3.19	3.26	3.33	3.40	3.46	3.52	3.57	3.63	3.68	3.72	3.77	3.81	3.85	3.89	3.93	3.96	3.99	4.02	4.05	4.08	4.11	4.13	4.16	4.18	4.20	4.22	4.57
Capital Stock	CEM	- 0.00	- 0.02	0.04	0.13	0.24	0.36	0.48	0.61	0.73	0.85	0.97	1.08	1.19	1.29	1.38	1.47	1.56	1.64	1.72	1.79	1.86	1.93	1.99	2.05	2.11	2.16	2.21	2.26	2.31	2.35	2.39	2.43	2.46	2.50	2.53	2.56	2.59	2.62	2.65	2.67	2.70	2.72	2.74	2.76	2.78	2.80	2.81	2.83	2.84	3.11
Capital Stock	IRO	Eps	- 0.06	0.01	0.13	0.28	0.44	0.61	0.78	0.96	1.13	1.29	1.46	1.61	1.76	1.91	2.05	2.18	2.31	2.43	2.55	2.66	2.76	2.86	2.96	3.05	3.13	3.22	3.29	3.37	3.44	3.50	3.57	3.63	3.69	3.74	3.79	3.84	3.89	3.93	3.97	4.01	4.05	4.09	4.12	4.15	4.18	4.21	4.24	4.26	4.72
Capital Stock	MEQ	Eps	- 0.14	- 0.20	- 0.22	- 0.21	- 0.17	- 0.11	- 0.04	0.05	0.15	0.26	0.38	0.49	0.62	0.74	0.86	0.99	1.11	1.23	1.35	1.47	1.58	1.69	1.80	1.91	2.01	2.11	2.20	2.29	2.38	2.47	2.55	2.62	2.70	2.77	2.84	2.90	2.96	3.02	3.08	3.13	3.18	3.23	3.28	3.32	3.36	3.40	3.44	3.48	4.13
Capital Stock	AIR	Eps	- 0.22	- 0.38	- 0.49	- 0.56	- 0.60	- 0.61	- 0.60	- 0.57	- 0.52	- 0.46	- 0.39	- 0.31	- 0.22	- 0.13	- 0.03	0.08	0.18	0.29	0.40	0.52	0.63	0.74	0.85	0.96	1.07	1.17	1.28	1.38	1.48	1.57	1.67	1.76	1.85	1.93	2.02	2.10	2.18	2.25	2.32	2.39	2.46	2.53	2.59	2.65	2.70	2.76	2.81	2.86	3.88
Capital Stock	WAT	Eps	- 0.05	- 0.06	- 0.03	0.01	0.07	0.14	0.21	0.28	0.36	0.44	0.51	0.59	0.66	0.73	0.79	0.86	0.92	0.98	1.04	1.09	1.14	1.19	1.24	1.29	1.33	1.37	1.41	1.45	1.48	1.51	1.55	1.58	1.60	1.63	1.66	1.68	1.70	1.73	1.75	1.77	1.79	1.80	1.82	1.84	1.85	1.87	1.88	1.89	2.12
Capital Stock	CON	- 0.00	0.16	0.33	0.49	0.64	0.77	0.89	1.01	1.11	1.21	1.30	1.39	1.47	1.54	1.62	1.68	1.75	1.81	1.86	1.92	1.97	2.02	2.06	2.11	2.15	2.19	2.22	2.26	2.29	2.32	2.35	2.38	2.41	2.43	2.46	2.48	2.50	2.52	2.54	2.56	2.57	2.59	2.61	2.62	2.63	2.65	2.66	2.67	2.68	2.88
Capital Stock	DIS	- 0.00	0.08	0.17	0.27	0.37	0.47	0.57	0.67	0.76	0.85	0.94	1.03	1.11	1.20	1.27	1.35	1.42	1.49	1.56	1.62	1.68	1.74	1.79	1.84	1.90	1.94	1.99	2.03	2.07	2.11	2.15	2.19	2.22	2.25	2.28	2.31	2.34	2.37	2.39	2.42	2.44	2.46	2.48	2.50	2.52	2.54	2.55	2.57	2.58	2.85
Capital Stock	TRA	Eps	0.26	0.50	0.70	0.87	1.03	1.17	1.29	1.40	1.51	1.61	1.70	1.78	1.86	1.94	2.01	2.08	2.14	2.21	2.26	2.32	2.37	2.42	2.46	2.51	2.55	2.59	2.63	2.66	2.70	2.73	2.76	2.79	2.81	2.84	2.86	2.89	2.91	2.93	2.95	2.97	2.98	3.00	3.02	3.03	3.05	3.06	3.07	3.08	3.30
Capital Stock	COM	Eps	0.20	0.39	0.57	0.73	0.88	1.02	1.15	1.27	1.38	1.49	1.59	1.68	1.77	1.85	1.93	2.01	2.08	2.15	2.21	2.27	2.33	2.39	2.44	2.49	2.54	2.58	2.63	2.67	2.70	2.74	2.78	2.81	2.84	2.87	2.90	2.92	2.95	2.97	3.00	3.02	3.04	3.06	3.08	3.09	3.11	3.13	3.14	3.16	3.41
Capital Stock	PRS	Eps	0.14	0.29	0.45	0.60	0.75	0.89	1.02	1.15	1.26	1.38	1.49	1.59	1.69	1.78	1.87	1.96	2.04	2.11	2.19	2.26	2.32	2.39	2.45	2.50	2.56	2.61	2.66	2.71	2.75	2.79	2.83	2.87	2.91	2.94	2.98	3.01	3.04	3.07	3.09	3.12	3.14	3.16	3.19	3.21	3.22	3.24	3.26	3.28	3.57
Capital Stock	PHE	- 0.00	0.06	0.10	0.13	0.15	0.17	0.19	0.20	0.22	0.23	0.25	0.26	0.27	0.29	0.30	0.31	0.32	0.33	0.34	0.35	0.36	0.37	0.37	0.38	0.39	0.40	0.40	0.41	0.42	0.42	0.43	0.43	0.44	0.44	0.45	0.45	0.45	0.46	0.46	0.46	0.47	0.47	0.47	0.48	0.48	0.48	0.48	0.48	0.49	0.52
Capital Stock	OTH	Eps	0.07	0.16	0.24	0.33	0.41	0.49	0.57	0.65	0.73	0.80	0.87	0.94	1.01	1.07	1.13	1.19	1.24	1.29	1.34	1.39	1.44	1.48	1.52	1.56	1.60	1.63	1.67	1.70	1.73	1.76	1.79	1.82	1.84	1.86	1.89	1.91	1.93	1.95	1.97	1.98	2.00	2.02	2.03	2.05	2.06	2.07	2.08	2.10	2.30
Capital Stock	HSS	Eps	0.07	0.10	0.13	0.15	0.17	0.18	0.20	0.21	0.22	0.24	0.25	0.26	0.27	0.28	0.29	0.30	0.31	0.32	0.33	0.34	0.34	0.35	0.36	0.36	0.37	0.38	0.38	0.39	0.39	0.40	0.40	0.41	0.41	0.41	0.42	0.42	0.42	0.43	0.43	0.43	0.44	0.44	0.44	0.44	0.45	0.45	0.45	0.45	0.48
Capital Stock	RET	Eps	0.07	0.14	0.22	0.30	0.38	0.45	0.52	0.59	0.66	0.72	0.78	0.84	0.90	0.95	1.00	1.05	1.10	1.14	1.18	1.23	1.26	1.30	1.34	1.37	1.40	1.43	1.46	1.49	1.52	1.54	1.57	1.59	1.61	1.63	1.65	1.67	1.69	1.70	1.72	1.73	1.75	1.76	1.77	1.79	1.80	1.81	1.82	1.83	2.00
Capital Stock	ELE	Eps	0.24	0.47	0.67	0.85	1.02	1.17	1.31	1.44	1.56	1.68	1.78	1.88	1.98	2.07	2.15	2.23	2.31	2.38	2.45	2.52	2.58	2.64	2.69	2.75	2.80	2.85	2.89	2.94	2.98	3.02	3.05	3.09	3.12	3.15	3.19	3.21	3.24	3.27	3.29	3.32	3.34	3.36	3.38	3.40	3.41	3.43	3.45	3.46	3.73
Capital Stock	OGK	Eps	0.71	1.22	1.60	1.88	2.10	2.28	2.43	2.55	2.66	2.76	2.84	2.92	2.99	3.05	3.11	3.17	3.22	3.26	3.31	3.35	3.38	3.42	3.45	3.48	3.51	3.54	3.56	3.58	3.61	3.63	3.65	3.66	3.68	3.70	3.71	3.72	3.74	3.75	3.76	3.77	3.78	3.79	3.80	3.81	3.82	3.82	3.83	3.84	3.95
Capital Stock	COAL	Eps	0.38	0.67	0.89	1.08	1.24	1.38	1.51	1.63	1.74	1.85	1.95	2.04	2.13	2.21	2.29	2.37	2.44	2.51	2.58	2.64	2.70	2.76	2.81	2.87	2.91	2.96	3.01	3.05	3.09	3.12	3.16	3.19	3.23	3.26	3.29	3.31	3.34	3.37	3.39	3.41	3.43	3.45	3.47	3.49	3.51	3.52	3.54	3.55	3.81

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	LR
Total Output	AGR	0.45	0.68	0.89	1.08	1.26	1.42	1.57	1.71	1.85	1.97	2.08	2.19	2.29	2.38	2.47	2.55	2.63	2.70	2.77	2.84	2.90	2.96	3.01	3.06	3.11	3.15	3.20	3.24	3.28	3.31	3.35	3.38	3.41	3.44	3.46	3.49	3.51	3.54	3.56	3.58	3.60	3.62	3.64	3.65	3.67	3.68	3.70	3.71	3.72	3.94
Total Output	EXT	0.85	1.16	1.42	1.64	1.83	1.99	2.14	2.27	2.39	2.50	2.60	2.69	2.77	2.85	2.92	2.99	3.05	3.11	3.16	3.21	3.26	3.30	3.35	3.39	3.42	3.46	3.49	3.52	3.55	3.58	3.61	3.63	3.65	3.68	3.70	3.72	3.73	3.75	3.77	3.78	3.80	3.81	3.83	3.84	3.85	3.86	3.87	3.88	3.89	4.05
Total Output	FOO	0.17	0.36	0.53	0.71	0.88	1.05	1.21	1.37	1.53	1.68	1.82	1.96	2.09	2.22	2.34	2.46	2.57	2.67	2.77	2.87	2.96	3.04	3.12	3.20	3.27	3.34	3.41	3.47	3.53	3.58	3.64	3.69	3.73	3.78	3.82	3.86	3.90	3.94	3.97	4.00	4.04	4.06	4.09	4.12	4.14	4.17	4.19	4.21	4.23	4.58
Total Output	CLG	0.02	0.18	0.34	0.50	0.66	0.83	0.99	1.15	1.31	1.46	1.61	1.75	1.89	2.02	2.14	2.26	2.38	2.48	2.59	2.69	2.78	2.87	2.95	3.03	3.11	3.18	3.25	3.32	3.38	3.44	3.50	3.55	3.60	3.65	3.69	3.74	3.78	3.82	3.85	3.89	3.92	3.95	3.98	4.01	4.04	4.06	4.09	4.11	4.13	4.51
Total Output	WWP	0.10	0.25	0.40	0.55	0.69	0.84	0.99	1.13	1.27	1.40	1.53	1.66	1.78	1.90	2.01	2.11	2.22	2.31	2.41	2.49	2.58	2.66	2.74	2.81	2.88	2.94	3.01	3.07	3.12	3.18	3.23	3.28	3.32	3.36	3.41	3.45	3.48	3.52	3.55	3.58	3.61	3.64	3.67	3.69	3.72	3.74	3.76	3.78	3.80	4.15
Total Output	CHE	0.43	0.69	0.93	1.15	1.36	1.55	1.73	1.91	2.07	2.22	2.36	2.50	2.63	2.75	2.86	2.97	3.07	3.17	3.26	3.34	3.42	3.50	3.57	3.64	3.71	3.77	3.83	3.88	3.93	3.98	4.03	4.07	4.12	4.16	4.19	4.23	4.26	4.30	4.33	4.36	4.38	4.41	4.43	4.46	4.48	4.50	4.52	4.54	4.55	4.87
Total Output	PHA	0.34	0.59	0.81	1.02	1.22	1.40	1.57	1.74	1.89	2.04	2.18	2.31	2.43	2.55	2.66	2.76	2.86	2.95	3.04	3.12	3.20	3.28	3.35	3.41	3.48	3.54	3.59	3.65	3.70	3.75	3.79	3.84	3.88	3.92	3.95	3.99	4.02	4.05	4.08	4.11	4.14	4.16	4.19	4.21	4.23	4.25	4.27	4.29	4.31	4.61
Total Output	RUB	0.29	0.53	0.75	0.95	1.14	1.31	1.48	1.65	1.80	1.94	2.08	2.21	2.33	2.45	2.56	2.67	2.77	2.86	2.95	3.03	3.11	3.19	3.26	3.33	3.40	3.46	3.52	3.57	3.63	3.68	3.72	3.77	3.81	3.85	3.89	3.93	3.96	3.99	4.02	4.05	4.08	4.11	4.13	4.16	4.18	4.20	4.22	4.24	4.26	4.57
Total Output	CEM	- 0.01	0.10	0.21	0.34	0.46	0.59	0.72	0.84	0.96	1.07	1.18	1.28	1.38	1.47	1.56	1.64	1.72	1.79	1.86	1.93	1.99	2.05	2.11	2.16	2.21	2.26	2.30	2.35	2.39	2.43	2.46	2.50	2.53	2.56	2.59	2.62	2.65	2.67	2.69	2.72	2.74	2.76	2.78	2.80	2.81	2.83	2.84	2.86	2.87	3.11
Total Output	IRO	- 0.12	0.06	0.23	0.41	0.58	0.76	0.94	1.11	1.28	1.44	1.60	1.75	1.90	2.04	2.17	2.30	2.42	2.54	2.65	2.75	2.85	2.95	3.04	3.13	3.21	3.29	3.36	3.43	3.50	3.57	3.63	3.68	3.74	3.79	3.84	3.89	3.93	3.97	4.01	4.05	4.08	4.12	4.15	4.18	4.21	4.24	4.26	4.29	4.31	4.72
Total Output	MEQ	- 0.21	- 0.22	- 0.21	- 0.18	- 0.13	- 0.05	0.03	0.13	0.23	0.35	0.46	0.58	0.71	0.83	0.96	1.08	1.20	1.32	1.44	1.55	1.67	1.78	1.88	1.98	2.08	2.18	2.27	2.36	2.44	2.53	2.60	2.68	2.75	2.82	2.88	2.95	3.01	3.06	3.12	3.17	3.22	3.27	3.31	3.35	3.39	3.43	3.47	3.50	3.53	4.13
Total Output	AIR	- 0.26	- 0.37	- 0.45	- 0.50	- 0.52	- 0.52	- 0.50	- 0.46	- 0.40	- 0.34	- 0.26	- 0.18	- 0.09	0.01	0.11	0.21	0.32	0.43	0.54	0.65	0.75	0.86	0.97	1.08	1.18	1.28	1.39	1.48	1.58	1.67	1.76	1.85	1.94	2.02	2.10	2.18	2.25	2.33	2.39	2.46	2.53	2.59	2.65	2.70	2.76	2.81	2.86	2.91	2.96	3.88
Total Output	WAT	0.02	0.02	0.04	0.09	0.14	0.21	0.28	0.35	0.42	0.50	0.57	0.64	0.71	0.78	0.84	0.91	0.97	1.02	1.08	1.13	1.18	1.23	1.27	1.32	1.36	1.40	1.44	1.47	1.50	1.54	1.57	1.60	1.62	1.65	1.67	1.70	1.72	1.74	1.76	1.78	1.80	1.82	1.83	1.85	1.86	1.88	1.89	1.90	1.91	2.12
Total Output	CON	0.37	0.55	0.70	0.84	0.96	1.07	1.17	1.27	1.36	1.45	1.52	1.60	1.67	1.73	1.80	1.85	1.91	1.96	2.01	2.06	2.10	2.14	2.18	2.22	2.25	2.29	2.32	2.35	2.38	2.40	2.43	2.45	2.48	2.50	2.52	2.54	2.56	2.57	2.59	2.61	2.62	2.63	2.65	2.66	2.67	2.68	2.69	2.70	2.71	2.88
Total Output	DIS	0.15	0.26	0.36	0.47	0.57	0.66	0.76	0.85	0.94	1.03	1.11	1.19	1.27	1.34	1.42	1.49	1.55	1.62	1.68	1.73	1.79	1.84	1.89	1.94	1.99	2.03	2.07	2.11	2.15	2.19	2.22	2.25	2.28	2.31	2.34	2.37	2.39	2.42	2.44	2.46	2.48	2.50	2.52	2.54	2.55	2.57	2.58	2.60	2.61	2.85
Total Output	TRA	0.57	0.79	0.97	1.13	1.26	1.39	1.50	1.60	1.70	1.79	1.87	1.95	2.02	2.09	2.15	2.22	2.27	2.33	2.38	2.43	2.48	2.52	2.56	2.60	2.64	2.67	2.71	2.74	2.77	2.80	2.82	2.85	2.87	2.89	2.92	2.94	2.96	2.97	2.99	3.01	3.02	3.04	3.05	3.07	3.08	3.09	3.10	3.11	3.12	3.30
Total Output	COM	0.39	0.58	0.75	0.90	1.04	1.17	1.29	1.40	1.51	1.61	1.70	1.79	1.87	1.95	2.02	2.10	2.16	2.23	2.29	2.34	2.40	2.45	2.50	2.55	2.59	2.63	2.67	2.71	2.75	2.78	2.82	2.85	2.88	2.90	2.93	2.96	2.98	3.00	3.02	3.04	3.06	3.08	3.10	3.11	3.13	3.14	3.16	3.17	3.18	3.41
Total Output	PRS	0.25	0.43	0.59	0.73	0.87	1.01	1.13	1.25	1.37	1.47	1.58	1.68	1.77	1.86	1.95	2.03	2.10	2.18	2.25	2.32	2.38	2.44	2.50	2.55	2.60	2.65	2.70	2.75	2.79	2.83	2.87	2.91	2.94	2.97	3.00	3.03	3.06	3.09	3.11	3.14	3.16	3.18	3.20	3.22	3.24	3.26	3.28	3.29	3.31	3.57
Total Output	PHE	0.16	0.18	0.20	0.21	0.23	0.24	0.25	0.27	0.28	0.29	0.30	0.31	0.32	0.33	0.34	0.35	0.36	0.37	0.38	0.38	0.39	0.40	0.40	0.41	0.42	0.42	0.43	0.43	0.44	0.44	0.44	0.45	0.45	0.46	0.46	0.46	0.47	0.47	0.47	0.47	0.48	0.48	0.48	0.48	0.49	0.49	0.49	0.49	0.49	0.52
Total Output	OTH	0.09	0.18	0.26	0.35	0.43	0.51	0.59	0.67	0.75	0.82	0.89	0.96	1.02	1.08	1.14	1.20	1.25	1.30	1.35	1.40	1.45	1.49	1.53	1.57	1.61	1.64	1.68	1.71	1.74	1.77	1.79	1.82	1.85	1.87	1.89	1.91	1.93	1.95	1.97	1.99	2.01	2.02	2.04	2.05	2.06	2.08	2.09	2.10	2.11	2.30
Total Output	HSS	0.11	0.13	0.15	0.17	0.18	0.20	0.21	0.22	0.23	0.25	0.26	0.27	0.28	0.29	0.30	0.31	0.32	0.32	0.33	0.34	0.35	0.35	0.36	0.37	0.37	0.38	0.38	0.39	0.39	0.40	0.40	0.41	0.41	0.41	0.42	0.42	0.42	0.43	0.43	0.43	0.44	0.44	0.44	0.44	0.45	0.45	0.45	0.45	0.45	0.48
Total Output	RET	0.15	0.24	0.32	0.39	0.47	0.54	0.60	0.67	0.73	0.79	0.85	0.91	0.96	1.01	1.06	1.10	1.15	1.19	1.23	1.27	1.31	1.34	1.38	1.41	1.44	1.47	1.49	1.52	1.55	1.57	1.59	1.61	1.63	1.65	1.67	1.69	1.70	1.72	1.74	1.75	1.76	1.78	1.79	1.80	1.81	1.82	1.83	1.84	1.85	2.00
Total Output	ELE	0.56	0.77	0.95	1.12	1.27	1.41	1.53	1.65	1.76	1.86	1.96	2.05	2.14	2.22	2.30	2.37	2.44	2.51	2.57	2.63	2.69	2.74	2.79	2.84	2.89	2.93	2.97	3.01	3.05	3.08	3.12	3.15	3.18	3.21	3.24	3.26	3.29	3.31	3.33	3.36	3.38	3.39	3.41	3.43	3.45	3.46	3.48	3.49	3.50	3.73
Total Output	OGK	1.54	1.87	2.12	2.32	2.48	2.61	2.72	2.82	2.91	2.99	3.06	3.12	3.18	3.24	3.29	3.33	3.37	3.41	3.45	3.48	3.51	3.54	3.57	3.59	3.61	3.63	3.65	3.67	3.69	3.71	3.72	3.73	3.75	3.76	3.77	3.78	3.79	3.80	3.81	3.82	3.83	3.83	3.84	3.85	3.85	3.86	3.86	3.87	3.87	3.95
Total Output	COAL	0.92	1.12	1.27	1.41	1.54	1.66	1.77	1.87	1.97	2.07	2.16	2.24	2.32	2.40	2.47	2.54	2.60	2.66	2.72	2.78	2.83	2.88	2.93	2.98	3.02	3.06	3.10	3.14	3.17	3.21	3.24	3.27	3.30	3.32	3.35	3.37	3.40	3.42	3.44	3.46	3.48	3.50	3.51	3.53	3.54	3.56	3.57	3.58	3.59	3.81
Value Added	AGR	0.15	0.39	0.61	0.82	1.01	1.18	1.35	1.50	1.64	1.77	1.90	2.01	2.12	2.22	2.32	2.41	2.49	2.57	2.65	2.72	2.79	2.85	2.91	2.97	3.02	3.07	3.12	3.16	3.20	3.24	3.28	3.32	3.35	3.38	3.41	3.44	3.47	3.49	3.52	3.54	3.56	3.58	3.60	3.62	3.64	3.65	3.67	3.68	3.70	3.94
Value Added	EXT	0.48	0.83	1.11	1.35	1.56	1.75	1.91	2.06	2.19	2.31	2.41	2.51	2.61	2.69	2.77	2.85	2.91	2.98	3.04	3.10	3.15	3.20	3.25	3.29	3.33	3.37	3.41	3.45	3.48	3.51	3.54	3.57	3.59	3.62	3.64	3.67	3.69	3.71	3.73	3.74	3.76	3.78	3.79	3.80	3.82	3.83	3.84	3.85	3.86	4.05
Value Added	FOO	0.10	0.27	0.44	0.61	0.78	0.95	1.12	1.28	1.44	1.59	1.74	1.88	2.01	2.14	2.27	2.38	2.50	2.60	2.71	2.80	2.90	2.98	3.07	3.15	3.22	3.29	3.36	3.43	3.49	3.55	3.60	3.65	3.70	3.75	3.79	3.83	3.87	3.91	3.95	3.98	4.01	4.04	4.07	4.10	4.13	4.15	4.17	4.19	4.22	4.58
Value Added	CLG	- 0.11	0.05	0.20	0.35	0.52	0.68	0.85	1.01	1.17	1.33	1.48	1.63	1.77	1.91	2.04	2.16	2.28	2.39	2.50	2.60	2.70	2.79	2.88	2.96	3.04	3.12	3.19	3.26	3.33	3.39	3.45	3.50	3.56	3.61	3.65	3.70	3.74	3.78	3.82	3.86	3.89	3.93	3.96	3.99	4.01	4.04	4.07	4.09	4.11	4.51
Value Added	WWP	0.04	0.18	0.32	0.47	0.61	0.76	0.91	1.05	1.19	1.33	1.46	1.59	1.71	1.83	1.94	2.05	2.16	2.26	2.35	2.44	2.53	2.61	2.69	2.76	2.84	2.90	2.97	3.03	3.09	3.14	3.20	3.25	3.29	3.34	3.38	3.42	3.46	3.50	3.53	3.56	3.59	3.62	3.65	3.68	3.70	3.73	3.75	3.77	3.79	4.15
Value Added	CHE	0.23	0.50	0.74	0.97	1.18	1.38	1.57	1.75	1.92	2.08	2.23	2.37	2.51	2.63	2.75	2.87	2.97	3.07	3.17	3.26	3.34	3.42	3.50	3.57	3.64	3.71	3.77	3.83	3.88	3.93	3.98	4.03	4.07	4.12	4.16	4.19	4.23	4.26	4.30	4.33	4.35	4.38	4.41	4.43	4.46	4.48	4.50	4.52	4.54	4.87
Value Added	PHA	0.21	0.46	0.68	0.89	1.09	1.28	1.45	1.62	1.78	1.93	2.07	2.21	2.34	2.46	2.57	2.68	2.78	2.88	2.97	3.05	3.14	3.21	3.29	3.36	3.42	3.49	3.55	3.60	3.66	3.71	3.75	3.80	3.84	3.88	3.92	3.96	3.99	4.03	4.06	4.09	4.11	4.14	4.17	4.19	4.21	4.23	4.25	4.27	4.29	4.61
Value Added	RUB	0.18	0.42	0.63	0.83	1.02	1.20	1.37	1.54	1.70	1.84	1.98	2.12	2.25	2.37	2.48	2.59	2.69	2.79	2.88	2.97	3.05	3.13	3.21	3.28	3.35	3.41	3.47	3.53	3.59	3.64	3.69	3.73	3.78	3.82	3.86	3.90	3.93	3.97	4.00	4.03	4.06	4.09	4.11	4.14	4.16	4.18	4.20	4.22	4.24	4.57
Value Added	CEM	- 0.07	0.01	0.11	0.22	0.35	0.47	0.60	0.72	0.85	0.96	1.07	1.18	1.28	1.38	1.47	1.55	1.64	1.71	1.79	1.86	1.92	1.99	2.05	2.10	2.16	2.21	2.26	2.30	2.34	2.38	2.42	2.46	2.49	2.53	2.56	2.59	2.62	2.64	2.67	2.69	2.71	2.74	2.76	2.78	2.79	2.81	2.83	2.84	2.86	3.11
Value Added	IRO	- 0.17	0.00	0.16	0.33	0.50	0.68	0.86	1.03	1.20	1.37	1.53	1.68	1.83	1.97	2.11	2.24	2.36	2.48	2.59	2.70	2.80	2.90	3.00	3.08	3.17	3.25	3.33	3.40	3.47	3.53	3.59	3.65	3.71	3.76	3.81	3.86	3.91	3.95	3.99	4.03	4.07	4.10	4.13	4.17	4.19	4.22	4.25	4.27	4.30	4.72
Value Added	MEQ	- 0.23	- 0.26	- 0.26	- 0.24	- 0.20	- 0.13	- 0.05	0.04	0.15	0.26	0.38	0.50	0.62	0.75	0.87	1.00	1.12	1.24	1.36	1.48	1.59	1.71	1.81	1.92	2.02	2.12	2.21	2.30	2.39	2.47	2.55	2.63	2.71	2.78	2.84	2.91	2.97	3.03	3.08	3.14	3.19	3.24	3.28	3.33	3.37	3.41	3.44	3.48	3.51	4.13
Value Added	AIR	- 0.30	- 0.43	- 0.53	- 0.60	- 0.63	- 0.64	- 0.63	- 0.60	- 0.55	- 0.49	- 0.41	- 0.33	- 0.24	- 0.14	- 0.04	0.07	0.17	0.28	0.40	0.51	0.62	0.73	0.84	0.95	1.06	1.17	1.27	1.38	1.48	1.57	1.67	1.76	1.85	1.93	2.02	2.10	2.18	2.25	2.32	2.39	2.46	2.53	2.59	2.65	2.71	2.76	2.81	2.86	2.91	3.88
Value Added	WAT	- 0.05	- 0.07	- 0.06	- 0.02	0.03	0.09	0.16	0.23	0.31	0.39	0.46	0.54	0.61	0.68	0.75	0.82	0.88	0.94	1.00	1.06	1.11	1.16	1.21	1.26	1.30	1.34	1.38	1.42	1.46	1.49	1.52	1.56	1.58	1.61	1.64	1.67	1.69	1.71	1.73	1.75	1.77	1.79	1.81	1.83	1.84	1.86	1.87	1.88	1.90	2.12
Value Added	CON	0.14	0.33	0.49	0.63	0.76	0.88	1.00	1.10	1.20	1.29	1.37	1.46	1.53	1.60	1.67	1.73	1.80	1.85	1.91	1.96	2.01	2.05	2.10	2.14	2.18	2.22	2.25	2.28	2.32	2.35	2.37	2.40	2.43	2.45	2.47	2.49	2.52	2.53	2.55	2.57	2.59	2.60	2.62	2.63	2.64	2.66	2.67	2.68	2.69	2.88
Value Added	DIS	0.04	0.15	0.25	0.35	0.45	0.55	0.65	0.75	0.84	0.93	1.02	1.10	1.18	1.26	1.34	1.41	1.48	1.54	1.61	1.67	1.73	1.78	1.84	1.89	1.94	1.98	2.03	2.07	2.11	2.15	2.18	2.22	2.25	2.28	2.31	2.34	2.36	2.39	2.41	2.44	2.46	2.48	2.50	2.52	2.53	2.55	2.57	2.58	2.60	2.85
Value Added	TRA	0.31	0.55	0.74	0.91	1.05	1.18	1.30	1.41	1.52	1.61	1.70	1.79	1.87	1.94	2.01	2.08	2.14	2.20	2.26	2.32	2.37	2.42	2.46	2.51	2.55	2.59	2.62	2.66	2.69	2.73	2.76	2.78	2.81	2.84	2.86	2.88	2.91	2.93	2.95	2.97	2.98	3.00	3.02	3.03	3.05	3.06	3.07	3.08	3.10	3.30
Value Added	COM	0.16	0.36	0.54	0.71	0.86	1.00	1.13	1.25	1.36	1.47	1.57	1.66	1.75	1.83	1.91	1.99	2.06	2.13	2.20	2.26	2.32	2.37	2.43	2.48	2.52	2.57	2.61	2.65	2.69	2.73	2.77	2.80	2.83	2.86	2.89	2.92	2.94	2.97	2.99	3.01	3.03	3.05	3.07	3.09	3.11	3.12	3.14	3.15	3.17	3.41
Value Added	PRS	0.13	0.31	0.48	0.63	0.77	0.91	1.04	1.16	1.28	1.39	1.50	1.60	1.70	1.79	1.88	1.96	2.04	2.12	2.19	2.26	2.33	2.39	2.45	2.51	2.56	2.61	2.66	2.71	2.75	2.80	2.84	2.87	2.91	2.95	2.98	3.01	3.04	3.07	3.09	3.12	3.14	3.16	3.19	3.21	3.23	3.24	3.26	3.28	3.29	3.57
Value Added	PHE	0.03	0.07	0.09	0.11	0.13	0.15	0.17	0.18	0.20	0.21	0.23	0.24	0.26	0.27	0.28	0.29	0.30	0.32	0.33	0.34	0.34	0.35	0.36	0.37	0.38	0.39	0.39	0.40	0.41	0.41	0.42	0.42	0.43	0.43	0.44	0.44	0.45	0.45	0.45	0.46	0.46	0.46	0.47	0.47	0.47	0.48	0.48	0.48	0.48	0.52
Value Added	OTH	0.02	0.11	0.19	0.28	0.36	0.45	0.53	0.61	0.68	0.76	0.83	0.90	0.97	1.03	1.09	1.15	1.21	1.26	1.31	1.36	1.41	1.45	1.50	1.54	1.58	1.61	1.65	1.68	1.71	1.74	1.77	1.80	1.83	1.85	1.87	1.90	1.92	1.94	1.96	1.97	1.99	2.01	2.02	2.04	2.05	2.07	2.08	2.09	2.10	2.30
Value Added	HSS	0.04	0.08	0.10	0.12	0.13	0.15	0.16	0.18	0.19	0.21	0.22	0.23	0.24	0.25	0.27	0.28	0.29	0.30	0.30	0.31	0.32	0.33	0.34	0.35	0.35	0.36	0.37	0.37	0.38	0.38	0.39	0.39	0.40	0.40	0.41	0.41	0.41	0.42	0.42	0.42	0.43	0.43	0.43	0.44	0.44	0.44	0.44	0.45	0.45	0.48
Value Added	RET	0.04	0.13	0.21	0.29	0.37	0.44	0.51	0.58	0.65	0.71	0.77	0.83	0.89	0.94	0.99	1.04	1.09	1.13	1.18	1.22	1.26	1.29	1.33	1.36	1.40	1.43	1.46	1.48	1.51	1.54	1.56	1.58	1.61	1.63	1.65	1.66	1.68	1.70	1.71	1.73	1.74	1.76	1.77	1.78	1.79	1.81	1.82	1.83	1.84	2.00
Value Added	ELE	0.13	0.37	0.58	0.77	0.94	1.10	1.25	1.38	1.51	1.62	1.73	1.83	1.93	2.02	2.11	2.19	2.27	2.35	2.42	2.48	2.55	2.61	2.66	2.72	2.77	2.82	2.87	2.91	2.96	3.00	3.03	3.07	3.11	3.14	3.17	3.20	3.23	3.25	3.28	3.30	3.33	3.35	3.37	3.39	3.41	3.42	3.44	3.45	3.47	3.73
Value Added	OGK	1.08	1.49	1.79	2.02	2.20	2.35	2.48	2.59	2.69	2.77	2.86	2.93	3.00	3.06	3.11	3.17	3.22	3.26	3.30	3.34	3.38	3.41	3.45	3.48	3.51	3.53	3.56	3.58	3.60	3.62	3.64	3.66	3.68	3.69	3.71	3.72	3.73	3.75	3.76	3.77	3.78	3.79	3.80	3.81	3.81	3.82	3.83	3.84	3.84	3.95
Value Added	COAL	0.64	0.87	1.04	1.19	1.33	1.45	1.57	1.68	1.79	1.89	1.99	2.08	2.17	2.25	2.33	2.40	2.47	2.54	2.61	2.67	2.73	2.78	2.83	2.88	2.93	2.98	3.02	3.06	3.10	3.14	3.17	3.21	3.24	3.27	3.30	3.32	3.35	3.37	3.40	3.42	3.44	3.46	3.48	3.49	3.51	3.53	3.54	3.56	3.57	3.81

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	LR
Employment	AGR	0.40	0.64	0.84	1.03	1.20	1.36	1.51	1.65	1.78	1.90	2.02	2.12	2.23	2.32	2.41	2.49	2.57	2.65	2.72	2.78	2.85	2.91	2.96	3.02	3.07	3.11	3.16	3.20	3.24	3.28	3.31	3.35	3.38	3.41	3.44	3.46	3.49	3.51	3.54	3.56	3.58	3.60	3.62	3.63	3.65	3.67	3.68	3.69	3.71	3.94
Employment	EXT	0.71	1.03	1.29	1.50	1.69	1.85	2.00	2.14	2.26	2.37	2.47	2.56	2.65	2.73	2.81	2.88	2.95	3.01	3.07	3.12	3.17	3.22	3.27	3.31	3.35	3.39	3.43	3.46	3.49	3.52	3.55	3.58	3.61	3.63	3.65	3.67	3.69	3.71	3.73	3.75	3.77	3.78	3.80	3.81	3.82	3.84	3.85	3.86	3.87	4.05
Employment	FOO	0.17	0.37	0.55	0.73	0.90	1.07	1.23	1.39	1.54	1.69	1.83	1.97	2.10	2.23	2.35	2.46	2.57	2.67	2.77	2.87	2.96	3.04	3.12	3.20	3.27	3.34	3.41	3.47	3.53	3.58	3.64	3.69	3.73	3.78	3.82	3.86	3.90	3.94	3.97	4.00	4.03	4.06	4.09	4.12	4.14	4.17	4.19	4.21	4.23	4.58
Employment	CLG	- 0.13	0.06	0.23	0.40	0.56	0.73	0.90	1.06	1.22	1.38	1.53	1.68	1.81	1.95	2.08	2.20	2.31	2.43	2.53	2.63	2.73	2.82	2.91	2.99	3.07	3.14	3.21	3.28	3.35	3.41	3.47	3.52	3.57	3.62	3.67	3.71	3.76	3.80	3.83	3.87	3.90	3.94	3.97	4.00	4.02	4.05	4.07	4.10	4.12	4.51
Employment	WWP	0.06	0.23	0.39	0.54	0.69	0.84	0.98	1.13	1.26	1.40	1.53	1.65	1.78	1.89	2.00	2.11	2.21	2.31	2.40	2.49	2.57	2.65	2.73	2.80	2.87	2.94	3.00	3.06	3.12	3.17	3.22	3.27	3.32	3.36	3.40	3.44	3.48	3.51	3.55	3.58	3.61	3.64	3.67	3.69	3.72	3.74	3.76	3.78	3.80	4.15
Employment	CHE	0.40	0.68	0.91	1.13	1.34	1.53	1.71	1.88	2.04	2.19	2.34	2.47	2.60	2.72	2.83	2.94	3.04	3.14	3.23	3.32	3.40	3.48	3.55	3.62	3.69	3.75	3.81	3.86	3.92	3.97	4.01	4.06	4.10	4.14	4.18	4.22	4.25	4.28	4.32	4.34	4.37	4.40	4.42	4.45	4.47	4.49	4.51	4.53	4.55	4.87
Employment	PHA	0.28	0.55	0.78	0.99	1.18	1.36	1.53	1.70	1.85	2.00	2.14	2.27	2.39	2.51	2.62	2.72	2.82	2.92	3.01	3.09	3.17	3.25	3.32	3.39	3.45	3.51	3.57	3.63	3.68	3.73	3.77	3.82	3.86	3.90	3.94	3.97	4.01	4.04	4.07	4.10	4.13	4.15	4.18	4.20	4.22	4.24	4.26	4.28	4.30	4.61
Employment	RUB	0.24	0.50	0.71	0.91	1.10	1.28	1.44	1.61	1.76	1.90	2.04	2.17	2.29	2.41	2.52	2.63	2.73	2.83	2.92	3.00	3.09	3.16	3.24	3.31	3.37	3.44	3.50	3.55	3.61	3.66	3.71	3.75	3.79	3.84	3.87	3.91	3.95	3.98	4.01	4.04	4.07	4.10	4.12	4.15	4.17	4.19	4.21	4.23	4.25	4.57
Employment	CEM	- 0.12	0.03	0.16	0.29	0.42	0.55	0.68	0.80	0.92	1.03	1.14	1.24	1.34	1.43	1.52	1.61	1.69	1.76	1.83	1.90	1.96	2.02	2.08	2.14	2.19	2.24	2.28	2.33	2.37	2.41	2.45	2.48	2.51	2.55	2.58	2.61	2.63	2.66	2.68	2.71	2.73	2.75	2.77	2.79	2.80	2.82	2.84	2.85	2.86	3.11
Employment	IRO	- 0.20	0.01	0.19	0.37	0.55	0.73	0.90	1.08	1.25	1.41	1.57	1.72	1.87	2.01	2.14	2.27	2.40	2.51	2.62	2.73	2.83	2.93	3.02	3.11	3.19	3.27	3.35	3.42	3.49	3.55	3.61	3.67	3.72	3.78	3.83	3.87	3.92	3.96	4.00	4.04	4.08	4.11	4.14	4.17	4.20	4.23	4.26	4.28	4.30	4.72
Employment	MEQ	- 0.35	- 0.33	- 0.30	- 0.25	- 0.19	- 0.11	- 0.01	0.09	0.20	0.32	0.44	0.57	0.69	0.82	0.95	1.07	1.19	1.32	1.44	1.55	1.66	1.77	1.88	1.98	2.08	2.18	2.27	2.36	2.45	2.53	2.61	2.68	2.75	2.82	2.89	2.95	3.01	3.07	3.12	3.17	3.22	3.27	3.31	3.35	3.39	3.43	3.47	3.50	3.54	4.13
Employment	AIR	- 0.53	- 0.60	- 0.65	- 0.68	- 0.69	- 0.68	- 0.64	- 0.59	- 0.53	- 0.46	- 0.37	- 0.28	- 0.18	- 0.08	0.03	0.14	0.25	0.37	0.48	0.59	0.71	0.82	0.93	1.04	1.15	1.25	1.35	1.46	1.55	1.65	1.74	1.83	1.92	2.00	2.08	2.16	2.24	2.31	2.38	2.45	2.52	2.58	2.64	2.70	2.75	2.80	2.86	2.90	2.95	3.88
Employment	WAT	- 0.18	- 0.12	- 0.07	- 0.00	0.07	0.15	0.23	0.31	0.39	0.46	0.54	0.61	0.68	0.75	0.82	0.88	0.94	1.00	1.06	1.11	1.16	1.21	1.26	1.30	1.34	1.38	1.42	1.46	1.49	1.52	1.56	1.59	1.61	1.64	1.67	1.69	1.71	1.73	1.75	1.77	1.79	1.81	1.83	1.84	1.86	1.87	1.88	1.90	1.91	2.12
Employment	CON	0.24	0.44	0.59	0.73	0.85	0.96	1.07	1.16	1.26	1.34	1.42	1.50	1.57	1.64	1.71	1.77	1.83	1.88	1.94	1.99	2.03	2.08	2.12	2.16	2.20	2.23	2.27	2.30	2.33	2.36	2.39	2.41	2.44	2.46	2.48	2.51	2.53	2.54	2.56	2.58	2.59	2.61	2.62	2.64	2.65	2.66	2.67	2.69	2.70	2.88
Employment	DIS	0.07	0.20	0.31	0.41	0.51	0.61	0.71	0.80	0.89	0.98	1.07	1.15	1.23	1.31	1.38	1.45	1.52	1.58	1.65	1.70	1.76	1.82	1.87	1.92	1.96	2.01	2.05	2.09	2.13	2.17	2.20	2.24	2.27	2.30	2.33	2.35	2.38	2.40	2.43	2.45	2.47	2.49	2.51	2.53	2.54	2.56	2.58	2.59	2.60	2.85
Employment	TRA	0.44	0.67	0.84	0.99	1.13	1.25	1.36	1.46	1.56	1.65	1.74	1.82	1.90	1.97	2.04	2.11	2.17	2.23	2.28	2.34	2.39	2.43	2.48	2.52	2.56	2.60	2.64	2.67	2.71	2.74	2.77	2.79	2.82	2.85	2.87	2.89	2.91	2.93	2.95	2.97	2.99	3.01	3.02	3.04	3.05	3.06	3.08	3.09	3.10	3.30
Employment	COM	0.32	0.52	0.69	0.84	0.97	1.10	1.22	1.34	1.44	1.54	1.64	1.73	1.81	1.89	1.97	2.04	2.11	2.18	2.24	2.30	2.36	2.41	2.46	2.51	2.56	2.60	2.64	2.68	2.72	2.76	2.79	2.82	2.85	2.88	2.91	2.94	2.96	2.98	3.01	3.03	3.05	3.07	3.08	3.10	3.12	3.13	3.15	3.16	3.17	3.41
Employment	PRS	0.19	0.39	0.55	0.70	0.84	0.97	1.10	1.22	1.33	1.44	1.55	1.64	1.74	1.83	1.92	2.00	2.08	2.15	2.22	2.29	2.36	2.42	2.48	2.53	2.59	2.64	2.68	2.73	2.77	2.81	2.85	2.89	2.93	2.96	2.99	3.02	3.05	3.08	3.10	3.13	3.15	3.17	3.20	3.22	3.23	3.25	3.27	3.28	3.30	3.57
Employment	PHE	0.04	0.07	0.09	0.11	0.13	0.15	0.16	0.18	0.20	0.21	0.23	0.24	0.25	0.27	0.28	0.29	0.30	0.31	0.32	0.33	0.34	0.35	0.36	0.37	0.38	0.38	0.39	0.40	0.40	0.41	0.42	0.42	0.43	0.43	0.44	0.44	0.45	0.45	0.45	0.46	0.46	0.46	0.47	0.47	0.47	0.48	0.48	0.48	0.48	0.52
Employment	OTH	0.07	0.18	0.27	0.35	0.44	0.52	0.60	0.68	0.75	0.82	0.89	0.96	1.03	1.09	1.15	1.20	1.26	1.31	1.36	1.40	1.45	1.49	1.53	1.57	1.61	1.64	1.68	1.71	1.74	1.77	1.80	1.82	1.85	1.87	1.89	1.91	1.93	1.95	1.97	1.99	2.01	2.02	2.04	2.05	2.06	2.08	2.09	2.10	2.11	2.30
Employment	HSS	0.05	0.08	0.10	0.11	0.13	0.14	0.16	0.17	0.19	0.20	0.21	0.23	0.24	0.25	0.26	0.27	0.28	0.29	0.30	0.31	0.32	0.33	0.33	0.34	0.35	0.36	0.36	0.37	0.37	0.38	0.39	0.39	0.40	0.40	0.40	0.41	0.41	0.42	0.42	0.42	0.43	0.43	0.43	0.43	0.44	0.44	0.44	0.44	0.45	0.48
Employment	RET	0.05	0.16	0.24	0.32	0.39	0.47	0.54	0.61	0.67	0.73	0.79	0.85	0.91	0.96	1.01	1.06	1.10	1.15	1.19	1.23	1.27	1.31	1.34	1.38	1.41	1.44	1.47	1.49	1.52	1.55	1.57	1.59	1.61	1.63	1.65	1.67	1.69	1.70	1.72	1.74	1.75	1.76	1.78	1.79	1.80	1.81	1.82	1.83	1.84	2.00
Employment	ELE	0.40	0.63	0.81	0.98	1.13	1.27	1.40	1.52	1.63	1.74	1.84	1.94	2.03	2.11	2.19	2.27	2.35	2.42	2.48	2.55	2.61	2.66	2.72	2.77	2.82	2.87	2.91	2.95	3.00	3.03	3.07	3.10	3.14	3.17	3.20	3.23	3.25	3.28	3.30	3.32	3.35	3.37	3.39	3.40	3.42	3.44	3.45	3.47	3.48	3.73
Employment	OGK	1.33	1.67	1.92	2.11	2.27	2.40	2.52	2.62	2.72	2.80	2.88	2.95	3.01	3.07	3.13	3.18	3.23	3.27	3.31	3.35	3.39	3.42	3.45	3.48	3.51	3.54	3.56	3.58	3.60	3.62	3.64	3.66	3.68	3.69	3.71	3.72	3.73	3.75	3.76	3.77	3.78	3.79	3.80	3.81	3.81	3.82	3.83	3.84	3.84	3.95
Employment	COAL	0.67	0.89	1.06	1.21	1.34	1.47	1.58	1.69	1.80	1.90	2.00	2.09	2.17	2.25	2.33	2.41	2.48	2.55	2.61	2.67	2.73	2.78	2.84	2.89	2.94	2.98	3.02	3.06	3.10	3.14	3.18	3.21	3.24	3.27	3.30	3.33	3.35	3.38	3.40	3.42	3.44	3.46	3.48	3.50	3.51	3.53	3.54	3.56	3.57	3.81
Total Import	AGR	2.50	2.49	2.49	2.49	2.50	2.51	2.53	2.55	2.58	2.60	2.63	2.65	2.68	2.71	2.73	2.76	2.79	2.81	2.84	2.86	2.88	2.90	2.93	2.95	2.97	2.98	3.00	3.02	3.04	3.05	3.07	3.08	3.10	3.11	3.12	3.13	3.14	3.15	3.16	3.17	3.18	3.19	3.20	3.21	3.22	3.22	3.23	3.24	3.24	3.35
Total Import	EXT	2.02	1.98	1.96	1.96	1.97	2.00	2.03	2.06	2.10	2.14	2.18	2.22	2.26	2.30	2.34	2.37	2.41	2.44	2.48	2.51	2.54	2.57	2.60	2.63	2.65	2.68	2.70	2.73	2.75	2.77	2.79	2.81	2.83	2.84	2.86	2.87	2.89	2.90	2.92	2.93	2.94	2.95	2.96	2.97	2.98	2.99	3.00	3.01	3.02	3.16
Total Import	FOO	2.59	2.58	2.58	2.57	2.57	2.56	2.56	2.55	2.55	2.54	2.54	2.53	2.53	2.53	2.52	2.52	2.52	2.51	2.51	2.51	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.49	2.49	2.49	2.49	2.49	2.49	2.49	2.49	2.49	2.49	2.49	2.49	2.49	2.49	2.49	2.49	2.49	2.49	2.49	2.49	2.49	2.49
Total Import	CLG	1.85	1.86	1.87	1.87	1.88	1.89	1.89	1.89	1.89	1.90	1.90	1.90	1.90	1.91	1.91	1.91	1.91	1.92	1.92	1.92	1.92	1.93	1.93	1.93	1.93	1.94	1.94	1.94	1.94	1.95	1.95	1.95	1.95	1.96	1.96	1.96	1.96	1.96	1.97	1.97	1.97	1.97	1.97	1.97	1.98	1.98	1.98	1.98	1.98	2.00
Total Import	WWP	2.61	2.64	2.66	2.68	2.69	2.70	2.71	2.72	2.73	2.73	2.74	2.75	2.75	2.76	2.76	2.77	2.77	2.78	2.78	2.79	2.79	2.79	2.80	2.80	2.80	2.81	2.81	2.81	2.82	2.82	2.82	2.83	2.83	2.83	2.83	2.84	2.84	2.84	2.84	2.84	2.85	2.85	2.85	2.85	2.85	2.85	2.86	2.86	2.86	2.88
Total Import	CHE	2.71	2.77	2.83	2.89	2.95	3.01	3.07	3.12	3.18	3.23	3.28	3.33	3.37	3.42	3.46	3.50	3.55	3.58	3.62	3.66	3.69	3.72	3.75	3.78	3.81	3.84	3.86	3.89	3.91	3.93	3.95	3.97	3.99	4.01	4.03	4.04	4.06	4.07	4.09	4.10	4.11	4.12	4.13	4.14	4.15	4.16	4.17	4.18	4.19	4.33
Total Import	PHA	2.38	2.31	2.27	2.23	2.19	2.16	2.14	2.11	2.09	2.07	2.05	2.03	2.02	2.01	1.99	1.98	1.97	1.96	1.95	1.95	1.94	1.93	1.93	1.92	1.92	1.91	1.91	1.90	1.90	1.90	1.89	1.89	1.89	1.89	1.88	1.88	1.88	1.88	1.88	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.86	1.86	1.85
Total Import	RUB	2.54	2.54	2.54	2.54	2.54	2.55	2.56	2.57	2.58	2.60	2.62	2.63	2.65	2.67	2.69	2.70	2.72	2.74	2.76	2.77	2.79	2.81	2.82	2.84	2.85	2.87	2.88	2.89	2.90	2.92	2.93	2.94	2.95	2.96	2.97	2.98	2.99	3.00	3.00	3.01	3.02	3.03	3.03	3.04	3.04	3.05	3.05	3.06	3.06	3.15
Total Import	CEM	2.53	2.67	2.74	2.78	2.80	2.81	2.81	2.81	2.80	2.79	2.78	2.77	2.76	2.76	2.75	2.74	2.73	2.72	2.72	2.71	2.71	2.70	2.70	2.69	2.69	2.68	2.68	2.67	2.67	2.67	2.67	2.66	2.66	2.66	2.65	2.65	2.65	2.65	2.65	2.65	2.64	2.64	2.64	2.64	2.64	2.64	2.64	2.63	2.63	2.62
Total Import	IRO	2.44	2.54	2.60	2.63	2.67	2.70	2.73	2.75	2.78	2.81	2.84	2.86	2.89	2.92	2.94	2.97	2.99	3.02	3.04	3.07	3.09	3.11	3.13	3.15	3.17	3.19	3.21	3.23	3.24	3.26	3.28	3.29	3.30	3.32	3.33	3.34	3.35	3.37	3.38	3.39	3.40	3.41	3.41	3.42	3.43	3.44	3.44	3.45	3.46	3.58
Total Import	MEQ	2.10	2.26	2.36	2.44	2.51	2.57	2.62	2.66	2.70	2.73	2.75	2.78	2.80	2.81	2.82	2.83	2.84	2.85	2.86	2.86	2.86	2.87	2.87	2.87	2.87	2.87	2.87	2.87	2.87	2.87	2.87	2.87	2.87	2.86	2.86	2.86	2.86	2.86	2.86	2.86	2.85	2.85	2.85	2.85	2.85	2.85	2.85	2.85	2.84	2.82
Total Import	AIR	1.53	1.65	1.75	1.84	1.92	1.99	2.05	2.11	2.16	2.20	2.24	2.27	2.30	2.33	2.35	2.37	2.38	2.40	2.41	2.42	2.43	2.43	2.44	2.44	2.45	2.45	2.45	2.45	2.45	2.45	2.45	2.45	2.45	2.45	2.45	2.44	2.44	2.44	2.44	2.43	2.43	2.43	2.43	2.42	2.42	2.42	2.41	2.41	2.41	2.34
Total Import	WAT	1.55	1.73	1.88	1.98	2.04	2.08	2.11	2.12	2.12	2.11	2.11	2.09	2.08	2.07	2.05	2.04	2.03	2.01	2.00	1.98	1.97	1.96	1.95	1.94	1.93	1.92	1.91	1.90	1.89	1.89	1.88	1.87	1.86	1.86	1.85	1.85	1.84	1.84	1.83	1.83	1.82	1.82	1.82	1.81	1.81	1.81	1.80	1.80	1.80	1.75
Total Import	CON	2.30	2.34	2.33	2.31	2.30	2.29	2.29	2.29	2.29	2.30	2.30	2.31	2.32	2.33	2.34	2.35	2.36	2.37	2.38	2.39	2.40	2.41	2.42	2.43	2.43	2.44	2.45	2.46	2.46	2.47	2.48	2.48	2.49	2.50	2.50	2.51	2.51	2.52	2.52	2.53	2.53	2.54	2.54	2.54	2.55	2.55	2.55	2.56	2.56	2.61
Total Import	DIS	2.26	2.23	2.21	2.19	2.18	2.16	2.15	2.14	2.13	2.12	2.11	2.10	2.09	2.08	2.07	2.07	2.06	2.05	2.05	2.04	2.04	2.03	2.03	2.03	2.02	2.02	2.02	2.01	2.01	2.01	2.01	2.00	2.00	2.00	2.00	2.00	2.00	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.98	1.98	1.98	1.98	1.97
Total Import	TRA	2.06	1.97	1.92	1.89	1.87	1.87	1.87	1.88	1.89	1.91	1.93	1.95	1.97	1.99	2.02	2.04	2.06	2.09	2.11	2.13	2.15	2.18	2.20	2.22	2.24	2.26	2.27	2.29	2.31	2.33	2.34	2.36	2.37	2.39	2.40	2.41	2.42	2.44	2.45	2.46	2.47	2.48	2.49	2.50	2.50	2.51	2.52	2.53	2.53	2.66
Total Import	COM	2.62	2.57	2.53	2.51	2.50	2.49	2.48	2.48	2.48	2.48	2.49	2.50	2.50	2.51	2.52	2.53	2.54	2.55	2.56	2.57	2.58	2.59	2.60	2.61	2.62	2.63	2.63	2.64	2.65	2.66	2.66	2.67	2.68	2.68	2.69	2.70	2.70	2.71	2.71	2.72	2.72	2.72	2.73	2.73	2.74	2.74	2.74	2.75	2.75	2.81
Total Import	PRS	2.80	2.83	2.84	2.84	2.84	2.84	2.85	2.85	2.85	2.85	2.86	2.86	2.87	2.87	2.87	2.88	2.88	2.89	2.89	2.89	2.90	2.90	2.91	2.91	2.91	2.92	2.92	2.92	2.92	2.93	2.93	2.93	2.93	2.94	2.94	2.94	2.94	2.94	2.95	2.95	2.95	2.95	2.95	2.95	2.96	2.96	2.96	2.96	2.96	2.98
Total Import	PHE	2.23	2.16	2.16	2.18	2.20	2.22	2.24	2.26	2.28	2.29	2.31	2.33	2.35	2.37	2.38	2.40	2.42	2.43	2.44	2.46	2.47	2.49	2.50	2.51	2.52	2.53	2.54	2.55	2.56	2.57	2.58	2.59	2.60	2.61	2.62	2.62	2.63	2.64	2.64	2.65	2.65	2.66	2.66	2.67	2.67	2.68	2.68	2.69	2.69	2.76
Total Import	OTH	2.75	2.76	2.76	2.75	2.74	2.73	2.72	2.71	2.69	2.68	2.67	2.65	2.64	2.63	2.62	2.60	2.59	2.58	2.57	2.56	2.55	2.54	2.53	2.53	2.52	2.51	2.50	2.50	2.49	2.48	2.48	2.47	2.47	2.46	2.46	2.45	2.45	2.44	2.44	2.44	2.43	2.43	2.43	2.42	2.42	2.42	2.42	2.41	2.41	2.37
Total Import	HSS	2.44	2.25	2.17	2.13	2.10	2.07	2.05	2.02	2.00	1.98	1.96	1.94	1.92	1.91	1.89	1.87	1.86	1.84	1.83	1.82	1.81	1.79	1.78	1.77	1.76	1.75	1.74	1.74	1.73	1.72	1.71	1.71	1.70	1.69	1.69	1.68	1.68	1.67	1.67	1.66	1.66	1.66	1.65	1.65	1.65	1.64	1.64	1.64	1.63	1.59
Total Import	RET	2.44	2.37	2.34	2.32	2.30	2.29	2.28	2.27	2.26	2.25	2.25	2.24	2.24	2.23	2.23	2.22	2.22	2.22	2.22	2.22	2.21	2.21	2.21	2.21	2.21	2.21	2.21	2.21	2.21	2.21	2.21	2.21	2.21	2.21	2.21	2.21	2.21	2.21	2.21	2.21	2.21	2.21	2.21	2.21	2.21	2.21	2.21	2.21	2.21	2.22
Total Import	ELE	1.82	1.80	1.82	1.85	1.89	1.93	1.98	2.03	2.08	2.13	2.18	2.23	2.28	2.33	2.38	2.42	2.47	2.51	2.55	2.59	2.63	2.66	2.70	2.73	2.77	2.80	2.83	2.85	2.88	2.91	2.93	2.96	2.98	3.00	3.02	3.04	3.06	3.08	3.09	3.11	3.12	3.14	3.15	3.17	3.18	3.19	3.20	3.21	3.22	3.40
Total Import	OGK	1.99	1.99	2.01	2.03	2.07	2.10	2.14	2.18	2.22	2.26	2.30	2.34	2.38	2.41	2.45	2.49	2.52	2.55	2.59	2.62	2.65	2.68	2.70	2.73	2.76	2.78	2.81	2.83	2.85	2.87	2.89	2.91	2.93	2.95	2.96	2.98	2.99	3.01	3.02	3.03	3.05	3.06	3.07	3.08	3.09	3.10	3.11	3.12	3.13	3.28
Total Import	COAL	1.77	1.77	1.79	1.83	1.87	1.92	1.96	2.01	2.05	2.09	2.13	2.17	2.21	2.25	2.29	2.32	2.36	2.39	2.42	2.45	2.48	2.51	2.54	2.56	2.59	2.61	2.64	2.66	2.68	2.70	2.72	2.74	2.75	2.77	2.79	2.80	2.82	2.83	2.84	2.85	2.87	2.88	2.89	2.90	2.91	2.92	2.93	2.93	2.94	3.08

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	LR
Total Export	AGR	2.89	3.06	3.21	3.34	3.46	3.57	3.67	3.76	3.85	3.92	3.99	4.06	4.12	4.17	4.22	4.27	4.31	4.35	4.39	4.43	4.46	4.49	4.52	4.55	4.57	4.60	4.62	4.64	4.66	4.68	4.70	4.72	4.73	4.75	4.76	4.77	4.79	4.80	4.81	4.82	4.83	4.84	4.85	4.86	4.86	4.87	4.88	4.89	4.89	5.00
Total Export	EXT	2.85	3.11	3.31	3.48	3.62	3.74	3.85	3.94	4.02	4.09	4.16	4.22	4.27	4.32	4.36	4.40	4.44	4.47	4.51	4.54	4.57	4.59	4.62	4.64	4.66	4.68	4.70	4.72	4.73	4.75	4.76	4.78	4.79	4.80	4.81	4.82	4.83	4.84	4.85	4.86	4.87	4.87	4.88	4.89	4.89	4.90	4.91	4.91	4.92	5.00
Total Export	FOO	2.47	2.58	2.68	2.79	2.89	2.98	3.08	3.17	3.26	3.35	3.43	3.51	3.59	3.66	3.73	3.80	3.86	3.92	3.97	4.03	4.08	4.13	4.18	4.22	4.26	4.30	4.34	4.37	4.41	4.44	4.47	4.50	4.52	4.55	4.57	4.60	4.62	4.64	4.66	4.68	4.69	4.71	4.72	4.74	4.75	4.77	4.78	4.79	4.80	5.00
Total Export	CLG	3.41	3.47	3.53	3.59	3.65	3.71	3.77	3.83	3.89	3.95	4.00	4.05	4.10	4.15	4.19	4.23	4.27	4.31	4.35	4.38	4.41	4.45	4.48	4.50	4.53	4.55	4.58	4.60	4.62	4.64	4.66	4.68	4.70	4.71	4.73	4.74	4.76	4.77	4.78	4.79	4.81	4.82	4.83	4.83	4.84	4.85	4.86	4.87	4.87	5.00
Total Export	WWP	2.61	2.70	2.79	2.87	2.96	3.05	3.13	3.22	3.30	3.38	3.46	3.53	3.61	3.67	3.74	3.80	3.86	3.92	3.98	4.03	4.08	4.13	4.17	4.22	4.26	4.30	4.33	4.37	4.40	4.43	4.46	4.49	4.52	4.54	4.57	4.59	4.61	4.63	4.65	4.67	4.69	4.71	4.72	4.74	4.75	4.76	4.78	4.79	4.80	5.00
Total Export	CHE	2.51	2.66	2.80	2.93	3.04	3.16	3.26	3.36	3.45	3.54	3.62	3.70	3.77	3.84	3.90	3.96	4.02	4.07	4.12	4.17	4.21	4.25	4.29	4.33	4.37	4.40	4.43	4.46	4.49	4.52	4.55	4.57	4.59	4.61	4.64	4.65	4.67	4.69	4.71	4.72	4.74	4.75	4.77	4.78	4.79	4.80	4.81	4.82	4.83	5.00
Total Export	PHA	2.72	2.86	2.99	3.10	3.20	3.30	3.40	3.49	3.57	3.65	3.72	3.79	3.86	3.92	3.98	4.03	4.08	4.13	4.18	4.22	4.27	4.31	4.34	4.38	4.41	4.44	4.47	4.50	4.53	4.55	4.58	4.60	4.62	4.64	4.66	4.68	4.70	4.71	4.73	4.74	4.76	4.77	4.78	4.79	4.81	4.82	4.83	4.83	4.84	5.00
Total Export	RUB	2.71	2.85	2.97	3.08	3.19	3.29	3.38	3.47	3.55	3.63	3.71	3.78	3.84	3.90	3.96	4.02	4.07	4.12	4.17	4.21	4.25	4.29	4.33	4.37	4.40	4.43	4.46	4.49	4.52	4.55	4.57	4.59	4.61	4.63	4.65	4.67	4.69	4.71	4.72	4.74	4.75	4.76	4.78	4.79	4.80	4.81	4.82	4.83	4.84	5.00
Total Export	CEM	3.05	3.04	3.07	3.12	3.18	3.26	3.34	3.42	3.49	3.57	3.65	3.72	3.78	3.85	3.91	3.97	4.02	4.08	4.13	4.17	4.22	4.26	4.30	4.34	4.37	4.40	4.44	4.47	4.50	4.52	4.55	4.57	4.60	4.62	4.64	4.66	4.68	4.69	4.71	4.72	4.74	4.75	4.77	4.78	4.79	4.80	4.81	4.82	4.83	5.00
Total Export	IRO	2.83	2.92	3.00	3.08	3.16	3.24	3.32	3.41	3.48	3.56	3.63	3.70	3.77	3.83	3.89	3.95	4.00	4.05	4.10	4.15	4.20	4.24	4.28	4.32	4.35	4.39	4.42	4.45	4.48	4.51	4.53	4.56	4.58	4.60	4.62	4.64	4.66	4.68	4.70	4.71	4.73	4.74	4.76	4.77	4.78	4.79	4.81	4.82	4.83	5.00
Total Export	MEQ	3.39	3.38	3.37	3.38	3.39	3.41	3.44	3.48	3.52	3.56	3.60	3.65	3.69	3.74	3.79	3.84	3.88	3.93	3.98	4.02	4.06	4.10	4.15	4.18	4.22	4.26	4.29	4.33	4.36	4.39	4.42	4.45	4.48	4.50	4.53	4.55	4.58	4.60	4.62	4.64	4.66	4.67	4.69	4.71	4.72	4.74	4.75	4.76	4.78	5.00
Total Export	AIR	4.10	4.06	4.03	4.01	3.99	3.98	3.98	3.99	4.00	4.01	4.02	4.04	4.06	4.08	4.10	4.13	4.15	4.18	4.20	4.23	4.26	4.28	4.31	4.33	4.36	4.38	4.41	4.43	4.45	4.48	4.50	4.52	4.54	4.56	4.58	4.60	4.61	4.63	4.65	4.66	4.68	4.69	4.71	4.72	4.73	4.75	4.76	4.77	4.78	5.00
Total Export	WAT	3.70	3.53	3.42	3.36	3.34	3.35	3.37	3.41	3.46	3.52	3.58	3.64	3.70	3.76	3.82	3.87	3.93	3.98	4.03	4.08	4.13	4.17	4.21	4.25	4.29	4.33	4.36	4.40	4.43	4.46	4.49	4.51	4.54	4.56	4.59	4.61	4.63	4.65	4.67	4.68	4.70	4.72	4.73	4.75	4.76	4.77	4.78	4.80	4.81	5.00
Total Export	CON	3.32	3.43	3.55	3.66	3.76	3.85	3.93	4.00	4.07	4.13	4.18	4.23	4.28	4.32	4.36	4.40	4.43	4.47	4.50	4.53	4.55	4.58	4.60	4.62	4.65	4.67	4.68	4.70	4.72	4.73	4.75	4.76	4.78	4.79	4.80	4.81	4.82	4.83	4.84	4.85	4.86	4.86	4.87	4.88	4.89	4.89	4.90	4.90	4.91	5.00
Total Export	DIS	2.87	2.98	3.08	3.17	3.25	3.34	3.42	3.49	3.57	3.64	3.70	3.77	3.83	3.89	3.95	4.00	4.05	4.10	4.14	4.19	4.23	4.27	4.31	4.34	4.38	4.41	4.44	4.47	4.50	4.52	4.55	4.57	4.59	4.62	4.64	4.66	4.67	4.69	4.71	4.72	4.74	4.75	4.76	4.78	4.79	4.80	4.81	4.82	4.83	5.00
Total Export	TRA	3.24	3.47	3.64	3.78	3.90	4.00	4.09	4.16	4.23	4.29	4.34	4.39	4.43	4.47	4.51	4.54	4.57	4.60	4.63	4.65	4.68	4.70	4.72	4.73	4.75	4.77	4.78	4.79	4.81	4.82	4.83	4.84	4.85	4.86	4.87	4.87	4.88	4.89	4.90	4.90	4.91	4.91	4.92	4.92	4.93	4.93	4.94	4.94	4.94	5.00
Total Export	COM	2.54	2.73	2.88	3.02	3.14	3.25	3.35	3.45	3.54	3.62	3.70	3.77	3.83	3.90	3.96	4.01	4.06	4.11	4.16	4.20	4.25	4.29	4.32	4.36	4.39	4.43	4.46	4.48	4.51	4.54	4.56	4.59	4.61	4.63	4.65	4.67	4.68	4.70	4.72	4.73	4.75	4.76	4.77	4.79	4.80	4.81	4.82	4.83	4.84	5.00
Total Export	PRS	2.77	2.89	3.00	3.10	3.20	3.29	3.38	3.46	3.54	3.61	3.68	3.75	3.81	3.87	3.93	3.99	4.04	4.09	4.13	4.18	4.22	4.26	4.30	4.34	4.37	4.40	4.43	4.46	4.49	4.52	4.54	4.57	4.59	4.61	4.63	4.65	4.67	4.69	4.70	4.72	4.73	4.75	4.76	4.77	4.79	4.80	4.81	4.82	4.83	5.00
Total Export	PHE	2.95	3.16	3.27	3.36	3.44	3.52	3.59	3.66	3.72	3.79	3.84	3.90	3.96	4.01	4.06	4.11	4.15	4.19	4.23	4.27	4.31	4.35	4.38	4.41	4.44	4.47	4.50	4.53	4.55	4.57	4.60	4.62	4.64	4.66	4.67	4.69	4.71	4.72	4.74	4.75	4.77	4.78	4.79	4.80	4.81	4.82	4.83	4.84	4.85	5.00
Total Export	OTH	2.56	2.66	2.75	2.84	2.93	3.02	3.10	3.19	3.27	3.35	3.43	3.51	3.58	3.65	3.71	3.78	3.84	3.89	3.95	4.00	4.05	4.10	4.15	4.19	4.23	4.27	4.31	4.34	4.38	4.41	4.44	4.47	4.50	4.52	4.55	4.57	4.59	4.61	4.63	4.65	4.67	4.69	4.71	4.72	4.74	4.75	4.76	4.78	4.79	5.00
Total Export	HSS	2.65	2.93	3.07	3.17	3.26	3.34	3.42	3.50	3.57	3.64	3.70	3.77	3.83	3.89	3.94	3.99	4.04	4.09	4.14	4.18	4.22	4.26	4.30	4.34	4.37	4.40	4.43	4.46	4.49	4.52	4.54	4.57	4.59	4.61	4.63	4.65	4.67	4.69	4.70	4.72	4.73	4.75	4.76	4.77	4.78	4.80	4.81	4.82	4.83	5.00
Total Export	RET	2.78	2.93	3.04	3.13	3.22	3.30	3.38	3.46	3.54	3.61	3.68	3.74	3.81	3.87	3.92	3.98	4.03	4.08	4.13	4.17	4.21	4.25	4.29	4.33	4.36	4.40	4.43	4.46	4.49	4.51	4.54	4.56	4.59	4.61	4.63	4.65	4.67	4.68	4.70	4.72	4.73	4.75	4.76	4.77	4.78	4.80	4.81	4.82	4.83	5.00
Total Export	ELE	3.21	3.40	3.54	3.66	3.77	3.86	3.94	4.01	4.07	4.13	4.18	4.23	4.28	4.32	4.36	4.39	4.43	4.46	4.49	4.52	4.55	4.57	4.60	4.62	4.64	4.66	4.68	4.70	4.71	4.73	4.74	4.76	4.77	4.78	4.80	4.81	4.82	4.83	4.84	4.85	4.85	4.86	4.87	4.88	4.88	4.89	4.90	4.90	4.91	5.00
Total Export	OGK	3.74	3.99	4.16	4.29	4.40	4.48	4.54	4.60	4.65	4.69	4.73	4.76	4.79	4.81	4.83	4.85	4.87	4.88	4.90	4.91	4.92	4.93	4.94	4.95	4.95	4.96	4.96	4.97	4.97	4.98	4.98	4.98	4.99	4.99	4.99	4.99	4.99	4.99	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Total Export	COAL	3.88	4.02	4.11	4.19	4.25	4.30	4.35	4.39	4.43	4.46	4.50	4.53	4.56	4.58	4.61	4.63	4.66	4.68	4.70	4.71	4.73	4.75	4.76	4.78	4.79	4.80	4.81	4.83	4.84	4.84	4.85	4.86	4.87	4.88	4.89	4.89	4.90	4.90	4.91	4.91	4.92	4.92	4.93	4.93	4.94	4.94	4.94	4.95	4.95	5.00
RUK. Export	AGR	2.89	3.06	3.21	3.34	3.46	3.57	3.67	3.76	3.85	3.92	3.99	4.06	4.12	4.17	4.22	4.27	4.31	4.35	4.39	4.43	4.46	4.49	4.52	4.55	4.57	4.60	4.62	4.64	4.66	4.68	4.70	4.72	4.73	4.75	4.76	4.77	4.79	4.80	4.81	4.82	4.83	4.84	4.85	4.86	4.86	4.87	4.88	4.89	4.89	5.00
RUK. Export	EXT	2.85	3.11	3.31	3.48	3.62	3.74	3.85	3.94	4.02	4.09	4.16	4.22	4.27	4.32	4.36	4.40	4.44	4.47	4.51	4.54	4.57	4.59	4.62	4.64	4.66	4.68	4.70	4.72	4.73	4.75	4.76	4.78	4.79	4.80	4.81	4.82	4.83	4.84	4.85	4.86	4.87	4.87	4.88	4.89	4.89	4.90	4.91	4.91	4.92	5.00
RUK. Export	FOO	2.47	2.58	2.68	2.79	2.89	2.98	3.08	3.17	3.26	3.35	3.43	3.51	3.59	3.66	3.73	3.80	3.86	3.92	3.97	4.03	4.08	4.13	4.18	4.22	4.26	4.30	4.34	4.37	4.41	4.44	4.47	4.50	4.52	4.55	4.57	4.60	4.62	4.64	4.66	4.68	4.69	4.71	4.72	4.74	4.75	4.77	4.78	4.79	4.80	5.00
RUK. Export	CLG	3.41	3.47	3.53	3.59	3.65	3.71	3.77	3.83	3.89	3.95	4.00	4.05	4.10	4.15	4.19	4.23	4.27	4.31	4.35	4.38	4.41	4.45	4.48	4.50	4.53	4.55	4.58	4.60	4.62	4.64	4.66	4.68	4.70	4.71	4.73	4.74	4.76	4.77	4.78	4.79	4.81	4.82	4.83	4.83	4.84	4.85	4.86	4.87	4.87	5.00
RUK. Export	WWP	2.61	2.70	2.79	2.87	2.96	3.05	3.13	3.22	3.30	3.38	3.46	3.53	3.61	3.67	3.74	3.80	3.86	3.92	3.98	4.03	4.08	4.13	4.17	4.22	4.26	4.30	4.33	4.37	4.40	4.43	4.46	4.49	4.52	4.54	4.57	4.59	4.61	4.63	4.65	4.67	4.69	4.71	4.72	4.74	4.75	4.76	4.78	4.79	4.80	5.00
RUK. Export	CHE	2.51	2.66	2.80	2.93	3.04	3.16	3.26	3.36	3.45	3.54	3.62	3.70	3.77	3.84	3.90	3.96	4.02	4.07	4.12	4.17	4.21	4.25	4.29	4.33	4.37	4.40	4.43	4.46	4.49	4.52	4.55	4.57	4.59	4.61	4.64	4.65	4.67	4.69	4.71	4.72	4.74	4.75	4.77	4.78	4.79	4.80	4.81	4.82	4.83	5.00
RUK. Export	PHA	2.72	2.86	2.99	3.10	3.20	3.30	3.40	3.49	3.57	3.65	3.72	3.79	3.86	3.92	3.98	4.03	4.08	4.13	4.18	4.22	4.27	4.31	4.34	4.38	4.41	4.44	4.47	4.50	4.53	4.55	4.58	4.60	4.62	4.64	4.66	4.68	4.70	4.71	4.73	4.74	4.76	4.77	4.78	4.79	4.81	4.82	4.83	4.83	4.84	5.00
RUK. Export	RUB	2.71	2.85	2.97	3.08	3.19	3.29	3.38	3.47	3.55	3.63	3.71	3.78	3.84	3.90	3.96	4.02	4.07	4.12	4.17	4.21	4.25	4.29	4.33	4.37	4.40	4.43	4.46	4.49	4.52	4.55	4.57	4.59	4.61	4.63	4.65	4.67	4.69	4.71	4.72	4.74	4.75	4.76	4.78	4.79	4.80	4.81	4.82	4.83	4.84	5.00
RUK. Export	CEM	3.05	3.04	3.07	3.12	3.18	3.26	3.34	3.42	3.49	3.57	3.65	3.72	3.78	3.85	3.91	3.97	4.02	4.08	4.13	4.17	4.22	4.26	4.30	4.34	4.37	4.40	4.44	4.47	4.50	4.52	4.55	4.57	4.60	4.62	4.64	4.66	4.68	4.69	4.71	4.72	4.74	4.75	4.77	4.78	4.79	4.80	4.81	4.82	4.83	5.00
RUK. Export	IRO	2.83	2.92	3.00	3.08	3.16	3.24	3.32	3.41	3.48	3.56	3.63	3.70	3.77	3.83	3.89	3.95	4.00	4.05	4.10	4.15	4.20	4.24	4.28	4.32	4.35	4.39	4.42	4.45	4.48	4.51	4.53	4.56	4.58	4.60	4.62	4.64	4.66	4.68	4.70	4.71	4.73	4.74	4.76	4.77	4.78	4.79	4.81	4.82	4.83	5.00
RUK. Export	MEQ	3.39	3.38	3.37	3.38	3.39	3.41	3.44	3.48	3.52	3.56	3.60	3.65	3.69	3.74	3.79	3.84	3.88	3.93	3.98	4.02	4.06	4.10	4.15	4.18	4.22	4.26	4.29	4.33	4.36	4.39	4.42	4.45	4.48	4.50	4.53	4.55	4.58	4.60	4.62	4.64	4.66	4.67	4.69	4.71	4.72	4.74	4.75	4.76	4.78	5.00
RUK. Export	AIR	4.10	4.06	4.03	4.01	3.99	3.98	3.98	3.99	4.00	4.01	4.02	4.04	4.06	4.08	4.10	4.13	4.15	4.18	4.20	4.23	4.26	4.28	4.31	4.33	4.36	4.38	4.41	4.43	4.45	4.48	4.50	4.52	4.54	4.56	4.58	4.60	4.61	4.63	4.65	4.66	4.68	4.69	4.71	4.72	4.73	4.75	4.76	4.77	4.78	5.00
RUK. Export	WAT	3.70	3.53	3.42	3.36	3.34	3.35	3.37	3.41	3.46	3.52	3.58	3.64	3.70	3.76	3.82	3.87	3.93	3.98	4.03	4.08	4.13	4.17	4.21	4.25	4.29	4.33	4.36	4.40	4.43	4.46	4.49	4.51	4.54	4.56	4.59	4.61	4.63	4.65	4.67	4.68	4.70	4.72	4.73	4.75	4.76	4.77	4.78	4.80	4.81	5.00
RUK. Export	CON	3.32	3.43	3.55	3.66	3.76	3.85	3.93	4.00	4.07	4.13	4.18	4.23	4.28	4.32	4.36	4.40	4.43	4.47	4.50	4.53	4.55	4.58	4.60	4.62	4.65	4.67	4.68	4.70	4.72	4.73	4.75	4.76	4.78	4.79	4.80	4.81	4.82	4.83	4.84	4.85	4.86	4.86	4.87	4.88	4.89	4.89	4.90	4.90	4.91	5.00
RUK. Export	DIS	2.87	2.98	3.08	3.17	3.25	3.34	3.42	3.49	3.57	3.64	3.70	3.77	3.83	3.89	3.95	4.00	4.05	4.10	4.14	4.19	4.23	4.27	4.31	4.34	4.38	4.41	4.44	4.47	4.50	4.52	4.55	4.57	4.59	4.62	4.64	4.66	4.67	4.69	4.71	4.72	4.74	4.75	4.76	4.78	4.79	4.80	4.81	4.82	4.83	5.00
RUK. Export	TRA	3.24	3.47	3.64	3.78	3.90	4.00	4.09	4.16	4.23	4.29	4.34	4.39	4.43	4.47	4.51	4.54	4.57	4.60	4.63	4.65	4.68	4.70	4.72	4.73	4.75	4.77	4.78	4.79	4.81	4.82	4.83	4.84	4.85	4.86	4.87	4.87	4.88	4.89	4.90	4.90	4.91	4.91	4.92	4.92	4.93	4.93	4.94	4.94	4.94	5.00
RUK. Export	COM	2.54	2.73	2.88	3.02	3.14	3.25	3.35	3.45	3.54	3.62	3.70	3.77	3.83	3.90	3.96	4.01	4.06	4.11	4.16	4.20	4.25	4.29	4.32	4.36	4.39	4.43	4.46	4.48	4.51	4.54	4.56	4.59	4.61	4.63	4.65	4.67	4.68	4.70	4.72	4.73	4.75	4.76	4.77	4.79	4.80	4.81	4.82	4.83	4.84	5.00
RUK. Export	PRS	2.77	2.89	3.00	3.10	3.20	3.29	3.38	3.46	3.54	3.61	3.68	3.75	3.81	3.87	3.93	3.99	4.04	4.09	4.13	4.18	4.22	4.26	4.30	4.34	4.37	4.40	4.43	4.46	4.49	4.52	4.54	4.57	4.59	4.61	4.63	4.65	4.67	4.69	4.70	4.72	4.73	4.75	4.76	4.77	4.79	4.80	4.81	4.82	4.83	5.00
RUK. Export	PHE	2.95	3.16	3.27	3.36	3.44	3.52	3.59	3.66	3.72	3.79	3.84	3.90	3.96	4.01	4.06	4.11	4.15	4.19	4.23	4.27	4.31	4.35	4.38	4.41	4.44	4.47	4.50	4.53	4.55	4.57	4.60	4.62	4.64	4.66	4.67	4.69	4.71	4.72	4.74	4.75	4.77	4.78	4.79	4.80	4.81	4.82	4.83	4.84	4.85	5.00
RUK. Export	OTH	2.56	2.66	2.75	2.84	2.93	3.02	3.10	3.19	3.27	3.35	3.43	3.51	3.58	3.65	3.71	3.78	3.84	3.89	3.95	4.00	4.05	4.10	4.15	4.19	4.23	4.27	4.31	4.34	4.38	4.41	4.44	4.47	4.50	4.52	4.55	4.57	4.59	4.61	4.63	4.65	4.67	4.69	4.71	4.72	4.74	4.75	4.76	4.78	4.79	5.00
RUK. Export	HSS	2.65	2.93	3.07	3.17	3.26	3.34	3.42	3.50	3.57	3.64	3.70	3.77	3.83	3.89	3.94	3.99	4.04	4.09	4.14	4.18	4.22	4.26	4.30	4.34	4.37	4.40	4.43	4.46	4.49	4.52	4.54	4.57	4.59	4.61	4.63	4.65	4.67	4.69	4.70	4.72	4.73	4.75	4.76	4.77	4.78	4.80	4.81	4.82	4.83	5.00
RUK. Export	RET	2.78	2.93	3.04	3.13	3.22	3.30	3.38	3.46	3.54	3.61	3.68	3.74	3.81	3.87	3.92	3.98	4.03	4.08	4.13	4.17	4.21	4.25	4.29	4.33	4.36	4.40	4.43	4.46	4.49	4.51	4.54	4.56	4.59	4.61	4.63	4.65	4.67	4.68	4.70	4.72	4.73	4.75	4.76	4.77	4.78	4.80	4.81	4.82	4.83	5.00
RUK. Export	ELE	3.21	3.40	3.54	3.66	3.77	3.86	3.94	4.01	4.07	4.13	4.18	4.23	4.28	4.32	4.36	4.39	4.43	4.46	4.49	4.52	4.55	4.57	4.60	4.62	4.64	4.66	4.68	4.70	4.71	4.73	4.74	4.76	4.77	4.78	4.80	4.81	4.82	4.83	4.84	4.85	4.85	4.86	4.87	4.88	4.88	4.89	4.90	4.90	4.91	5.00
RUK. Export	OGK	3.74	3.99	4.16	4.29	4.40	4.48	4.54	4.60	4.65	4.69	4.73	4.76	4.79	4.81	4.83	4.85	4.87	4.88	4.90	4.91	4.92	4.93	4.94	4.95	4.95	4.96	4.96	4.97	4.97	4.98	4.98	4.98	4.99	4.99	4.99	4.99	4.99	4.99	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
RUK. Export	COAL	3.88	4.02	4.11	4.19	4.25	4.30	4.35	4.39	4.43	4.46	4.50	4.53	4.56	4.58	4.61	4.63	4.66	4.68	4.70	4.71	4.73	4.75	4.76	4.78	4.79	4.80	4.81	4.83	4.84	4.84	4.85	4.86	4.87	4.88	4.89	4.89	4.90	4.90	4.91	4.91	4.92	4.92	4.93	4.93	4.94	4.94	4.94	4.95	4.95	5.00
ROW Export	AGR	2.89	3.06	3.21	3.34	3.46	3.57	3.67	3.76	3.85	3.92	3.99	4.06	4.12	4.17	4.22	4.27	4.31	4.35	4.39	4.43	4.46	4.49	4.52	4.55	4.57	4.60	4.62	4.64	4.66	4.68	4.70	4.72	4.73	4.75	4.76	4.77	4.79	4.80	4.81	4.82	4.83	4.84	4.85	4.86	4.86	4.87	4.88	4.89	4.89	5.00
ROW Export	EXT	2.85	3.11	3.31	3.48	3.62	3.74	3.85	3.94	4.02	4.09	4.16	4.22	4.27	4.32	4.36	4.40	4.44	4.47	4.51	4.54	4.57	4.59	4.62	4.64	4.66	4.68	4.70	4.72	4.73	4.75	4.76	4.78	4.79	4.80	4.81	4.82	4.83	4.84	4.85	4.86	4.87	4.87	4.88	4.89	4.89	4.90	4.91	4.91	4.92	5.00
ROW Export	FOO	2.47	2.58	2.68	2.79	2.89	2.98	3.08	3.17	3.26	3.35	3.43	3.51	3.59	3.66	3.73	3.80	3.86	3.92	3.97	4.03	4.08	4.13	4.18	4.22	4.26	4.30	4.34	4.37	4.41	4.44	4.47	4.50	4.52	4.55	4.57	4.60	4.62	4.64	4.66	4.68	4.69	4.71	4.72	4.74	4.75	4.77	4.78	4.79	4.80	5.00
ROW Export	CLG	3.41	3.47	3.53	3.59	3.65	3.71	3.77	3.83	3.89	3.95	4.00	4.05	4.10	4.15	4.19	4.23	4.27	4.31	4.35	4.38	4.41	4.45	4.48	4.50	4.53	4.55	4.58	4.60	4.62	4.64	4.66	4.68	4.70	4.71	4.73	4.74	4.76	4.77	4.78	4.79	4.81	4.82	4.83	4.83	4.84	4.85	4.86	4.87	4.87	5.00
ROW Export	WWP	2.61	2.70	2.79	2.87	2.96	3.05	3.13	3.22	3.30	3.38	3.46	3.53	3.61	3.67	3.74	3.80	3.86	3.92	3.98	4.03	4.08	4.13	4.17	4.22	4.26	4.30	4.33	4.37	4.40	4.43	4.46	4.49	4.52	4.54	4.57	4.59	4.61	4.63	4.65	4.67	4.69	4.71	4.72	4.74	4.75	4.76	4.78	4.79	4.80	5.00
ROW Export	CHE	2.51	2.66	2.80	2.93	3.04	3.16	3.26	3.36	3.45	3.54	3.62	3.70	3.77	3.84	3.90	3.96	4.02	4.07	4.12	4.17	4.21	4.25	4.29	4.33	4.37	4.40	4.43	4.46	4.49	4.52	4.55	4.57	4.59	4.61	4.64	4.65	4.67	4.69	4.71	4.72	4.74	4.75	4.77	4.78	4.79	4.80	4.81	4.82	4.83	5.00
ROW Export	PHA	2.72	2.86	2.99	3.10	3.20	3.30	3.40	3.49	3.57	3.65	3.72	3.79	3.86	3.92	3.98	4.03	4.08	4.13	4.18	4.22	4.27	4.31	4.34	4.38	4.41	4.44	4.47	4.50	4.53	4.55	4.58	4.60	4.62	4.64	4.66	4.68	4.70	4.71	4.73	4.74	4.76	4.77	4.78	4.79	4.81	4.82	4.83	4.83	4.84	5.00
ROW Export	RUB	2.71	2.85	2.97	3.08	3.19	3.29	3.38	3.47	3.55	3.63	3.71	3.78	3.84	3.90	3.96	4.02	4.07	4.12	4.17	4.21	4.25	4.29	4.33	4.37	4.40	4.43	4.46	4.49	4.52	4.55	4.57	4.59	4.61	4.63	4.65	4.67	4.69	4.71	4.72	4.74	4.75	4.76	4.78	4.79	4.80	4.81	4.82	4.83	4.84	5.00
ROW Export	CEM	3.05	3.04	3.07	3.12	3.18	3.26	3.34	3.42	3.49	3.57	3.65	3.72	3.78	3.85	3.91	3.97	4.02	4.08	4.13	4.17	4.22	4.26	4.30	4.34	4.37	4.40	4.44	4.47	4.50	4.52	4.55	4.57	4.60	4.62	4.64	4.66	4.68	4.69	4.71	4.72	4.74	4.75	4.77	4.78	4.79	4.80	4.81	4.82	4.83	5.00
ROW Export	IRO	2.83	2.92	3.00	3.08	3.16	3.24	3.32	3.41	3.48	3.56	3.63	3.70	3.77	3.83	3.89	3.95	4.00	4.05	4.10	4.15	4.20	4.24	4.28	4.32	4.35	4.39	4.42	4.45	4.48	4.51	4.53	4.56	4.58	4.60	4.62	4.64	4.66	4.68	4.70	4.71	4.73	4.74	4.76	4.77	4.78	4.79	4.81	4.82	4.83	5.00
ROW Export	MEQ	3.39	3.38	3.37	3.38	3.39	3.41	3.44	3.48	3.52	3.56	3.60	3.65	3.69	3.74	3.79	3.84	3.88	3.93	3.98	4.02	4.06	4.10	4.15	4.18	4.22	4.26	4.29	4.33	4.36	4.39	4.42	4.45	4.48	4.50	4.53	4.55	4.58	4.60	4.62	4.64	4.66	4.67	4.69	4.71	4.72	4.74	4.75	4.76	4.78	5.00
ROW Export	AIR	4.10	4.06	4.03	4.01	3.99	3.98	3.98	3.99	4.00	4.01	4.02	4.04	4.06	4.08	4.10	4.13	4.15	4.18	4.20	4.23	4.26	4.28	4.31	4.33	4.36	4.38	4.41	4.43	4.45	4.48	4.50	4.52	4.54	4.56	4.58	4.60	4.61	4.63	4.65	4.66	4.68	4.69	4.71	4.72	4.73	4.75	4.76	4.77	4.78	5.00
ROW Export	WAT	3.70	3.53	3.42	3.36	3.34	3.35	3.37	3.41	3.46	3.52	3.58	3.64	3.70	3.76	3.82	3.87	3.93	3.98	4.03	4.08	4.13	4.17	4.21	4.25	4.29	4.33	4.36	4.40	4.43	4.46	4.49	4.51	4.54	4.56	4.59	4.61	4.63	4.65	4.67	4.68	4.70	4.72	4.73	4.75	4.76	4.77	4.78	4.80	4.81	5.00
ROW Export	CON	3.32	3.43	3.55	3.66	3.76	3.85	3.93	4.00	4.07	4.13	4.18	4.23	4.28	4.32	4.36	4.40	4.43	4.47	4.50	4.53	4.55	4.58	4.60	4.62	4.65	4.67	4.68	4.70	4.72	4.73	4.75	4.76	4.78	4.79	4.80	4.81	4.82	4.83	4.84	4.85	4.86	4.86	4.87	4.88	4.89	4.89	4.90	4.90	4.91	5.00
ROW Export	DIS	2.87	2.98	3.08	3.17	3.25	3.34	3.42	3.49	3.57	3.64	3.70	3.77	3.83	3.89	3.95	4.00	4.05	4.10	4.14	4.19	4.23	4.27	4.31	4.34	4.38	4.41	4.44	4.47	4.50	4.52	4.55	4.57	4.59	4.62	4.64	4.66	4.67	4.69	4.71	4.72	4.74	4.75	4.76	4.78	4.79	4.80	4.81	4.82	4.83	5.00
ROW Export	TRA	3.24	3.47	3.64	3.78	3.90	4.00	4.09	4.16	4.23	4.29	4.34	4.39	4.43	4.47	4.51	4.54	4.57	4.60	4.63	4.65	4.68	4.70	4.72	4.73	4.75	4.77	4.78	4.79	4.81	4.82	4.83	4.84	4.85	4.86	4.87	4.87	4.88	4.89	4.90	4.90	4.91	4.91	4.92	4.92	4.93	4.93	4.94	4.94	4.94	5.00
ROW Export	COM	2.54	2.73	2.88	3.02	3.14	3.25	3.35	3.45	3.54	3.62	3.70	3.77	3.83	3.90	3.96	4.01	4.06	4.11	4.16	4.20	4.25	4.29	4.32	4.36	4.39	4.43	4.46	4.48	4.51	4.54	4.56	4.59	4.61	4.63	4.65	4.67	4.68	4.70	4.72	4.73	4.75	4.76	4.77	4.79	4.80	4.81	4.82	4.83	4.84	5.00
ROW Export	PRS	2.77	2.89	3.00	3.10	3.20	3.29	3.38	3.46	3.54	3.61	3.68	3.75	3.81	3.87	3.93	3.99	4.04	4.09	4.13	4.18	4.22	4.26	4.30	4.34	4.37	4.40	4.43	4.46	4.49	4.52	4.54	4.57	4.59	4.61	4.63	4.65	4.67	4.69	4.70	4.72	4.73	4.75	4.76	4.77	4.79	4.80	4.81	4.82	4.83	5.00
ROW Export	PHE	2.95	3.16	3.27	3.36	3.44	3.52	3.59	3.66	3.72	3.79	3.84	3.90	3.96	4.01	4.06	4.11	4.15	4.19	4.23	4.27	4.31	4.35	4.38	4.41	4.44	4.47	4.50	4.53	4.55	4.57	4.60	4.62	4.64	4.66	4.67	4.69	4.71	4.72	4.74	4.75	4.77	4.78	4.79	4.80	4.81	4.82	4.83	4.84	4.85	5.00
ROW Export	OTH	2.56	2.66	2.75	2.84	2.93	3.02	3.10	3.19	3.27	3.35	3.43	3.51	3.58	3.65	3.71	3.78	3.84	3.89	3.95	4.00	4.05	4.10	4.15	4.19	4.23	4.27	4.31	4.34	4.38	4.41	4.44	4.47	4.50	4.52	4.55	4.57	4.59	4.61	4.63	4.65	4.67	4.69	4.71	4.72	4.74	4.75	4.76	4.78	4.79	5.00
ROW Export	HSS	2.65	2.93	3.07	3.17	3.26	3.34	3.42	3.50	3.57	3.64	3.70	3.77	3.83	3.89	3.94	3.99	4.04	4.09	4.14	4.18	4.22	4.26	4.30	4.34	4.37	4.40	4.43	4.46	4.49	4.52	4.54	4.57	4.59	4.61	4.63	4.65	4.67	4.69	4.70	4.72	4.73	4.75	4.76	4.77	4.78	4.80	4.81	4.82	4.83	5.00
ROW Export	RET	2.78	2.93	3.04	3.13	3.22	3.30	3.38	3.46	3.54	3.61	3.68	3.74	3.81	3.87	3.92	3.98	4.03	4.08	4.13	4.17	4.21	4.25	4.29	4.33	4.36	4.40	4.43	4.46	4.49	4.51	4.54	4.56	4.59	4.61	4.63	4.65	4.67	4.68	4.70	4.72	4.73	4.75	4.76	4.77	4.78	4.80	4.81	4.82	4.83	5.00
ROW Export	ELE	3.21	3.40	3.54	3.66	3.77	3.86	3.94	4.01	4.07	4.13	4.18	4.23	4.28	4.32	4.36	4.39	4.43	4.46	4.49	4.52	4.55	4.57	4.60	4.62	4.64	4.66	4.68	4.70	4.71	4.73	4.74	4.76	4.77	4.78	4.80	4.81	4.82	4.83	4.84	4.85	4.85	4.86	4.87	4.88	4.88	4.89	4.90	4.90	4.91	5.00
ROW Export	OGK	3.74	3.99	4.16	4.29	4.40	4.48	4.54	4.60	4.65	4.69	4.73	4.76	4.79	4.81	4.83	4.85	4.87	4.88	4.90	4.91	4.92	4.93	4.94	4.95	4.95	4.96	4.96	4.97	4.97	4.98	4.98	4.98	4.99	4.99	4.99	4.99	4.99	4.99	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
ROW Export	COAL	3.88	4.02	4.11	4.19	4.25	4.30	4.35	4.39	4.43	4.46	4.50	4.53	4.56	4.58	4.61	4.63	4.66	4.68	4.70	4.71	4.73	4.75	4.76	4.78	4.79	4.80	4.81	4.83	4.84	4.84	4.85	4.86	4.87	4.88	4.89	4.89	4.90	4.90	4.91	4.91	4.92	4.92	4.93	4.93	4.94	4.94	4.94	4.95	4.95	5.00

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	LR
Investment by dest+adj cost	AGR	1.61	1.79	1.92	2.03	2.14	2.23	2.32	2.41	2.49	2.57	2.64	2.71	2.78	2.84	2.90	2.96	3.01	3.06	3.11	3.15	3.20	3.24	3.27	3.31	3.34	3.38	3.41	3.44	3.46	3.49	3.52	3.54	3.56	3.58	3.60	3.62	3.64	3.66	3.67	3.69	3.70	3.71	3.73	3.74	3.75	3.76	3.77	3.78	3.79	3.95
Investment by dest+adj cost	EXT	2.63	2.73	2.75	2.76	2.78	2.81	2.85	2.90	2.94	2.99	3.04	3.09	3.14	3.18	3.23	3.27	3.31	3.35	3.39	3.43	3.46	3.49	3.52	3.55	3.58	3.60	3.63	3.65	3.67	3.69	3.71	3.73	3.75	3.76	3.78	3.80	3.81	3.82	3.83	3.85	3.86	3.87	3.88	3.89	3.90	3.90	3.91	3.92	3.93	4.05

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	LR
Rate of Return to Cap.	AGR	2.58	2.45	2.30	2.14	2.00	1.87	1.75	1.64	1.54	1.44	1.35	1.27	1.20	1.13	1.06	1.00	0.94	0.89	0.84	0.79	0.75	0.71	0.67	0.63	0.60	0.56	0.53	0.50	0.48	0.45	0.43	0.40	0.38	0.36	0.34	0.32	0.31	0.29	0.27	0.26	0.24	0.23	0.22	0.21	0.20	0.19	0.18	0.17	0.16	- 0.00
Rate of Return to Cap.	EXT	3.63	3.26	2.86	2.52	2.24	2.00	1.81	1.65	1.51	1.39	1.29	1.19	1.11	1.04	0.97	0.91	0.86	0.80	0.76	0.71	0.67	0.63	0.60	0.56	0.53	0.50	0.48	0.45	0.42	0.40	0.38	0.36	0.34	0.32	0.30	0.29	0.27	0.26	0.24	0.23	0.22	0.20	0.19	0.18	0.17	0.16	0.15	0.15	0.14	- 0.00
Rate of Return to Cap.	FOO	1.80	1.94	1.96	1.94	1.90	1.85	1.79	1.72	1.66	1.59	1.52	1.46	1.39	1.32	1.26	1.20	1.14	1.08	1.03	0.98	0.93	0.88	0.83	0.79	0.75	0.71	0.67	0.64	0.60	0.57	0.54	0.51	0.49	0.46	0.44	0.41	0.39	0.37	0.35	0.33	0.31	0.30	0.28	0.27	0.25	0.24	0.23	0.21	0.20	- 0.00
Rate of Return to Cap.	CLG	0.78	1.40	1.65	1.75	1.80	1.80	1.78	1.74	1.69	1.63	1.57	1.51	1.44	1.38	1.31	1.25	1.19	1.14	1.08	1.03	0.97	0.93	0.88	0.83	0.79	0.75	0.71	0.68	0.64	0.61	0.58	0.55	0.52	0.49	0.47	0.44	0.42	0.40	0.37	0.36	0.34	0.32	0.30	0.29	0.27	0.26	0.24	0.23	0.22	- 0.00
Rate of Return to Cap.	WWP	1.42	1.66	1.74	1.75	1.73	1.70	1.65	1.60	1.55	1.49	1.43	1.37	1.32	1.26	1.20	1.14	1.09	1.04	0.99	0.94	0.89	0.85	0.81	0.77	0.73	0.69	0.66	0.62	0.59	0.56	0.53	0.50	0.48	0.45	0.43	0.41	0.38	0.36	0.35	0.33	0.31	0.29	0.28	0.26	0.25	0.24	0.22	0.21	0.20	- 0.00
Rate of Return to Cap.	CHE	2.59	2.58	2.47	2.34	2.20	2.08	1.96	1.85	1.74	1.64	1.55	1.46	1.38	1.30	1.23	1.16	1.10	1.04	0.98	0.93	0.88	0.83	0.78	0.74	0.70	0.67	0.63	0.60	0.56	0.53	0.51	0.48	0.45	0.43	0.41	0.38	0.36	0.34	0.33	0.31	0.29	0.28	0.26	0.25	0.23	0.22	0.21	0.20	0.19	- 0.00
Rate of Return to Cap.	PHA	2.19	2.36	2.32	2.22	2.11	2.00	1.89	1.79	1.69	1.60	1.51	1.43	1.35	1.28	1.21	1.14	1.08	1.02	0.97	0.91	0.86	0.82	0.77	0.73	0.69	0.66	0.62	0.59	0.56	0.53	0.50	0.47	0.45	0.42	0.40	0.38	0.36	0.34	0.32	0.31	0.29	0.27	0.26	0.25	0.23	0.22	0.21	0.20	0.19	- 0.00
Rate of Return to Cap.	RUB	2.03	2.24	2.23	2.15	2.06	1.96	1.86	1.77	1.67	1.59	1.50	1.42	1.35	1.28	1.21	1.15	1.09	1.03	0.98	0.92	0.88	0.83	0.79	0.75	0.71	0.67	0.63	0.60	0.57	0.54	0.51	0.48	0.46	0.43	0.41	0.39	0.37	0.35	0.33	0.31	0.30	0.28	0.27	0.25	0.24	0.23	0.21	0.20	0.19	- 0.00
Rate of Return to Cap.	CEM	0.83	1.26	1.45	1.54	1.57	1.56	1.53	1.48	1.42	1.36	1.29	1.23	1.17	1.11	1.05	1.00	0.94	0.89	0.85	0.80	0.76	0.72	0.68	0.64	0.61	0.58	0.55	0.52	0.49	0.46	0.44	0.42	0.39	0.37	0.35	0.33	0.32	0.30	0.28	0.27	0.25	0.24	0.23	0.22	0.20	0.19	0.18	0.17	0.16	- 0.00
Rate of Return to Cap.	IRO	0.57	1.34	1.65	1.79	1.85	1.87	1.85	1.81	1.75	1.69	1.63	1.56	1.49	1.43	1.36	1.30	1.24	1.18	1.12	1.06	1.01	0.96	0.91	0.87	0.82	0.78	0.74	0.70	0.67	0.63	0.60	0.57	0.54	0.51	0.48	0.46	0.43	0.41	0.39	0.37	0.35	0.33	0.31	0.30	0.28	0.27	0.25	0.24	0.23	- 0.00
Rate of Return to Cap.	MEQ	0.04	0.46	0.71	0.88	1.01	1.12	1.19	1.25	1.29	1.31	1.32	1.32	1.31	1.30	1.27	1.25	1.22	1.19	1.15	1.12	1.08	1.04	1.00	0.97	0.93	0.89	0.85	0.82	0.78	0.75	0.71	0.68	0.65	0.62	0.59	0.56	0.54	0.51	0.49	0.46	0.44	0.42	0.40	0.38	0.36	0.34	0.32	0.31	0.29	- 0.00
Rate of Return to Cap.	AIR	- 0.55	- 0.15	0.12	0.33	0.49	0.63	0.75	0.85	0.92	0.98	1.03	1.07	1.09	1.11	1.12	1.12	1.12	1.11	1.10	1.09	1.07	1.05	1.03	1.00	0.98	0.95	0.92	0.89	0.87	0.84	0.81	0.78	0.75	0.73	0.70	0.67	0.65	0.62	0.60	0.57	0.55	0.52	0.50	0.48	0.46	0.44	0.42	0.40	0.38	- 0.00
Rate of Return to Cap.	WAT	0.62	0.85	1.01	1.10	1.15	1.17	1.17	1.15	1.13	1.09	1.06	1.02	0.98	0.93	0.89	0.85	0.81	0.77	0.74	0.70	0.67	0.63	0.60	0.57	0.54	0.52	0.49	0.46	0.44	0.42	0.40	0.38	0.36	0.34	0.32	0.30	0.29	0.27	0.26	0.25	0.23	0.22	0.21	0.20	0.19	0.18	0.17	0.16	0.15	- 0.00
Rate of Return to Cap.	CON	2.05	2.05	1.92	1.78	1.65	1.54	1.44	1.35	1.26	1.19	1.12	1.06	1.00	0.94	0.89	0.84	0.80	0.76	0.72	0.68	0.64	0.61	0.57	0.54	0.52	0.49	0.46	0.44	0.41	0.39	0.37	0.35	0.33	0.32	0.30	0.28	0.27	0.25	0.24	0.23	0.21	0.20	0.19	0.18	0.17	0.16	0.15	0.15	0.14	- 0.00
Rate of Return to Cap.	DIS	1.47	1.53	1.51	1.48	1.43	1.38	1.33	1.28	1.23	1.18	1.13	1.08	1.03	0.99	0.94	0.90	0.86	0.82	0.78	0.74	0.70	0.67	0.64	0.61	0.58	0.55	0.52	0.49	0.47	0.45	0.42	0.40	0.38	0.36	0.34	0.32	0.31	0.29	0.28	0.26	0.25	0.24	0.22	0.21	0.20	0.19	0.18	0.17	0.16	- 0.00
Rate of Return to Cap.	TRA	2.73	2.47	2.20	1.97	1.79	1.64	1.51	1.41	1.31	1.23	1.16	1.09	1.03	0.97	0.92	0.87	0.82	0.78	0.74	0.70	0.66	0.63	0.59	0.56	0.53	0.50	0.48	0.45	0.43	0.41	0.38	0.36	0.35	0.33	0.31	0.29	0.28	0.26	0.25	0.24	0.22	0.21	0.20	0.19	0.18	0.17	0.16	0.15	0.14	- 0.00
Rate of Return to Cap.	COM	2.30	2.19	2.04	1.89	1.76	1.65	1.54	1.45	1.36	1.28	1.21	1.14	1.08	1.02	0.97	0.92	0.87	0.83	0.78	0.74	0.70	0.67	0.63	0.60	0.57	0.54	0.51	0.49	0.46	0.44	0.41	0.39	0.37	0.35	0.33	0.32	0.30	0.28	0.27	0.26	0.24	0.23	0.22	0.21	0.19	0.18	0.17	0.17	0.16	- 0.00
Rate of Return to Cap.	PRS	1.86	1.96	1.91	1.82	1.73	1.65	1.56	1.48	1.41	1.34	1.27	1.21	1.15	1.09	1.03	0.98	0.93	0.89	0.84	0.80	0.76	0.72	0.68	0.65	0.62	0.59	0.56	0.53	0.50	0.47	0.45	0.43	0.40	0.38	0.36	0.35	0.33	0.31	0.29	0.28	0.26	0.25	0.24	0.22	0.21	0.20	0.19	0.18	0.17	- 0.00
Rate of Return to Cap.	PHE	1.37	1.14	1.02	0.95	0.89	0.84	0.80	0.75	0.72	0.68	0.64	0.61	0.58	0.55	0.52	0.49	0.47	0.45	0.42	0.40	0.38	0.36	0.34	0.32	0.31	0.29	0.28	0.26	0.25	0.23	0.22	0.21	0.20	0.19	0.18	0.17	0.16	0.15	0.14	0.14	0.13	0.12	0.12	0.11	0.10	0.10	0.09	0.09	0.08	- 0.00
Rate of Return to Cap.	OTH	1.45	1.45	1.41	1.37	1.32	1.27	1.22	1.17	1.12	1.07	1.02	0.98	0.93	0.89	0.84	0.80	0.76	0.73	0.69	0.66	0.62	0.59	0.56	0.54	0.51	0.48	0.46	0.43	0.41	0.39	0.37	0.35	0.33	0.32	0.30	0.28	0.27	0.26	0.24	0.23	0.22	0.21	0.20	0.19	0.18	0.17	0.16	0.15	0.14	- 0.00
Rate of Return to Cap.	HSS	1.41	1.14	1.01	0.93	0.88	0.83	0.78	0.74	0.70	0.67	0.63	0.60	0.57	0.54	0.51	0.49	0.46	0.44	0.42	0.39	0.37	0.35	0.34	0.32	0.30	0.29	0.27	0.26	0.24	0.23	0.22	0.21	0.20	0.19	0.18	0.17	0.16	0.15	0.14	0.13	0.13	0.12	0.11	0.11	0.10	0.10	0.09	0.09	0.08	- 0.00
Rate of Return to Cap.	RET	1.41	1.41	1.37	1.32	1.27	1.21	1.16	1.11	1.06	1.01	0.96	0.91	0.87	0.83	0.79	0.75	0.71	0.68	0.64	0.61	0.58	0.55	0.52	0.50	0.47	0.45	0.43	0.40	0.38	0.36	0.34	0.33	0.31	0.29	0.28	0.26	0.25	0.24	0.22	0.21	0.20	0.19	0.18	0.17	0.16	0.15	0.15	0.14	0.13	- 0.00
Rate of Return to Cap.	ELE	2.58	2.40	2.21	2.03	1.87	1.74	1.62	1.51	1.42	1.33	1.26	1.19	1.12	1.06	1.00	0.95	0.90	0.85	0.81	0.77	0.73	0.69	0.66	0.62	0.59	0.56	0.53	0.50	0.48	0.45	0.43	0.41	0.39	0.37	0.35	0.33	0.31	0.30	0.28	0.27	0.25	0.24	0.23	0.21	0.20	0.19	0.18	0.17	0.16	- 0.00
Rate of Return to Cap.	OGK	5.79	4.38	3.37	2.69	2.22	1.89	1.65	1.47	1.32	1.21	1.11	1.03	0.95	0.89	0.83	0.78	0.73	0.68	0.64	0.60	0.57	0.53	0.50	0.47	0.44	0.42	0.39	0.37	0.35	0.33	0.31	0.29	0.28	0.26	0.25	0.23	0.22	0.21	0.20	0.18	0.17	0.16	0.16	0.15	0.14	0.13	0.12	0.12	0.11	- 0.00
Rate of Return to Cap.	COAL	3.53	2.85	2.36	2.04	1.82	1.66	1.54	1.44	1.36	1.28	1.21	1.15	1.09	1.03	0.98	0.93	0.88	0.84	0.79	0.75	0.71	0.68	0.64	0.61	0.58	0.55	0.52	0.49	0.47	0.44	0.42	0.40	0.38	0.36	0.34	0.32	0.30	0.29	0.27	0.26	0.25	0.23	0.22	0.21	0.20	0.19	0.18	0.17	0.16	- 0.00
Output Price	AGR	1.02	0.94	0.86	0.80	0.74	0.69	0.64	0.59	0.55	0.52	0.48	0.45	0.42	0.40	0.37	0.35	0.33	0.31	0.29	0.27	0.26	0.24	0.23	0.22	0.20	0.19	0.18	0.17	0.16	0.15	0.14	0.14	0.13	0.12	0.11	0.11	0.10	0.10	0.09	0.09	0.08	0.08	0.07	0.07	0.06	0.06	0.06	0.05	0.05	- 0.00
Output Price	EXT	1.04	0.91	0.81	0.73	0.66	0.60	0.55	0.51	0.47	0.43	0.40	0.38	0.35	0.33	0.31	0.29	0.27	0.25	0.24	0.22	0.21	0.20	0.18	0.17	0.16	0.15	0.14	0.14	0.13	0.12	0.11	0.11	0.10	0.09	0.09	0.08	0.08	0.08	0.07	0.07	0.06	0.06	0.06	0.05	0.05	0.05	0.04	0.04	0.04	- 0.00
Output Price	FOO	1.22	1.17	1.12	1.07	1.02	0.97	0.93	0.88	0.84	0.80	0.76	0.72	0.68	0.64	0.61	0.58	0.55	0.52	0.49	0.47	0.44	0.42	0.40	0.37	0.35	0.34	0.32	0.30	0.28	0.27	0.25	0.24	0.23	0.22	0.20	0.19	0.18	0.17	0.16	0.15	0.15	0.14	0.13	0.12	0.12	0.11	0.11	0.10	0.09	- 0.00
Output Price	CLG	0.77	0.73	0.71	0.68	0.65	0.62	0.59	0.56	0.53	0.51	0.48	0.46	0.43	0.41	0.39	0.37	0.35	0.33	0.31	0.30	0.28	0.26	0.25	0.24	0.22	0.21	0.20	0.19	0.18	0.17	0.16	0.15	0.14	0.14	0.13	0.12	0.12	0.11	0.10	0.10	0.09	0.09	0.08	0.08	0.07	0.07	0.07	0.06	0.06	- 0.00
Output Price	WWP	1.16	1.11	1.07	1.03	0.99	0.94	0.90	0.86	0.82	0.78	0.74	0.71	0.67	0.64	0.61	0.57	0.55	0.52	0.49	0.47	0.44	0.42	0.40	0.38	0.36	0.34	0.32	0.30	0.29	0.27	0.26	0.24	0.23	0.22	0.21	0.20	0.19	0.18	0.17	0.16	0.15	0.14	0.13	0.13	0.12	0.11	0.11	0.10	0.10	- 0.00
Output Price	CHE	1.21	1.13	1.07	1.00	0.94	0.89	0.84	0.79	0.75	0.70	0.66	0.63	0.59	0.56	0.53	0.50	0.47	0.45	0.42	0.40	0.38	0.36	0.34	0.32	0.30	0.29	0.27	0.26	0.24	0.23	0.22	0.21	0.19	0.18	0.17	0.16	0.16	0.15	0.14	0.13	0.12	0.12	0.11	0.11	0.10	0.09	0.09	0.08	0.08	- 0.00
Output Price	PHA	1.10	1.03	0.97	0.92	0.87	0.82	0.77	0.73	0.69	0.65	0.61	0.58	0.55	0.52	0.49	0.46	0.44	0.41	0.39	0.37	0.35	0.33	0.31	0.30	0.28	0.27	0.25	0.24	0.23	0.21	0.20	0.19	0.18	0.17	0.16	0.15	0.14	0.14	0.13	0.12	0.12	0.11	0.10	0.10	0.09	0.09	0.08	0.08	0.07	- 0.00
Output Price	RUB	1.11	1.04	0.98	0.92	0.87	0.82	0.78	0.74	0.70	0.66	0.62	0.59	0.56	0.53	0.50	0.47	0.45	0.42	0.40	0.38	0.36	0.34	0.32	0.30	0.29	0.27	0.26	0.24	0.23	0.22	0.21	0.19	0.18	0.17	0.16	0.16	0.15	0.14	0.13	0.13	0.12	0.11	0.11	0.10	0.09	0.09	0.09	0.08	0.08	- 0.00
Output Price	CEM	0.94	0.95	0.93	0.91	0.88	0.84	0.80	0.76	0.72	0.69	0.65	0.62	0.58	0.55	0.52	0.49	0.47	0.44	0.42	0.40	0.38	0.36	0.34	0.32	0.30	0.28	0.27	0.25	0.24	0.23	0.22	0.20	0.19	0.18	0.17	0.16	0.16	0.15	0.14	0.13	0.12	0.12	0.11	0.11	0.10	0.09	0.09	0.08	0.08	- 0.00
Output Price	IRO	1.05	1.01	0.97	0.93	0.89	0.85	0.81	0.77	0.73	0.69	0.66	0.62	0.59	0.56	0.53	0.50	0.48	0.45	0.43	0.41	0.39	0.37	0.35	0.33	0.31	0.29	0.28	0.26	0.25	0.24	0.22	0.21	0.20	0.19	0.18	0.17	0.16	0.15	0.14	0.14	0.13	0.12	0.12	0.11	0.10	0.10	0.09	0.09	0.08	- 0.00
Output Price	MEQ	0.77	0.78	0.78	0.78	0.78	0.76	0.75	0.73	0.71	0.69	0.67	0.65	0.63	0.60	0.58	0.56	0.54	0.51	0.49	0.47	0.45	0.43	0.41	0.39	0.37	0.35	0.34	0.32	0.31	0.29	0.28	0.26	0.25	0.24	0.22	0.21	0.20	0.19	0.18	0.17	0.16	0.16	0.15	0.14	0.13	0.13	0.12	0.11	0.11	- 0.00
Output Price	AIR	0.43	0.45	0.47	0.48	0.48	0.49	0.49	0.49	0.48	0.48	0.47	0.46	0.45	0.44	0.43	0.42	0.41	0.39	0.38	0.37	0.36	0.34	0.33	0.32	0.31	0.30	0.28	0.27	0.26	0.25	0.24	0.23	0.22	0.21	0.20	0.19	0.18	0.18	0.17	0.16	0.15	0.15	0.14	0.13	0.13	0.12	0.11	0.11	0.10	- 0.00
Output Price	WAT	0.62	0.71	0.76	0.79	0.80	0.80	0.78	0.76	0.74	0.71	0.68	0.65	0.63	0.60	0.57	0.54	0.51	0.49	0.46	0.44	0.42	0.40	0.38	0.36	0.34	0.32	0.30	0.29	0.27	0.26	0.25	0.23	0.22	0.21	0.20	0.19	0.18	0.17	0.16	0.15	0.14	0.14	0.13	0.12	0.12	0.11	0.10	0.10	0.09	- 0.00
Output Price	CON	0.81	0.76	0.70	0.64	0.59	0.55	0.51	0.48	0.45	0.42	0.39	0.37	0.35	0.32	0.31	0.29	0.27	0.25	0.24	0.23	0.21	0.20	0.19	0.18	0.17	0.16	0.15	0.14	0.13	0.13	0.12	0.11	0.11	0.10	0.10	0.09	0.09	0.08	0.08	0.07	0.07	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.04	- 0.00
Output Price	DIS	1.03	0.97	0.93	0.88	0.84	0.80	0.76	0.73	0.69	0.66	0.62	0.59	0.56	0.53	0.51	0.48	0.46	0.43	0.41	0.39	0.37	0.35	0.33	0.31	0.30	0.28	0.27	0.25	0.24	0.23	0.22	0.20	0.19	0.18	0.17	0.16	0.16	0.15	0.14	0.13	0.13	0.12	0.11	0.11	0.10	0.10	0.09	0.09	0.08	- 0.00
Output Price	TRA	0.85	0.74	0.65	0.58	0.53	0.48	0.44	0.40	0.37	0.34	0.32	0.29	0.27	0.25	0.23	0.22	0.20	0.19	0.18	0.17	0.15	0.14	0.14	0.13	0.12	0.11	0.10	0.10	0.09	0.09	0.08	0.08	0.07	0.07	0.06	0.06	0.06	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	- 0.00
Output Price	COM	1.19	1.10	1.03	0.96	0.90	0.84	0.79	0.75	0.70	0.66	0.63	0.59	0.56	0.53	0.50	0.47	0.45	0.43	0.40	0.38	0.36	0.34	0.32	0.31	0.29	0.27	0.26	0.25	0.23	0.22	0.21	0.20	0.19	0.18	0.17	0.16	0.15	0.14	0.13	0.13	0.12	0.11	0.11	0.10	0.10	0.09	0.09	0.08	0.08	- 0.00
Output Price	PRS	1.08	1.02	0.96	0.91	0.87	0.82	0.78	0.74	0.70	0.67	0.63	0.60	0.57	0.54	0.51	0.49	0.46	0.44	0.42	0.39	0.37	0.35	0.34	0.32	0.30	0.29	0.27	0.26	0.24	0.23	0.22	0.21	0.20	0.19	0.18	0.17	0.16	0.15	0.14	0.13	0.13	0.12	0.11	0.11	0.10	0.10	0.09	0.09	0.08	- 0.00
Output Price	PHE	0.99	0.89	0.83	0.79	0.75	0.71	0.68	0.65	0.61	0.58	0.55	0.53	0.50	0.48	0.45	0.43	0.41	0.39	0.37	0.35	0.33	0.31	0.30	0.28	0.27	0.25	0.24	0.23	0.21	0.20	0.19	0.18	0.17	0.16	0.16	0.15	0.14	0.13	0.13	0.12	0.11	0.11	0.10	0.10	0.09	0.09	0.08	0.08	0.07	- 0.00
Output Price	OTH	1.18	1.13	1.09	1.05	1.00	0.96	0.92	0.87	0.83	0.79	0.76	0.72	0.68	0.65	0.62	0.59	0.56	0.53	0.50	0.48	0.45	0.43	0.41	0.39	0.37	0.35	0.33	0.31	0.30	0.28	0.27	0.25	0.24	0.23	0.22	0.20	0.19	0.18	0.17	0.17	0.16	0.15	0.14	0.13	0.13	0.12	0.11	0.11	0.10	- 0.00
Output Price	HSS	1.14	1.00	0.93	0.88	0.84	0.80	0.76	0.72	0.69	0.65	0.62	0.59	0.56	0.53	0.51	0.48	0.46	0.44	0.41	0.39	0.37	0.35	0.34	0.32	0.30	0.29	0.27	0.26	0.24	0.23	0.22	0.21	0.20	0.19	0.18	0.17	0.16	0.15	0.14	0.13	0.13	0.12	0.11	0.11	0.10	0.10	0.09	0.09	0.08	- 0.00
Output Price	RET	1.07	1.00	0.95	0.90	0.86	0.82	0.78	0.74	0.70	0.67	0.64	0.60	0.57	0.54	0.52	0.49	0.47	0.44	0.42	0.40	0.38	0.36	0.34	0.32	0.30	0.29	0.27	0.26	0.25	0.23	0.22	0.21	0.20	0.19	0.18	0.17	0.16	0.15	0.14	0.14	0.13	0.12	0.12	0.11	0.10	0.10	0.09	0.09	0.08	- 0.00
Output Price	ELE	0.86	0.77	0.70	0.64	0.59	0.55	0.51	0.48	0.45	0.42	0.39	0.37	0.35	0.33	0.31	0.29	0.27	0.26	0.24	0.23	0.22	0.20	0.19	0.18	0.17	0.16	0.15	0.15	0.14	0.13	0.12	0.12	0.11	0.10	0.10	0.09	0.09	0.08	0.08	0.07	0.07	0.07	0.06	0.06	0.06	0.05	0.05	0.05	0.04	- 0.00
Output Price	OGK	0.60	0.48	0.40	0.34	0.29	0.25	0.22	0.19	0.17	0.15	0.13	0.11	0.10	0.09	0.08	0.07	0.06	0.06	0.05	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	- 0.00	- 0.00	- 0.00	- 0.00	- 0.00	- 0.00	- 0.00
Output Price	COAL	0.54	0.47	0.42	0.39	0.36	0.34	0.31	0.29	0.27	0.26	0.24	0.23	0.21	0.20	0.19	0.17	0.16	0.15	0.15	0.14	0.13	0.12	0.11	0.11	0.10	0.09	0.09	0.08	0.08	0.07	0.07	0.07	0.06	0.06	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.02	- 0.00

Full CGE Model Output MigOFF Case

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
GRP Income measure	0.07	0.13	0.18	0.23	0.26	0.29	0.32	0.34	0.36	0.38	0.39	0.40	0.41	0.42	0.43	0.43	0.44	0.44	0.45	0.45	0.46	0.46	0.46	0.46	0.46
Consumer Price Index	1.02	1.00	0.98	0.97	0.95	0.94	0.93	0.92	0.91	0.90	0.89	0.89	0.88	0.88	0.87	0.87	0.87	0.87	0.86	0.86	0.86	0.86	0.86	0.86	0.86
Unemployment Rate	- 1.80	- 2.35	- 2.80	- 3.19	- 3.51	- 3.79	- 4.02	- 4.22	- 4.39	- 4.54	- 4.66	- 4.77	- 4.86	- 4.94	- 5.01	- 5.07	- 5.12	- 5.16	- 5.20	- 5.23	- 5.26	- 5.28	- 5.30	- 5.32	- 5.33
Total Employment	0.11	0.15	0.18	0.20	0.22	0.24	0.26	0.27	0.28	0.29	0.30	0.30	0.31	0.32	0.32	0.32	0.33	0.33	0.33	0.33	0.34	0.34	0.34	0.34	0.34
Nominal Gross Wage	1.23	1.27	1.31	1.34	1.36	1.38	1.40	1.41	1.42	1.43	1.44	1.45	1.45	1.46	1.46	1.47	1.47	1.47	1.47	1.48	1.48	1.48	1.48	1.48	1.48
Real Gross Wage	0.21	0.27	0.32	0.37	0.41	0.44	0.47	0.49	0.51	0.53	0.54	0.55	0.57	0.57	0.58	0.59	0.60	0.60	0.61	0.61	0.61	0.62	0.62	0.62	0.62
Replacment cost of capital	0.95	0.93	0.90	0.89	0.87	0.86	0.85	0.84	0.83	0.82	0.81	0.81	0.80	0.80	0.80	0.79	0.79	0.79	0.79	0.79	0.79	0.78	0.78	0.78	0.78
Labour supply	- 0.00	- 0.00	- 0.00	- 0.00	- 0.00	- 0.00	- 0.00	- 0.00	- 0.00	- 0.00	- 0.00	- 0.00	- 0.00	- 0.00	- 0.00	- 0.00	- 0.00	- 0.00	- 0.00	- 0.00	- 0.00	- 0.00	- 0.00	- 0.00	- 0.00
Households Consumption	0.17	0.22	0.27	0.31	0.34	0.37	0.39	0.41	0.43	0.44	0.46	0.47	0.48	0.48	0.49	0.50	0.50	0.51	0.51	0.51	0.52	0.52	0.52	0.52	0.53
Investment	0.72	0.71	0.70	0.70	0.69	0.69	0.69	0.69	0.69	0.69	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Capital Stock		0.11	0.19	0.27	0.33	0.38	0.43	0.47	0.50	0.53	0.55	0.57	0.59	0.60	0.62	0.63	0.64	0.65	0.65	0.66	0.66	0.67	0.67	0.67	0.68
Export RUK	2.88	2.95	3.01	3.06	3.10	3.13	3.16	3.18	3.20	3.22	3.23	3.24	3.26	3.26	3.27	3.28	3.28	3.29	3.29	3.30	3.30	3.30	3.31	3.31	3.31
Export ROW	2.95	2.99	3.03	3.06	3.08	3.10	3.12	3.14	3.15	3.16	3.17	3.18	3.19	3.20	3.20	3.21	3.21	3.21	3.22	3.22	3.22	3.23	3.23	3.23	3.23

	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	LR
GRP Income measure	0.46	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47
Consumer Price Index	0.86	0.86	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
Unemployment Rate	- 5.34	- 5.35	- 5.36	- 5.37	- 5.38	- 5.39	- 5.39	- 5.39	- 5.40	- 5.40	- 5.40	- 5.41	- 5.41	- 5.41	- 5.41	- 5.41	- 5.41	- 5.42	- 5.42	- 5.42	- 5.42	- 5.42	- 5.42	- 5.42	- 5.42
Total Employment	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Nominal Gross Wage	1.48	1.48	1.49	1.49	1.49	1.49	1.49	1.49	1.49	1.49	1.49	1.49	1.49	1.49	1.49	1.49	1.49	1.49	1.49	1.49	1.49	1.49	1.49	1.49	1.49
Real Gross Wage	0.62	0.62	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
Replacment cost of capital	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
Labour supply	- 0.00	- 0.00	- 0.00	- 0.00	- 0.00	- 0.00	- 0.00	- 0.00	- 0.00	- 0.00	- 0.00	- 0.00	- 0.00	- 0.00	- 0.00	- 0.00	- 0.00	- 0.00	- 0.00	- 0.00	- 0.00	- 0.00	- 0.00	- 0.00	- 0.00
Households Consumption	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53
Investment	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Capital Stock	0.68	0.68	0.68	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69
Export RUK	3.31	3.31	3.31	3.31	3.31	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32
Export ROW	3.23	3.23	3.23	3.23	3.23	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	LR
Households Consumption	AGR	0.17	0.24	0.30	0.35	0.39	0.43	0.46	0.48	0.51	0.53	0.54	0.56	0.57	0.58	0.59	0.60	0.60	0.61	0.62	0.62	0.62	0.63	0.63	0.63	0.63	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65
Households Consumption	EXT	0.17	0.24	0.30	0.35	0.40	0.43	0.46	0.48	0.50	0.52	0.53	0.54	0.55	0.56	0.57	0.57	0.58	0.58	0.59	0.59	0.59	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
Households Consumption	FOO	0.11	0.17	0.21	0.26	0.29	0.32	0.35	0.37	0.39	0.41	0.42	0.44	0.45	0.46	0.47	0.47	0.48	0.48	0.49	0.49	0.50	0.50	0.50	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52
Households Consumption	CLG	0.25	0.29	0.33	0.37	0.39	0.42	0.44	0.46	0.47	0.49	0.50	0.51	0.52	0.52	0.53	0.53	0.54	0.54	0.55	0.55	0.55	0.55	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57
Households Consumption	WWP	0.13	0.18	0.22	0.26	0.29	0.32	0.34	0.36	0.38	0.39	0.41	0.42	0.43	0.44	0.44	0.45	0.45	0.46	0.46	0.46	0.47	0.47	0.47	0.47	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.49
Households Consumption	CHE	0.11	0.18	0.23	0.28	0.32	0.35	0.38	0.40	0.42	0.44	0.46	0.47	0.48	0.49	0.50	0.50	0.51	0.51	0.52	0.52	0.53	0.53	0.53	0.53	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
Households Consumption	PHA	0.15	0.20	0.25	0.29	0.33	0.35	0.38	0.40	0.42	0.43	0.44	0.46	0.46	0.47	0.48	0.49	0.49	0.49	0.50	0.50	0.50	0.51	0.51	0.51	0.51	0.51	0.51	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52
Households Consumption	RUB	0.14	0.20	0.25	0.29	0.32	0.35	0.37	0.40	0.41	0.43	0.44	0.45	0.46	0.47	0.48	0.48	0.49	0.49	0.49	0.50	0.50	0.50	0.50	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52
Households Consumption	CEM	0.19	0.23	0.27	0.31	0.34	0.36	0.39	0.41	0.42	0.44	0.45	0.46	0.47	0.48	0.49	0.49	0.50	0.50	0.51	0.51	0.51	0.51	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53
Households Consumption	IRO	0.16	0.21	0.25	0.28	0.31	0.33	0.35	0.37	0.38	0.40	0.41	0.42	0.43	0.43	0.44	0.44	0.45	0.45	0.46	0.46	0.46	0.46	0.46	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
Households Consumption	MEQ	0.24	0.28	0.32	0.34	0.37	0.39	0.41	0.42	0.43	0.44	0.45	0.46	0.47	0.47	0.48	0.48	0.49	0.49	0.49	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51
Households Consumption	AIR	0.35	0.38	0.42	0.44	0.47	0.49	0.50	0.52	0.53	0.54	0.55	0.55	0.56	0.56	0.57	0.57	0.57	0.58	0.58	0.58	0.58	0.58	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Households Consumption	WAT	0.29	0.31	0.33	0.35	0.38	0.40	0.42	0.44	0.45	0.47	0.48	0.50	0.51	0.52	0.53	0.53	0.54	0.54	0.55	0.55	0.56	0.56	0.56	0.56	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58
Households Consumption	CON	0.23	0.30	0.35	0.39	0.43	0.46	0.49	0.51	0.52	0.54	0.55	0.56	0.57	0.58	0.59	0.59	0.60	0.60	0.60	0.61	0.61	0.61	0.61	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
Households Consumption	DIS	0.17	0.22	0.27	0.31	0.34	0.37	0.39	0.41	0.43	0.44	0.46	0.47	0.48	0.49	0.49	0.50	0.50	0.51	0.51	0.52	0.52	0.52	0.52	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54
Households Consumption	TRA	0.22	0.29	0.35	0.39	0.43	0.46	0.49	0.51	0.53	0.54	0.56	0.57	0.58	0.58	0.59	0.60	0.60	0.61	0.61	0.61	0.62	0.62	0.62	0.62	0.62	0.62	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
Households Consumption	COM	0.12	0.19	0.24	0.29	0.33	0.36	0.39	0.41	0.43	0.45	0.47	0.48	0.49	0.50	0.51	0.51	0.52	0.52	0.53	0.53	0.53	0.54	0.54	0.54	0.54	0.54	0.54	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
Households Consumption	PRS	0.15	0.21	0.25	0.29	0.32	0.35	0.37	0.39	0.41	0.42	0.44	0.45	0.46	0.46	0.47	0.48	0.48	0.48	0.49	0.49	0.49	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51
Households Consumption	PHE	0.18	0.23	0.27	0.30	0.33	0.35	0.37	0.39	0.40	0.41	0.42	0.43	0.44	0.45	0.45	0.46	0.46	0.46	0.47	0.47	0.47	0.47	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.49	0.49	0.49	0.49	0.49	0.49	0.49
Households Consumption	OTH	0.12	0.18	0.22	0.27	0.30	0.33	0.36	0.38	0.40	0.42	0.44	0.45	0.46	0.47	0.48	0.49	0.49	0.50	0.50	0.51	0.51	0.51	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53
Households Consumption	HSS	0.14	0.18	0.22	0.25	0.28	0.30	0.32	0.34	0.35	0.36	0.37	0.38	0.39	0.39	0.40	0.40	0.41	0.41	0.41	0.42	0.42	0.42	0.42	0.42	0.42	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43
Households Consumption	RET	0.16	0.20	0.25	0.28	0.31	0.34	0.36	0.38	0.40	0.41	0.42	0.43	0.44	0.45	0.46	0.46	0.47	0.47	0.48	0.48	0.48	0.48	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Households Consumption	ELE	0.22	0.29	0.34	0.39	0.43	0.46	0.48	0.51	0.53	0.54	0.56	0.57	0.58	0.59	0.59	0.60	0.61	0.61	0.61	0.62	0.62	0.62	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64
Households Consumption	OGK	0.30	0.37	0.43	0.47	0.51	0.54	0.57	0.59	0.61	0.62	0.64	0.65	0.66	0.66	0.67	0.68	0.68	0.69	0.69	0.69	0.70	0.70	0.70	0.70	0.70	0.70	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71
Households Consumption	COAL	0.31	0.37	0.41	0.45	0.48	0.51	0.53	0.55	0.56	0.58	0.59	0.60	0.61	0.61	0.62	0.63	0.63	0.63	0.64	0.64	0.64	0.64	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66
Capital Stock	AGR	Eps	0.24	0.45	0.64	0.80	0.94	1.06	1.16	1.25	1.33	1.40	1.46	1.52	1.56	1.60	1.63	1.66	1.69	1.71	1.73	1.75	1.76	1.77	1.78	1.79	1.80	1.81	1.81	1.82	1.82	1.83	1.83	1.83	1.84	1.84	1.84	1.84	1.84	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.85
Capital Stock	EXT	Eps	0.39	0.70	0.94	1.12	1.27	1.38	1.47	1.54	1.59	1.63	1.67	1.69	1.72	1.73	1.75	1.76	1.77	1.78	1.78	1.79	1.79	1.80	1.80	1.80	1.81	1.81	1.81	1.81	1.81	1.81	1.81	1.81	1.81	1.81	1.81	1.81	1.81	1.82	1.82	1.82	1.82	1.82	1.82	1.82	1.82	1.82	1.82	1.82	1.82
Capital Stock	FOO	Eps	0.13	0.24	0.35	0.46	0.55	0.64	0.72	0.79	0.85	0.91	0.96	1.01	1.05	1.08	1.12	1.14	1.17	1.19	1.21	1.23	1.24	1.26	1.27	1.28	1.29	1.30	1.30	1.31	1.32	1.32	1.32	1.33	1.33	1.33	1.34	1.34	1.34	1.34	1.34	1.34	1.35	1.35	1.35	1.35	1.35	1.35	1.35	1.35	1.35
Capital Stock	CLG	Eps	-0.03	-0.03	-0.03	-0.02	-0.01	0.00	0.02	0.03	0.05	0.06	0.07	0.08	0.09	0.10	0.11	0.11	0.12	0.12	0.13	0.13	0.13	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Capital Stock	WWP	Eps	0.07	0.14	0.20	0.25	0.30	0.35	0.39	0.43	0.46	0.49	0.51	0.53	0.55	0.57	0.58	0.59	0.60	0.61	0.62	0.63	0.64	0.64	0.65	0.65	0.65	0.66	0.66	0.66	0.66	0.66	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67
Capital Stock	CHE	Eps	0.24	0.45	0.64	0.80	0.94	1.05	1.16	1.25	1.32	1.39	1.44	1.49	1.53	1.57	1.60	1.62	1.64	1.66	1.68	1.69	1.70	1.71	1.72	1.73	1.74	1.74	1.75	1.75	1.75	1.76	1.76	1.76	1.76	1.76	1.76	1.77	1.77	1.77	1.77	1.77	1.77	1.77	1.77	1.77	1.77	1.77	1.77	1.77	1.77
Capital Stock	PHA	Eps	0.18	0.34	0.47	0.58	0.67	0.75	0.81	0.87	0.91	0.95	0.98	1.01	1.03	1.05	1.06	1.07	1.09	1.10	1.10	1.11	1.11	1.12	1.12	1.13	1.13	1.13	1.13	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.15	1.15	1.15
Capital Stock	RUB	Eps	0.16	0.30	0.41	0.51	0.59	0.66	0.72	0.77	0.81	0.85	0.88	0.90	0.92	0.94	0.95	0.97	0.98	0.99	1.00	1.00	1.01	1.01	1.02	1.02	1.02	1.03	1.03	1.03	1.03	1.03	1.03	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
Capital Stock	CEM	-0.00	-0.02	-0.01	0.02	0.06	0.10	0.14	0.17	0.21	0.24	0.26	0.28	0.30	0.32	0.33	0.35	0.36	0.37	0.37	0.38	0.39	0.39	0.39	0.40	0.40	0.40	0.40	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.42
Capital Stock	IRO	Eps	-0.06	-0.09	-0.10	-0.11	-0.11	-0.10	-0.09	-0.09	-0.08	-0.07	-0.07	-0.06	-0.06	-0.05	-0.05	-0.05	-0.05	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03
Capital Stock	MEQ	Eps	-0.14	-0.25	-0.34	-0.42	-0.48	-0.54	-0.58	-0.62	-0.65	-0.68	-0.70	-0.72	-0.74	-0.75	-0.76	-0.77	-0.77	-0.78	-0.79	-0.79	-0.79	-0.80	-0.80	-0.80	-0.80	-0.80	-0.80	-0.81	-0.81	-0.81	-0.81	-0.81	-0.81	-0.81	-0.81	-0.81	-0.81	-0.81	-0.81	-0.81	-0.81	-0.81	-0.81	-0.81	-0.81	-0.81	-0.81	-0.81	-0.81
Capital Stock	AIR	Eps	-0.22	-0.42	-0.59	-0.73	-0.86	-0.98	-1.08	-1.17	-1.24	-1.31	-1.37	-1.43	-1.48	-1.52	-1.56	-1.59	-1.62	-1.65	-1.67	-1.69	-1.71	-1.73	-1.75	-1.76	-1.77	-1.78	-1.79	-1.80	-1.81	-1.82	-1.83	-1.83	-1.84	-1.84	-1.85	-1.85	-1.86	-1.86	-1.86	-1.86	-1.87	-1.87	-1.87	-1.87	-1.87	-1.88	-1.88	-1.88	-1.89
Capital Stock	WAT	Eps	-0.05	-0.07	-0.06	-0.05	-0.03	0.00	0.03	0.06	0.08	0.11	0.13	0.15	0.17	0.19	0.20	0.21	0.22	0.23	0.24	0.25	0.26	0.26	0.27	0.27	0.28	0.28	0.28	0.28	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Capital Stock	CON	-0.00	0.16	0.29	0.38	0.46	0.52	0.57	0.60	0.63	0.66	0.68	0.69	0.71	0.72	0.73	0.73	0.74	0.74	0.75	0.75	0.76	0.76	0.76	0.76	0.76	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
Capital Stock	DIS	-0.00	0.08	0.14	0.20	0.25	0.30	0.34	0.37	0.40	0.43	0.45	0.47	0.48	0.50	0.51	0.52	0.53	0.54	0.54	0.55	0.55	0.56	0.56	0.57	0.57	0.57	0.57	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Capital Stock	TRA	Eps	0.26	0.46	0.61	0.72	0.81	0.88	0.94	0.98	1.02	1.05	1.07	1.09	1.11	1.12	1.14	1.15	1.15	1.16	1.17	1.17	1.18	1.18	1.18	1.19	1.19	1.19	1.19	1.19	1.19	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
Capital Stock	COM	Eps	0.20	0.37	0.50	0.62	0.72	0.80	0.86	0.92	0.97	1.01	1.04	1.07	1.09	1.11	1.13	1.14	1.16	1.17	1.18	1.18	1.19	1.20	1.20	1.20	1.21	1.21	1.21	1.21	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23
Capital Stock	PRS	Eps	0.14	0.25	0.34	0.41	0.47	0.52	0.56	0.60	0.63	0.65	0.67	0.69	0.70	0.71	0.72	0.73	0.74	0.75	0.75	0.76	0.76	0.76	0.77	0.77	0.77	0.77	0.77	0.77	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
Capital Stock	PHE	-0.00	0.06	0.10	0.13	0.15	0.16	0.18	0.19	0.20	0.20	0.21	0.21	0.22	0.22	0.23	0.23	0.23	0.23	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Capital Stock	OTH	Eps	0.07	0.14	0.21	0.27	0.32	0.36	0.41	0.44	0.47	0.50	0.52	0.55	0.56	0.58	0.59	0.60	0.61	0.62	0.63	0.64	0.64	0.65	0.65	0.65	0.66	0.66	0.66	0.66	0.66	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67
Capital Stock	HSS	Eps	0.07	0.11	0.14	0.16	0.18	0.19	0.20	0.21	0.22	0.22	0.23	0.23	0.24	0.24	0.24	0.25	0.25	0.25	0.25	0.25	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26
Capital Stock	RET	Eps	0.07	0.13	0.18	0.23	0.27	0.30	0.33	0.36	0.38	0.40	0.42	0.43	0.44	0.45	0.46	0.47	0.48	0.48	0.49	0.49	0.50	0.50	0.50	0.50	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52
Capital Stock	ELE	Eps	0.24	0.44	0.61	0.75	0.86	0.96	1.04	1.10	1.16	1.21	1.24	1.28	1.30	1.33	1.35	1.36	1.38	1.39	1.40	1.41	1.41	1.42	1.42	1.43	1.43	1.44	1.44	1.44	1.44	1.44	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45
Capital Stock	OGK	Eps	0.71	1.18	1.50	1.73	1.89	2.00	2.09	2.16	2.21	2.25	2.28	2.31	2.33	2.35	2.36	2.37	2.38	2.39	2.40	2.41	2.41	2.42	2.42	2.42	2.43	2.43	2.43	2.43	2.43	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44
Capital Stock	COAL	Eps	0.38	0.62	0.79	0.90	0.99	1.06	1.12	1.16	1.20	1.23	1.26	1.28	1.30	1.31	1.32	1.34	1.34	1.35	1.36	1.37	1.37	1.37	1.38	1.38	1.38	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	LR
Total Output	AGR	0.45	0.65	0.82	0.97	1.09	1.21	1.30	1.39	1.46	1.53	1.58	1.63	1.67	1.71	1.74	1.77	1.79	1.81	1.83	1.84	1.86	1.87	1.88	1.88	1.89	1.90	1.90	1.91	1.91	1.92	1.92	1.92	1.92	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.94	1.94	1.94	1.94	1.94	1.94	1.94	1.94	1.94
Total Output	EXT	0.85	1.08	1.26	1.40	1.50	1.59	1.65	1.71	1.75	1.78	1.81	1.83	1.84	1.86	1.87	1.88	1.88	1.89	1.89	1.90	1.90	1.90	1.91	1.91	1.91	1.91	1.91	1.91	1.91	1.92	1.92	1.92	1.92	1.92	1.92	1.92	1.92	1.92	1.92	1.92	1.92	1.92	1.92	1.92	1.92	1.92	1.92	1.92	1.92	1.92
Total Output	FOO	0.17	0.29	0.39	0.49	0.58	0.66	0.73	0.80	0.86	0.91	0.96	1.00	1.04	1.07	1.10	1.13	1.15	1.17	1.19	1.21	1.22	1.23	1.24	1.25	1.26	1.27	1.28	1.28	1.29	1.29	1.29	1.30	1.30	1.30	1.30	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.32	1.32	1.32	1.32	1.32
Total Output	CLG	0.02	0.02	0.02	0.03	0.05	0.06	0.07	0.08	0.09	0.10	0.11	0.12	0.13	0.13	0.14	0.14	0.15	0.15	0.15	0.16	0.16	0.16	0.16	0.16	0.16	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Total Output	WWP	0.10	0.15	0.21	0.26	0.30	0.34	0.38	0.41	0.43	0.46	0.48	0.50	0.51	0.53	0.54	0.55	0.56	0.57	0.57	0.58	0.59	0.59	0.59	0.60	0.60	0.60	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62
Total Output	CHE	0.43	0.62	0.78	0.92	1.05	1.15	1.24	1.32	1.38	1.44	1.49	1.53	1.57	1.60	1.62	1.65	1.66	1.68	1.69	1.71	1.72	1.73	1.73	1.74	1.74	1.75	1.75	1.76	1.76	1.76	1.76	1.77	1.77	1.77	1.77	1.77	1.77	1.77	1.77	1.77	1.77	1.77	1.77	1.77	1.78	1.78	1.78	1.78	1.78	1.78
Total Output	PHA	0.34	0.47	0.58	0.67	0.74	0.80	0.85	0.90	0.93	0.96	0.99	1.01	1.03	1.04	1.06	1.07	1.07	1.08	1.09	1.09	1.10	1.10	1.11	1.11	1.11	1.11	1.11	1.11	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12
Total Output	RUB	0.29	0.41	0.50	0.58	0.65	0.71	0.76	0.80	0.83	0.86	0.88	0.90	0.92	0.93	0.95	0.96	0.97	0.97	0.98	0.99	0.99	0.99	1.00	1.00	1.00	1.00	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
Total Output	CEM	-0.01	0.02	0.06	0.10	0.13	0.17	0.20	0.23	0.26	0.28	0.30	0.32	0.33	0.34	0.35	0.36	0.37	0.38	0.38	0.39	0.39	0.39	0.39	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41
Total Output	IRO	-0.12	-0.13	-0.14	-0.14	-0.14	-0.13	-0.13	-0.12	-0.12	-0.12	-0.11	-0.11	-0.11	-0.10	-0.10	-0.10	-0.10	-0.10	-0.10	-0.09	-0.09	-0.09	-0.09	-0.09	-0.09	-0.09	-0.09	-0.09	-0.09	-0.09	-0.09	-0.09	-0.09	-0.09	-0.09	-0.09	-0.09	-0.09	-0.09	-0.09	-0.09	-0.09	-0.09	-0.09	-0.09	-0.09	-0.09	-0.09	-0.09	-0.09
Total Output	MEQ	-0.21	-0.31	-0.40	-0.47	-0.53	-0.58	-0.63	-0.66	-0.69	-0.72	-0.74	-0.75	-0.77	-0.78	-0.79	-0.80	-0.81	-0.81	-0.82	-0.82	-0.82	-0.83	-0.83	-0.83	-0.83	-0.83	-0.84	-0.84	-0.84	-0.84	-0.84	-0.84	-0.84	-0.84	-0.84	-0.84	-0.84	-0.84	-0.84	-0.84	-0.84	-0.84	-0.84	-0.84	-0.84	-0.84	-0.84	-0.84	-0.84	-0.84
Total Output	AIR	-0.26	-0.44	-0.60	-0.73	-0.85	-0.96	-1.05	-1.13	-1.21	-1.27	-1.33	-1.38	-1.42	-1.46	-1.50	-1.53	-1.56	-1.58	-1.61	-1.63	-1.64	-1.66	-1.68	-1.69	-1.70	-1.71	-1.72	-1.73	-1.74	-1.74	-1.75	-1.76	-1.76	-1.77	-1.77	-1.77	-1.78	-1.78	-1.78	-1.79	-1.79	-1.79	-1.79	-1.79	-1.80	-1.80	-1.80	-1.80	-1.80	-1.81
Total Output	WAT	0.02	-0.00	0.00	0.02	0.04	0.06	0.09	0.11	0.14	0.16	0.18	0.20	0.22	0.24	0.25	0.26	0.27	0.28	0.29	0.30	0.30	0.31	0.31	0.32	0.32	0.33	0.33	0.33	0.33	0.33	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
Total Output	CON	0.37	0.47	0.54	0.60	0.65	0.69	0.71	0.74	0.76	0.77	0.78	0.79	0.80	0.81	0.81	0.82	0.82	0.83	0.83	0.83	0.83	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
Total Output	DIS	0.15	0.21	0.26	0.30	0.34	0.38	0.40	0.43	0.45	0.47	0.48	0.50	0.51	0.52	0.53	0.54	0.54	0.55	0.55	0.56	0.56	0.57	0.57	0.57	0.57	0.57	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Total Output	TRA	0.57	0.72	0.83	0.92	0.98	1.04	1.08	1.12	1.14	1.17	1.19	1.20	1.22	1.23	1.24	1.24	1.25	1.26	1.26	1.27	1.27	1.27	1.27	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29
Total Output	COM	0.39	0.53	0.65	0.75	0.83	0.90	0.96	1.01	1.05	1.08	1.11	1.13	1.15	1.17	1.18	1.20	1.21	1.21	1.22	1.23	1.23	1.24	1.24	1.25	1.25	1.25	1.25	1.25	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.27	1.27
Total Output	PRS	0.25	0.33	0.40	0.46	0.50	0.54	0.58	0.60	0.62	0.64	0.66	0.67	0.68	0.69	0.70	0.71	0.71	0.72	0.72	0.73	0.73	0.73	0.73	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Total Output	PHE	0.16	0.17	0.18	0.19	0.19	0.20	0.20	0.21	0.21	0.21	0.21	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23
Total Output	OTH	0.09	0.16	0.22	0.27	0.32	0.36	0.40	0.44	0.47	0.49	0.51	0.53	0.55	0.57	0.58	0.59	0.60	0.61	0.61	0.62	0.63	0.63	0.63	0.64	0.64	0.64	0.64	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66
Total Output	HSS	0.11	0.12	0.13	0.13	0.14	0.14	0.15	0.15	0.15	0.15	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Total Output	RET	0.15	0.20	0.24	0.28	0.31	0.34	0.36	0.38	0.40	0.42	0.43	0.44	0.45	0.46	0.47	0.47	0.48	0.48	0.49	0.49	0.49	0.50	0.50	0.50	0.50	0.50	0.50	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51
Total Output	ELE	0.56	0.73	0.87	0.98	1.08	1.16	1.22	1.28	1.32	1.36	1.39	1.42	1.44	1.46	1.48	1.49	1.50	1.51	1.52	1.53	1.53	1.54	1.54	1.55	1.55	1.55	1.55	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57
Total Output	OGK	1.54	1.79	1.97	2.11	2.21	2.28	2.34	2.39	2.42	2.45	2.48	2.50	2.52	2.53	2.54	2.55	2.56	2.57	2.57	2.58	2.58	2.59	2.59	2.59	2.59	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.61	2.61	2.61	2.61	2.61	2.61	2.61	2.61	2.61	2.61	2.61	2.61	2.61	2.61	2.61	2.61
Total Output	COAL	0.92	1.02	1.11	1.17	1.23	1.28	1.32	1.35	1.38	1.40	1.42	1.44	1.45	1.46	1.47	1.48	1.49	1.49	1.50	1.50	1.51	1.51	1.51	1.51	1.52	1.52	1.52	1.52	1.52	1.52	1.52	1.52	1.52	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53
Value Added	AGR	0.15	0.36	0.54	0.71	0.85	0.97	1.07	1.17	1.25	1.32	1.38	1.43	1.48	1.52	1.55	1.58	1.61	1.63	1.65	1.66	1.68	1.69	1.70	1.71	1.72	1.73	1.73	1.74	1.74	1.75	1.75	1.75	1.76	1.76	1.76	1.76	1.76	1.76	1.77	1.77	1.77	1.77	1.77	1.77	1.77	1.77	1.77	1.77	1.77	1.77
Value Added	EXT	0.48	0.74	0.94	1.10	1.22	1.31	1.39	1.44	1.49	1.52	1.55	1.57	1.59	1.61	1.62	1.63	1.63	1.64	1.65	1.65	1.65	1.66	1.66	1.66	1.66	1.66	1.66	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67
Value Added	FOO	0.10	0.21	0.30	0.40	0.48	0.56	0.63	0.70	0.76	0.81	0.86	0.90	0.94	0.97	1.00	1.03	1.05	1.07	1.09	1.11	1.12	1.14	1.15	1.16	1.16	1.17	1.18	1.18	1.19	1.19	1.20	1.20	1.20	1.21	1.21	1.21	1.21	1.21	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22
Value Added	CLG	-0.11	-0.12	-0.13	-0.12	-0.12	-0.11	-0.11	-0.10	-0.09	-0.08	-0.07	-0.07	-0.06	-0.06	-0.05	-0.05	-0.04	-0.04	-0.04	-0.04	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02
Value Added	WWP	0.04	0.09	0.14	0.18	0.22	0.26	0.29	0.32	0.35	0.37	0.39	0.41	0.43	0.44	0.45	0.46	0.47	0.48	0.49	0.49	0.50	0.50	0.51	0.51	0.51	0.51	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53
Value Added	CHE	0.23	0.43	0.60	0.75	0.87	0.98	1.08	1.16	1.23	1.29	1.34	1.39	1.42	1.46	1.48	1.51	1.53	1.54	1.56	1.57	1.58	1.59	1.60	1.61	1.61	1.62	1.62	1.63	1.63	1.63	1.63	1.63	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.65	1.65
Value Added	PHA	0.21	0.34	0.44	0.53	0.61	0.67	0.72	0.76	0.80	0.83	0.86	0.88	0.89	0.91	0.92	0.93	0.94	0.95	0.95	0.96	0.96	0.97	0.97	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
Value Added	RUB	0.18	0.29	0.38	0.46	0.53	0.58	0.63	0.67	0.70	0.73	0.75	0.77	0.78	0.80	0.81	0.82	0.83	0.84	0.84	0.85	0.85	0.86	0.86	0.86	0.86	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88
Value Added	CEM	-0.07	-0.07	-0.04	-0.01	0.02	0.05	0.08	0.11	0.13	0.16	0.18	0.19	0.21	0.22	0.23	0.24	0.25	0.25	0.26	0.26	0.27	0.27	0.27	0.27	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29
Value Added	IRO	-0.17	-0.20	-0.21	-0.22	-0.23	-0.23	-0.23	-0.23	-0.23	-0.22	-0.22	-0.22	-0.22	-0.22	-0.22	-0.21	-0.21	-0.21	-0.21	-0.21	-0.21	-0.21	-0.21	-0.21	-0.21	-0.21	-0.21	-0.21	-0.21	-0.21	-0.21	-0.21	-0.21	-0.21	-0.21	-0.21	-0.21	-0.21	-0.21	-0.21	-0.21	-0.21	-0.21	-0.21	-0.21	-0.21	-0.21	-0.21	-0.21	-0.21
Value Added	MEQ	-0.23	-0.34	-0.44	-0.53	-0.59	-0.65	-0.70	-0.74	-0.77	-0.80	-0.83	-0.85	-0.86	-0.88	-0.89	-0.90	-0.90	-0.91	-0.92	-0.92	-0.92	-0.93	-0.93	-0.93	-0.93	-0.94	-0.94	-0.94	-0.94	-0.94	-0.94	-0.94	-0.94	-0.94	-0.94	-0.94	-0.94	-0.94	-0.94	-0.94	-0.94	-0.94	-0.94	-0.94	-0.94	-0.94	-0.94	-0.94	-0.94	-0.94
Value Added	AIR	-0.30	-0.50	-0.67	-0.83	-0.96	-1.08	-1.18	-1.27	-1.35	-1.42	-1.48	-1.54	-1.59	-1.63	-1.67	-1.70	-1.73	-1.76	-1.79	-1.81	-1.83	-1.85	-1.86	-1.88	-1.89	-1.90	-1.91	-1.92	-1.93	-1.94	-1.94	-1.95	-1.95	-1.96	-1.96	-1.97	-1.97	-1.97	-1.98	-1.98	-1.98	-1.98	-1.99	-1.99	-1.99	-1.99	-1.99	-1.99	-2.00	-2.01
Value Added	WAT	-0.05	-0.09	-0.10	-0.09	-0.07	-0.05	-0.03	-0.00	0.03	0.05	0.07	0.09	0.11	0.13	0.14	0.16	0.17	0.18	0.19	0.20	0.20	0.21	0.21	0.22	0.22	0.22	0.23	0.23	0.23	0.23	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.25	0.25	0.25	0.25
Value Added	CON	0.14	0.25	0.33	0.39	0.44	0.48	0.51	0.54	0.56	0.57	0.58	0.59	0.60	0.61	0.62	0.62	0.62	0.63	0.63	0.63	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65
Value Added	DIS	0.04	0.09	0.14	0.19	0.22	0.25	0.28	0.31	0.33	0.35	0.36	0.38	0.39	0.40	0.41	0.41	0.42	0.43	0.43	0.44	0.44	0.44	0.45	0.45	0.45	0.45	0.45	0.45	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46
Value Added	TRA	0.31	0.47	0.59	0.68	0.75	0.80	0.85	0.88	0.91	0.93	0.95	0.97	0.98	0.99	1.00	1.01	1.01	1.02	1.02	1.03	1.03	1.03	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05
Value Added	COM	0.16	0.32	0.45	0.55	0.64	0.72	0.78	0.83	0.88	0.91	0.95	0.97	0.99	1.01	1.03	1.04	1.05	1.06	1.07	1.08	1.08	1.09	1.09	1.10	1.10	1.10	1.10	1.10	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.12	1.12	1.12	1.12	1.12	1.12	1.12
Value Added	PRS	0.13	0.22	0.29	0.35	0.39	0.43	0.46	0.49	0.51	0.53	0.55	0.56	0.57	0.58	0.59	0.59	0.60	0.60	0.61	0.61	0.61	0.62	0.62	0.62	0.62	0.62	0.62	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
Value Added	PHE	0.03	0.04	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Value Added	OTH	0.02	0.09	0.15	0.20	0.25	0.30	0.34	0.37	0.41	0.43	0.46	0.48	0.49	0.51	0.52	0.54	0.55	0.55	0.56	0.57	0.57	0.58	0.58	0.59	0.59	0.59	0.59	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
Value Added	HSS	0.04	0.05	0.06	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Value Added	RET	0.04	0.08	0.12	0.15	0.18	0.21	0.23	0.25	0.27	0.28	0.29	0.31	0.31	0.32	0.33	0.34	0.34	0.35	0.35	0.35	0.36	0.36	0.36	0.36	0.36	0.36	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
Value Added	ELE	0.13	0.34	0.51	0.66	0.78	0.87	0.96	1.02	1.08	1.13	1.17	1.20	1.23	1.25	1.27	1.29	1.30	1.31	1.32	1.33	1.34	1.35	1.35	1.36	1.36	1.36	1.37	1.37	1.37	1.37	1.37	1.37	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38
Value Added	OGK	1.08	1.39	1.61	1.76	1.87	1.95	2.01	2.06	2.09	2.12	2.15	2.17	2.18	2.19	2.21	2.22	2.22	2.23	2.23	2.24	2.24	2.25	2.25	2.25	2.25	2.26	2.26	2.26	2.26	2.26	2.26	2.26	2.26	2.26	2.26	2.26	2.26	2.26	2.27	2.27	2.27	2.27	2.27	2.27	2.27	2.27	2.27	2.27	2.27	2.27
Value Added	COAL	0.64	0.74	0.82	0.88	0.93	0.98	1.01	1.04	1.06	1.08	1.10	1.12	1.13	1.14	1.15	1.15	1.16	1.17	1.17	1.17	1.18	1.18	1.18	1.18	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	LR
Employment	AGR	0.40	0.56	0.70	0.82	0.93	1.02	1.10	1.17	1.24	1.29	1.34	1.38	1.41	1.44	1.47	1.49	1.51	1.53	1.54	1.56	1.57	1.58	1.58	1.59	1.60	1.60	1.61	1.61	1.62	1.62	1.62	1.62	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64
Employment	EXT	0.71	0.90	1.06	1.17	1.26	1.33	1.39	1.43	1.47	1.49	1.51	1.53	1.54	1.55	1.56	1.57	1.58	1.58	1.58	1.59	1.59	1.59	1.59	1.59	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60
Employment	FOO	0.17	0.26	0.35	0.43	0.50	0.57	0.63	0.69	0.74	0.78	0.82	0.86	0.89	0.92	0.95	0.97	0.99	1.01	1.03	1.04	1.05	1.06	1.07	1.08	1.09	1.09	1.10	1.11	1.11	1.11	1.12	1.12	1.12	1.12	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.14	1.14	1.14	1.14	1.14	1.14	1.14
Employment	CLG	-0.13	-0.14	-0.15	-0.15	-0.14	-0.14	-0.13	-0.12	-0.12	-0.11	-0.10	-0.10	-0.09	-0.09	-0.08	-0.08	-0.08	-0.08	-0.07	-0.07	-0.07	-0.07	-0.07	-0.07	-0.07	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06
Employment	WWP	0.06	0.10	0.14	0.18	0.21	0.24	0.27	0.29	0.31	0.33	0.35	0.36	0.38	0.39	0.40	0.41	0.41	0.42	0.43	0.43	0.44	0.44	0.44	0.44	0.45	0.45	0.45	0.45	0.45	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46
Employment	CHE	0.40	0.56	0.70	0.82	0.93	1.02	1.09	1.16	1.22	1.27	1.31	1.35	1.38	1.40	1.43	1.44	1.46	1.48	1.49	1.50	1.51	1.51	1.52	1.53	1.53	1.53	1.54	1.54	1.54	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56
Employment	PHA	0.28	0.39	0.48	0.56	0.62	0.67	0.71	0.75	0.78	0.80	0.82	0.84	0.86	0.87	0.88	0.89	0.89	0.90	0.91	0.91	0.91	0.92	0.92	0.92	0.92	0.92	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93
Employment	RUB	0.24	0.33	0.41	0.47	0.53	0.58	0.62	0.65	0.68	0.70	0.72	0.74	0.75	0.76	0.77	0.78	0.79	0.79	0.80	0.80	0.81	0.81	0.81	0.81	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83
Employment	CEM	-0.12	-0.10	-0.07	-0.04	-0.01	0.02	0.05	0.07	0.09	0.11	0.12	0.13	0.14	0.15	0.16	0.17	0.17	0.18	0.18	0.19	0.19	0.19	0.19	0.19	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Employment	IRO	-0.20	-0.22	-0.24	-0.24	-0.25	-0.25	-0.25	-0.25	-0.25	-0.25	-0.25	-0.25	-0.25	-0.25	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24
Employment	MEQ	-0.35	-0.46	-0.55	-0.63	-0.69	-0.75	-0.79	-0.83	-0.86	-0.89	-0.91	-0.93	-0.94	-0.95	-0.96	-0.97	-0.98	-0.99	-0.99	-1.00	-1.00	-1.00	-1.01	-1.01	-1.01	-1.01	-1.01	-1.01	-1.01	-1.02	-1.02	-1.02	-1.02	-1.02	-1.02	-1.02	-1.02	-1.02	-1.02	-1.02	-1.02	-1.02	-1.02	-1.02	-1.02	-1.02	-1.02	-1.02	-1.02	-1.02
Employment	AIR	-0.53	-0.71	-0.87	-1.01	-1.14	-1.24	-1.34	-1.42	-1.49	-1.56	-1.62	-1.67	-1.71	-1.75	-1.79	-1.82	-1.85	-1.87	-1.90	-1.92	-1.93	-1.95	-1.96	-1.98	-1.99	-2.00	-2.01	-2.02	-2.03	-2.03	-2.04	-2.04	-2.05	-2.05	-2.06	-2.06	-2.07	-2.07	-2.07	-2.07	-2.08	-2.08	-2.08	-2.08	-2.08	-2.08	-2.09	-2.09	-2.09	-2.10
Employment	WAT	-0.18	-0.19	-0.18	-0.17	-0.15	-0.13	-0.11	-0.09	-0.07	-0.05	-0.03	-0.02	-0.00	0.01	0.02	0.03	0.04	0.04	0.05	0.05	0.06	0.06	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Employment	CON	0.24	0.31	0.36	0.40	0.43	0.46	0.48	0.49	0.50	0.51	0.52	0.53	0.53	0.54	0.54	0.54	0.55	0.55	0.55	0.55	0.55	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56
Employment	DIS	0.07	0.11	0.14	0.17	0.20	0.22	0.24	0.26	0.28	0.29	0.30	0.31	0.32	0.33	0.33	0.34	0.34	0.35	0.35	0.35	0.36	0.36	0.36	0.36	0.36	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
Employment	TRA	0.44	0.55	0.64	0.70	0.76	0.80	0.83	0.86	0.88	0.90	0.91	0.92	0.93	0.94	0.95	0.95	0.96	0.96	0.97	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
Employment	COM	0.32	0.43	0.52	0.60	0.67	0.72	0.77	0.81	0.84	0.86	0.89	0.91	0.92	0.94	0.95	0.96	0.97	0.97	0.98	0.98	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
Employment	PRS	0.19	0.25	0.31	0.35	0.39	0.42	0.44	0.46	0.48	0.49	0.50	0.51	0.52	0.53	0.54	0.54	0.55	0.55	0.55	0.55	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57
Employment	PHE	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Employment	OTH	0.07	0.11	0.15	0.19	0.23	0.26	0.28	0.31	0.33	0.35	0.36	0.38	0.39	0.40	0.41	0.42	0.42	0.43	0.43	0.44	0.44	0.44	0.45	0.45	0.45	0.45	0.45	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46
Employment	HSS	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Employment	RET	0.05	0.08	0.11	0.14	0.16	0.18	0.20	0.21	0.23	0.24	0.25	0.26	0.26	0.27	0.27	0.28	0.28	0.29	0.29	0.29	0.29	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31
Employment	ELE	0.40	0.54	0.66	0.75	0.83	0.90	0.95	1.00	1.04	1.07	1.09	1.12	1.14	1.15	1.17	1.18	1.19	1.19	1.20	1.21	1.21	1.22	1.22	1.22	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.24	1.24	1.24	1.24	1.24	1.24	1.24	1.24	1.24	1.24	1.24	1.24	1.24	1.24	1.24	1.24	1.24	1.24	1.24
Employment	OGK	1.33	1.55	1.71	1.82	1.90	1.96	2.01	2.05	2.08	2.10	2.12	2.14	2.15	2.16	2.17	2.18	2.19	2.19	2.20	2.20	2.21	2.21	2.21	2.21	2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.23	2.23	2.23	2.23	2.23	2.23	2.23	2.23	2.23	2.23	2.23	2.23	2.23	2.23	2.23
Employment	COAL	0.67	0.76	0.83	0.89	0.93	0.97	1.01	1.04	1.06	1.08	1.09	1.11	1.12	1.13	1.14	1.14	1.15	1.16	1.16	1.16	1.17	1.17	1.17	1.17	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.19
Total Import	AGR	2.50	2.44	2.40	2.36	2.33	2.30	2.28	2.26	2.25	2.23	2.22	2.21	2.21	2.20	2.20	2.19	2.19	2.19	2.19	2.18	2.18	2.18	2.18	2.18	2.18	2.18	2.18	2.18	2.18	2.18	2.18	2.18	2.18	2.18	2.18	2.18	2.18	2.18	2.18	2.18	2.18	2.18	2.18	2.18	2.18	2.18	2.18	2.18	2.18	2.18
Total Import	EXT	2.02	1.93	1.86	1.82	1.78	1.76	1.74	1.73	1.73	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72
Total Import	FOO	2.59	2.60	2.61	2.62	2.62	2.62	2.62	2.61	2.61	2.61	2.61	2.60	2.60	2.60	2.60	2.59	2.59	2.59	2.59	2.58	2.58	2.58	2.58	2.58	2.58	2.58	2.58	2.58	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57
Total Import	CLG	1.85	1.89	1.92	1.95	1.97	1.99	2.00	2.01	2.02	2.03	2.04	2.05	2.05	2.06	2.06	2.06	2.07	2.07	2.07	2.07	2.07	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
Total Import	WWP	2.61	2.62	2.63	2.64	2.65	2.65	2.66	2.66	2.66	2.66	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67
Total Import	CHE	2.71	2.73	2.75	2.76	2.78	2.79	2.80	2.81	2.81	2.82	2.83	2.83	2.83	2.84	2.84	2.84	2.84	2.85	2.85	2.85	2.85	2.85	2.85	2.85	2.85	2.85	2.86	2.86	2.86	2.86	2.86	2.86	2.86	2.86	2.86	2.86	2.86	2.86	2.86	2.86	2.86	2.86	2.86	2.86	2.86	2.86	2.86	2.86	2.86	2.86
Total Import	PHA	2.38	2.37	2.36	2.36	2.36	2.35	2.35	2.35	2.35	2.35	2.35	2.35	2.35	2.36	2.36	2.36	2.36	2.36	2.36	2.36	2.36	2.36	2.36	2.36	2.36	2.36	2.36	2.36	2.36	2.36	2.36	2.37	2.37	2.37	2.37	2.37	2.37	2.37	2.37	2.37	2.37	2.37	2.37	2.37	2.37	2.37	2.37	2.37	2.37	2.37
Total Import	RUB	2.54	2.52	2.50	2.49	2.48	2.47	2.47	2.46	2.46	2.46	2.46	2.46	2.46	2.46	2.46	2.46	2.46	2.46	2.46	2.46	2.46	2.46	2.46	2.46	2.46	2.46	2.46	2.46	2.46	2.47	2.47	2.47	2.47	2.47	2.47	2.47	2.47	2.47	2.47	2.47	2.47	2.47	2.47	2.47	2.47	2.47	2.47	2.47	2.47	2.47
Total Import	CEM	2.53	2.58	2.61	2.62	2.62	2.61	2.60	2.60	2.59	2.58	2.57	2.56	2.56	2.55	2.55	2.54	2.54	2.54	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52
Total Import	IRO	2.44	2.45	2.45	2.46	2.46	2.46	2.46	2.46	2.46	2.46	2.46	2.46	2.46	2.46	2.46	2.46	2.46	2.46	2.46	2.46	2.46	2.46	2.46	2.46	2.46	2.46	2.46	2.46	2.46	2.47	2.47	2.47	2.47	2.47	2.47	2.47	2.47	2.47	2.47	2.47	2.47	2.47	2.47	2.47	2.47	2.47	2.47	2.47	2.47	2.47
Total Import	MEQ	2.10	2.14	2.18	2.21	2.24	2.26	2.28	2.30	2.32	2.33	2.34	2.35	2.36	2.37	2.37	2.38	2.38	2.38	2.39	2.39	2.39	2.39	2.39	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40
Total Import	AIR	1.53	1.58	1.63	1.68	1.72	1.76	1.80	1.83	1.85	1.88	1.90	1.92	1.93	1.95	1.96	1.97	1.98	1.99	2.00	2.00	2.01	2.01	2.02	2.02	2.03	2.03	2.03	2.04	2.04	2.04	2.04	2.04	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.06	2.06	2.06	2.06	2.06	2.06	2.06	2.06
Total Import	WAT	1.55	1.76	1.91	2.00	2.06	2.09	2.11	2.12	2.12	2.12	2.12	2.11	2.10	2.09	2.09	2.08	2.07	2.07	2.06	2.06	2.05	2.05	2.05	2.04	2.04	2.04	2.04	2.04	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03
Total Import	CON	2.30	2.21	2.13	2.08	2.04	2.01	1.98	1.96	1.95	1.94	1.93	1.93	1.92	1.92	1.91	1.91	1.91	1.91	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90
Total Import	DIS	2.26	2.28	2.29	2.29	2.29	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30
Total Import	TRA	2.06	1.99	1.95	1.92	1.90	1.88	1.88	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87
Total Import	COM	2.62	2.57	2.53	2.50	2.47	2.45	2.43	2.42	2.41	2.40	2.39	2.38	2.38	2.38	2.37	2.37	2.37	2.37	2.37	2.36	2.36	2.36	2.36	2.36	2.36	2.36	2.36	2.36	2.36	2.36	2.36	2.36	2.36	2.36	2.36	2.36	2.36	2.36	2.36	2.36	2.36	2.36	2.36	2.36	2.36	2.36	2.36	2.36	2.36	2.36
Total Import	PRS	2.80	2.77	2.75	2.73	2.72	2.71	2.70	2.69	2.69	2.69	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68
Total Import	PHE	2.23	2.28	2.33	2.37	2.41	2.44	2.46	2.49	2.50	2.52	2.53	2.54	2.55	2.56	2.57	2.57	2.58	2.58	2.59	2.59	2.59	2.60	2.60	2.60	2.60	2.60	2.60	2.61	2.61	2.61	2.61	2.61	2.61	2.61	2.61	2.61	2.61	2.61	2.61	2.61	2.61	2.61	2.61	2.61	2.61	2.61	2.61	2.61	2.61	2.61
Total Import	OTH	2.75	2.74	2.72	2.69	2.67	2.64	2.61	2.59	2.57	2.55	2.53	2.52	2.50	2.49	2.48	2.47	2.47	2.46	2.45	2.45	2.44	2.44	2.44	2.43	2.43	2.43	2.43	2.43	2.43	2.42	2.42	2.42	2.42	2.42	2.42	2.42	2.42	2.42	2.42	2.42	2.42	2.42	2.42	2.42	2.42	2.42	2.42	2.42	2.42	2.42
Total Import	HSS	2.44	2.46	2.50	2.54	2.58	2.61	2.64	2.66	2.68	2.70	2.71	2.73	2.74	2.75	2.76	2.76	2.77	2.77	2.78	2.78	2.78	2.79	2.79	2.79	2.79	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.81
Total Import	RET	2.44	2.45	2.47	2.48	2.48	2.49	2.49	2.50	2.50	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52
Total Import	ELE	1.82	1.81	1.81	1.82	1.83	1.84	1.85	1.86	1.87	1.88	1.89	1.90	1.91	1.91	1.92	1.92	1.93	1.93	1.93	1.94	1.94	1.94	1.94	1.94	1.94	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95
Total Import	OGK	1.99	1.99	2.00	2.01	2.02	2.03	2.04	2.05	2.05	2.06	2.07	2.07	2.08	2.08	2.09	2.09	2.09	2.09	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11
Total Import	COAL	1.77	1.80	1.84	1.87	1.91	1.94	1.96	1.99	2.01	2.02	2.04	2.05	2.06	2.07	2.08	2.09	2.09	2.10	2.10	2.10	2.11	2.11	2.11	2.11	2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.13	2.13	2.13	2.13	2.13	2.13	2.13	2.13

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	LR
Total Export	AGR	2.89	3.04	3.17	3.29	3.39	3.47	3.54	3.61	3.66	3.71	3.75	3.78	3.81	3.84	3.86	3.88	3.90	3.91	3.93	3.94	3.95	3.95	3.96	3.97	3.97	3.98	3.98	3.98	3.99	3.99	3.99	3.99	3.99	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Total Export	EXT	2.85	3.05	3.21	3.33	3.42	3.49	3.55	3.59	3.62	3.65	3.67	3.69	3.70	3.71	3.72	3.73	3.73	3.74	3.74	3.74	3.74	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.76	3.76	3.76	3.76	3.76	3.76	3.76	3.76	3.76	3.76	3.76	3.76	3.76
Total Export	FOO	2.47	2.54	2.60	2.65	2.71	2.75	2.79	2.83	2.87	2.90	2.93	2.95	2.97	2.99	3.01	3.02	3.04	3.05	3.06	3.07	3.08	3.09	3.09	3.10	3.10	3.11	3.11	3.11	3.12	3.12	3.12	3.12	3.12	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.14
Total Export	CLG	3.41	3.41	3.41	3.41	3.41	3.42	3.42	3.42	3.43	3.43	3.43	3.44	3.44	3.44	3.44	3.44	3.44	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45
Total Export	WWP	2.61	2.64	2.67	2.69	2.72	2.74	2.76	2.77	2.79	2.80	2.82	2.83	2.84	2.84	2.85	2.86	2.86	2.87	2.87	2.87	2.88	2.88	2.88	2.88	2.89	2.89	2.89	2.89	2.89	2.89	2.89	2.89	2.89	2.89	2.89	2.89	2.89	2.89	2.89	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90
Total Export	CHE	2.51	2.62	2.72	2.80	2.88	2.94	2.99	3.04	3.08	3.11	3.14	3.17	3.19	3.21	3.22	3.24	3.25	3.26	3.27	3.27	3.28	3.28	3.29	3.29	3.30	3.30	3.30	3.30	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.32
Total Export	PHA	2.72	2.79	2.85	2.90	2.94	2.97	3.00	3.02	3.04	3.06	3.07	3.08	3.09	3.10	3.11	3.11	3.12	3.12	3.12	3.13	3.13	3.13	3.13	3.13	3.13	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14
Total Export	RUB	2.71	2.78	2.83	2.88	2.92	2.95	2.98	3.00	3.02	3.03	3.04	3.05	3.06	3.07	3.08	3.08	3.09	3.09	3.09	3.10	3.10	3.10	3.10	3.10	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11
Total Export	CEM	3.05	3.01	3.00	3.00	3.01	3.03	3.05	3.07	3.08	3.10	3.11	3.13	3.14	3.15	3.15	3.16	3.17	3.17	3.18	3.18	3.18	3.18	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20
Total Export	IRO	2.83	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83
Total Export	MEQ	3.39	3.34	3.30	3.26	3.23	3.21	3.18	3.17	3.15	3.14	3.13	3.12	3.11	3.11	3.10	3.10	3.09	3.09	3.09	3.09	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07
Total Export	AIR	4.10	4.04	3.99	3.95	3.91	3.88	3.85	3.82	3.80	3.78	3.76	3.75	3.73	3.72	3.71	3.70	3.69	3.68	3.68	3.67	3.66	3.66	3.66	3.65	3.65	3.64	3.64	3.64	3.64	3.63	3.63	3.63	3.63	3.63	3.63	3.63	3.62	3.62	3.62	3.62	3.62	3.62	3.62	3.62	3.62	3.62	3.62	3.62	3.62	3.61
Total Export	WAT	3.70	3.50	3.38	3.31	3.28	3.27	3.27	3.28	3.30	3.32	3.34	3.36	3.38	3.40	3.42	3.43	3.45	3.46	3.47	3.48	3.49	3.49	3.50	3.50	3.51	3.51	3.52	3.52	3.52	3.52	3.53	3.53	3.53	3.53	3.53	3.53	3.53	3.53	3.53	3.53	3.54	3.54	3.54	3.54	3.54	3.54	3.54	3.54	3.54	3.54
Total Export	CON	3.32	3.44	3.53	3.61	3.66	3.70	3.74	3.76	3.78	3.80	3.81	3.82	3.83	3.83	3.84	3.84	3.85	3.85	3.85	3.85	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86
Total Export	DIS	2.87	2.92	2.96	3.00	3.03	3.06	3.09	3.11	3.13	3.15	3.16	3.17	3.18	3.19	3.20	3.21	3.21	3.22	3.22	3.23	3.23	3.23	3.23	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25
Total Export	TRA	3.24	3.39	3.51	3.59	3.66	3.71	3.75	3.78	3.80	3.82	3.83	3.85	3.86	3.87	3.87	3.88	3.88	3.89	3.89	3.89	3.89	3.90	3.90	3.90	3.90	3.90	3.90	3.90	3.90	3.90	3.90	3.91	3.91	3.91	3.91	3.91	3.91	3.91	3.91	3.91	3.91	3.91	3.91	3.91	3.91	3.91	3.91	3.91	3.91	3.91
Total Export	COM	2.54	2.68	2.79	2.88	2.96	3.02	3.08	3.12	3.16	3.19	3.21	3.24	3.25	3.27	3.28	3.29	3.30	3.31	3.32	3.32	3.33	3.33	3.33	3.34	3.34	3.34	3.34	3.34	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35
Total Export	PRS	2.77	2.82	2.87	2.90	2.93	2.95	2.97	2.99	3.00	3.01	3.02	3.03	3.03	3.04	3.04	3.04	3.05	3.05	3.05	3.05	3.05	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06
Total Export	PHE	2.95	2.96	2.96	2.95	2.94	2.94	2.93	2.93	2.92	2.92	2.92	2.92	2.91	2.91	2.91	2.91	2.91	2.91	2.91	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90
Total Export	OTH	2.56	2.61	2.67	2.73	2.78	2.83	2.88	2.92	2.96	2.99	3.02	3.05	3.07	3.09	3.11	3.12	3.13	3.14	3.15	3.16	3.17	3.17	3.18	3.18	3.19	3.19	3.19	3.20	3.20	3.20	3.20	3.20	3.20	3.21	3.21	3.21	3.21	3.21	3.21	3.21	3.21	3.21	3.21	3.21	3.21	3.21	3.21	3.21	3.21	3.21
Total Export	HSS	2.65	2.66	2.66	2.64	2.63	2.62	2.60	2.59	2.59	2.58	2.57	2.57	2.56	2.56	2.55	2.55	2.55	2.55	2.55	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53
Total Export	RET	2.78	2.80	2.82	2.84	2.86	2.87	2.89	2.90	2.91	2.92	2.93	2.94	2.95	2.95	2.96	2.96	2.97	2.97	2.97	2.98	2.98	2.98	2.98	2.98	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99
Total Export	ELE	3.21	3.35	3.47	3.56	3.63	3.68	3.73	3.76	3.80	3.82	3.84	3.86	3.87	3.88	3.89	3.90	3.91	3.91	3.92	3.92	3.93	3.93	3.93	3.93	3.94	3.94	3.94	3.94	3.94	3.94	3.94	3.94	3.94	3.94	3.94	3.94	3.94	3.94	3.95	3.95	3.95	3.95	3.95	3.95	3.95	3.95	3.95	3.95	3.95	3.95
Total Export	OGK	3.74	3.93	4.05	4.14	4.21	4.26	4.30	4.33	4.35	4.37	4.38	4.39	4.40	4.41	4.42	4.42	4.43	4.43	4.44	4.44	4.44	4.44	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.46	4.46	4.46	4.46	4.46	4.46	4.46	4.46	4.46	4.46	4.46	4.46
Total Export	COAL	3.88	3.93	3.97	4.00	4.01	4.03	4.04	4.04	4.05	4.06	4.06	4.06	4.06	4.07	4.07	4.07	4.07	4.07	4.07	4.07	4.07	4.07	4.07	4.07	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08
RUK. Export	AGR	2.89	3.04	3.17	3.29	3.39	3.47	3.54	3.61	3.66	3.71	3.75	3.78	3.81	3.84	3.86	3.88	3.90	3.91	3.93	3.94	3.95	3.95	3.96	3.97	3.97	3.98	3.98	3.98	3.99	3.99	3.99	3.99	3.99	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
RUK. Export	EXT	2.85	3.05	3.21	3.33	3.42	3.49	3.55	3.59	3.62	3.65	3.67	3.69	3.70	3.71	3.72	3.73	3.73	3.74	3.74	3.74	3.74	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.76	3.76	3.76	3.76	3.76	3.76	3.76	3.76	3.76	3.76	3.76	3.76	3.76
RUK. Export	FOO	2.47	2.54	2.60	2.65	2.71	2.75	2.79	2.83	2.87	2.90	2.93	2.95	2.97	2.99	3.01	3.02	3.04	3.05	3.06	3.07	3.08	3.09	3.09	3.10	3.10	3.11	3.11	3.11	3.12	3.12	3.12	3.12	3.12	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.14
RUK. Export	CLG	3.41	3.41	3.41	3.41	3.41	3.42	3.42	3.42	3.43	3.43	3.43	3.44	3.44	3.44	3.44	3.44	3.44	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45
RUK. Export	WWP	2.61	2.64	2.67	2.69	2.72	2.74	2.76	2.77	2.79	2.80	2.82	2.83	2.84	2.84	2.85	2.86	2.86	2.87	2.87	2.87	2.88	2.88	2.88	2.88	2.89	2.89	2.89	2.89	2.89	2.89	2.89	2.89	2.89	2.89	2.89	2.89	2.89	2.89	2.89	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90
RUK. Export	CHE	2.51	2.62	2.72	2.80	2.88	2.94	2.99	3.04	3.08	3.11	3.14	3.17	3.19	3.21	3.22	3.24	3.25	3.26	3.27	3.27	3.28	3.28	3.29	3.29	3.30	3.30	3.30	3.30	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.32
RUK. Export	PHA	2.72	2.79	2.85	2.90	2.94	2.97	3.00	3.02	3.04	3.06	3.07	3.08	3.09	3.10	3.11	3.11	3.12	3.12	3.12	3.13	3.13	3.13	3.13	3.13	3.13	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14
RUK. Export	RUB	2.71	2.78	2.83	2.88	2.92	2.95	2.98	3.00	3.02	3.03	3.04	3.05	3.06	3.07	3.08	3.08	3.09	3.09	3.09	3.10	3.10	3.10	3.10	3.10	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11
RUK. Export	CEM	3.05	3.01	3.00	3.00	3.01	3.03	3.05	3.07	3.08	3.10	3.11	3.13	3.14	3.15	3.15	3.16	3.17	3.17	3.18	3.18	3.18	3.18	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20
RUK. Export	IRO	2.83	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83
RUK. Export	MEQ	3.39	3.34	3.30	3.26	3.23	3.21	3.18	3.17	3.15	3.14	3.13	3.12	3.11	3.11	3.10	3.10	3.09	3.09	3.09	3.09	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07
RUK. Export	AIR	4.10	4.04	3.99	3.95	3.91	3.88	3.85	3.82	3.80	3.78	3.76	3.75	3.73	3.72	3.71	3.70	3.69	3.68	3.68	3.67	3.66	3.66	3.66	3.65	3.65	3.64	3.64	3.64	3.64	3.63	3.63	3.63	3.63	3.63	3.63	3.63	3.62	3.62	3.62	3.62	3.62	3.62	3.62	3.62	3.62	3.62	3.62	3.62	3.62	3.61
RUK. Export	WAT	3.70	3.50	3.38	3.31	3.28	3.27	3.27	3.28	3.30	3.32	3.34	3.36	3.38	3.40	3.42	3.43	3.45	3.46	3.47	3.48	3.49	3.49	3.50	3.50	3.51	3.51	3.52	3.52	3.52	3.52	3.53	3.53	3.53	3.53	3.53	3.53	3.53	3.53	3.53	3.53	3.54	3.54	3.54	3.54	3.54	3.54	3.54	3.54	3.54	3.54
RUK. Export	CON	3.32	3.44	3.53	3.61	3.66	3.70	3.74	3.76	3.78	3.80	3.81	3.82	3.83	3.83	3.84	3.84	3.85	3.85	3.85	3.85	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86
RUK. Export	DIS	2.87	2.92	2.96	3.00	3.03	3.06	3.09	3.11	3.13	3.15	3.16	3.17	3.18	3.19	3.20	3.21	3.21	3.22	3.22	3.23	3.23	3.23	3.23	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25
RUK. Export	TRA	3.24	3.39	3.51	3.59	3.66	3.71	3.75	3.78	3.80	3.82	3.83	3.85	3.86	3.87	3.87	3.88	3.88	3.89	3.89	3.89	3.89	3.90	3.90	3.90	3.90	3.90	3.90	3.90	3.90	3.90	3.90	3.91	3.91	3.91	3.91	3.91	3.91	3.91	3.91	3.91	3.91	3.91	3.91	3.91	3.91	3.91	3.91	3.91	3.91	3.91
RUK. Export	COM	2.54	2.68	2.79	2.88	2.96	3.02	3.08	3.12	3.16	3.19	3.21	3.24	3.25	3.27	3.28	3.29	3.30	3.31	3.32	3.32	3.33	3.33	3.33	3.34	3.34	3.34	3.34	3.34	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35
RUK. Export	PRS	2.77	2.82	2.87	2.90	2.93	2.95	2.97	2.99	3.00	3.01	3.02	3.03	3.03	3.04	3.04	3.04	3.05	3.05	3.05	3.05	3.05	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06
RUK. Export	PHE	2.95	2.96	2.96	2.95	2.94	2.94	2.93	2.93	2.92	2.92	2.92	2.92	2.91	2.91	2.91	2.91	2.91	2.91	2.91	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90
RUK. Export	OTH	2.56	2.61	2.67	2.73	2.78	2.83	2.88	2.92	2.96	2.99	3.02	3.05	3.07	3.09	3.11	3.12	3.13	3.14	3.15	3.16	3.17	3.17	3.18	3.18	3.19	3.19	3.19	3.20	3.20	3.20	3.20	3.20	3.20	3.21	3.21	3.21	3.21	3.21	3.21	3.21	3.21	3.21	3.21	3.21	3.21	3.21	3.21	3.21	3.21	3.21
RUK. Export	HSS	2.65	2.66	2.66	2.64	2.63	2.62	2.60	2.59	2.59	2.58	2.57	2.57	2.56	2.56	2.55	2.55	2.55	2.55	2.55	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53
RUK. Export	RET	2.78	2.80	2.82	2.84	2.86	2.87	2.89	2.90	2.91	2.92	2.93	2.94	2.95	2.95	2.96	2.96	2.97	2.97	2.97	2.98	2.98	2.98	2.98	2.98	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99
RUK. Export	ELE	3.21	3.35	3.47	3.56	3.63	3.68	3.73	3.76	3.80	3.82	3.84	3.86	3.87	3.88	3.89	3.90	3.91	3.91	3.92	3.92	3.93	3.93	3.93	3.93	3.94	3.94	3.94	3.94	3.94	3.94	3.94	3.94	3.94	3.94	3.94	3.94	3.94	3.94	3.95	3.95	3.95	3.95	3.95	3.95	3.95	3.95	3.95	3.95	3.95	3.95
RUK. Export	OGK	3.74	3.93	4.05	4.14	4.21	4.26	4.30	4.33	4.35	4.37	4.38	4.39	4.40	4.41	4.42	4.42	4.43	4.43	4.44	4.44	4.44	4.44	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.46	4.46	4.46	4.46	4.46	4.46	4.46	4.46	4.46	4.46	4.46	4.46
RUK. Export	COAL	3.88	3.93	3.97	4.00	4.01	4.03	4.04	4.04	4.05	4.06	4.06	4.06	4.06	4.07	4.07	4.07	4.07	4.07	4.07	4.07	4.07	4.07	4.07	4.07	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08
ROW Export	AGR	2.89	3.04	3.17	3.29	3.39	3.47	3.54	3.61	3.66	3.71	3.75	3.78	3.81	3.84	3.86	3.88	3.90	3.91	3.93	3.94	3.95	3.95	3.96	3.97	3.97	3.98	3.98	3.98	3.99	3.99	3.99	3.99	3.99	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
ROW Export	EXT	2.85	3.05	3.21	3.33	3.42	3.49	3.55	3.59	3.62	3.65	3.67	3.69	3.70	3.71	3.72	3.73	3.73	3.74	3.74	3.74	3.74	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.76	3.76	3.76	3.76	3.76	3.76	3.76	3.76	3.76	3.76	3.76	3.76	3.76
ROW Export	FOO	2.47	2.54	2.60	2.65	2.71	2.75	2.79	2.83	2.87	2.90	2.93	2.95	2.97	2.99	3.01	3.02	3.04	3.05	3.06	3.07	3.08	3.09	3.09	3.10	3.10	3.11	3.11	3.11	3.12	3.12	3.12	3.12	3.12	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.14
ROW Export	CLG	3.41	3.41	3.41	3.41	3.41	3.42	3.42	3.42	3.43	3.43	3.43	3.44	3.44	3.44	3.44	3.44	3.44	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45
ROW Export	WWP	2.61	2.64	2.67	2.69	2.72	2.74	2.76	2.77	2.79	2.80	2.82	2.83	2.84	2.84	2.85	2.86	2.86	2.87	2.87	2.87	2.88	2.88	2.88	2.88	2.89	2.89	2.89	2.89	2.89	2.89	2.89	2.89	2.89	2.89	2.89	2.89	2.89	2.89	2.89	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90
ROW Export	CHE	2.51	2.62	2.72	2.80	2.88	2.94	2.99	3.04	3.08	3.11	3.14	3.17	3.19	3.21	3.22	3.24	3.25	3.26	3.27	3.27	3.28	3.28	3.29	3.29	3.30	3.30	3.30	3.30	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.32
ROW Export	PHA	2.72	2.79	2.85	2.90	2.94	2.97	3.00	3.02	3.04	3.06	3.07	3.08	3.09	3.10	3.11	3.11	3.12	3.12	3.12	3.13	3.13	3.13	3.13	3.13	3.13	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14
ROW Export	RUB	2.71	2.78	2.83	2.88	2.92	2.95	2.98	3.00	3.02	3.03	3.04	3.05	3.06	3.07	3.08	3.08	3.09	3.09	3.09	3.10	3.10	3.10	3.10	3.10	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11
ROW Export	CEM	3.05	3.01	3.00	3.00	3.01	3.03	3.05	3.07	3.08	3.10	3.11	3.13	3.14	3.15	3.15	3.16	3.17	3.17	3.18	3.18	3.18	3.18	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20
ROW Export	IRO	2.83	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83
ROW Export	MEQ	3.39	3.34	3.30	3.26	3.23	3.21	3.18	3.17	3.15	3.14	3.13	3.12	3.11	3.11	3.10	3.10	3.09	3.09	3.09	3.09	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07
ROW Export	AIR	4.10	4.04	3.99	3.95	3.91	3.88	3.85	3.82	3.80	3.78	3.76	3.75	3.73	3.72	3.71	3.70	3.69	3.68	3.68	3.67	3.66	3.66	3.66	3.65	3.65	3.64	3.64	3.64	3.64	3.63	3.63	3.63	3.63	3.63	3.63	3.63	3.62	3.62	3.62	3.62	3.62	3.62	3.62	3.62	3.62	3.62	3.62	3.62	3.62	3.61
ROW Export	WAT	3.70	3.50	3.38	3.31	3.28	3.27	3.27	3.28	3.30	3.32	3.34	3.36	3.38	3.40	3.42	3.43	3.45	3.46	3.47	3.48	3.49	3.49	3.50	3.50	3.51	3.51	3.52	3.52	3.52	3.52	3.53	3.53	3.53	3.53	3.53	3.53	3.53	3.53	3.53	3.53	3.54	3.54	3.54	3.54	3.54	3.54	3.54	3.54	3.54	3.54
ROW Export	CON	3.32	3.44	3.53	3.61	3.66	3.70	3.74	3.76	3.78	3.80	3.81	3.82	3.83	3.83	3.84	3.84	3.85	3.85	3.85	3.85	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86
ROW Export	DIS	2.87	2.92	2.96	3.00	3.03	3.06	3.09	3.11	3.13	3.15	3.16	3.17	3.18	3.19	3.20	3.21	3.21	3.22	3.22	3.23	3.23	3.23	3.23	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25
ROW Export	TRA	3.24	3.39	3.51	3.59	3.66	3.71	3.75	3.78	3.80	3.82	3.83	3.85	3.86	3.87	3.87	3.88	3.88	3.89	3.89	3.89	3.89	3.90	3.90	3.90	3.90	3.90	3.90	3.90	3.90	3.90	3.90	3.91	3.91	3.91	3.91	3.91	3.91	3.91	3.91	3.91	3.91	3.91	3.91	3.91	3.91	3.91	3.91	3.91	3.91	3.91
ROW Export	COM	2.54	2.68	2.79	2.88	2.96	3.02	3.08	3.12	3.16	3.19	3.21	3.24	3.25	3.27	3.28	3.29	3.30	3.31	3.32	3.32	3.33	3.33	3.33	3.34	3.34	3.34	3.34	3.34	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35
ROW Export	PRS	2.77	2.82	2.87	2.90	2.93	2.95	2.97	2.99	3.00	3.01	3.02	3.03	3.03	3.04	3.04	3.04	3.05	3.05	3.05	3.05	3.05	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06
ROW Export	PHE	2.95	2.96	2.96	2.95	2.94	2.94	2.93	2.93	2.92	2.92	2.92	2.92	2.91	2.91	2.91	2.91	2.91	2.91	2.91	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90
ROW Export	OTH	2.56	2.61	2.67	2.73	2.78	2.83	2.88	2.92	2.96	2.99	3.02	3.05	3.07	3.09	3.11	3.12	3.13	3.14	3.15	3.16	3.17	3.17	3.18	3.18	3.19	3.19	3.19	3.20	3.20	3.20	3.20	3.20	3.20	3.21	3.21	3.21	3.21	3.21	3.21	3.21	3.21	3.21	3.21	3.21	3.21	3.21	3.21	3.21	3.21	3.21
ROW Export	HSS	2.65	2.66	2.66	2.64	2.63	2.62	2.60	2.59	2.59	2.58	2.57	2.57	2.56	2.56	2.55	2.55	2.55	2.55	2.55	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53
ROW Export	RET	2.78	2.80	2.82	2.84	2.86	2.87	2.89	2.90	2.91	2.92	2.93	2.94	2.95	2.95	2.96	2.96	2.97	2.97	2.97	2.98	2.98	2.98	2.98	2.98	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99
ROW Export	ELE	3.21	3.35	3.47	3.56	3.63	3.68	3.73	3.76	3.80	3.82	3.84	3.86	3.87	3.88	3.89	3.90	3.91	3.91	3.92	3.92	3.93	3.93	3.93	3.93	3.94	3.94	3.94	3.94	3.94	3.94	3.94	3.94	3.94	3.94	3.94	3.94	3.94	3.94	3.95	3.95	3.95	3.95	3.95	3.95	3.95	3.95	3.95	3.95	3.95	3.95
ROW Export	OGK	3.74	3.93	4.05	4.14	4.21	4.26	4.30	4.33	4.35	4.37	4.38	4.39	4.40	4.41	4.42	4.42	4.43	4.43	4.44	4.44	4.44	4.44	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.46	4.46	4.46	4.46	4.46	4.46	4.46	4.46	4.46	4.46	4.46	4.46
ROW Export	COAL	3.88	3.93	3.97	4.00	4.01	4.03	4.04	4.04	4.05	4.06	4.06	4.06	4.06	4.07	4.07	4.07	4.07	4.07	4.07	4.07	4.07	4.07	4.07	4.07	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	LR
Investment by dest+adj cost	AGR	1.61	1.65	1.69	1.71	1.73	1.75	1.77	1.78	1.79	1.80	1.81	1.82	1.82	1.83	1.83	1.84	1.84	1.84	1.84	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86
Investment by dest+adj cost	EXT	2.63	2.44	2.29	2.17	2.08	2.01	1.96	1.93	1.90	1.88	1.86	1.85	1.84	1.84	1.83	1.83	1.82	1.82	1.82	1.82	1.82	1.82	1.82	1.82	1.82	1.82	1.82	1.82	1.82	1.82	1.82	1.82	1.82	1.82	1.82	1.82	1.82	1.82	1.82	1.82	1.82	1.82	1.82	1.82	1.82	1.82	1.82	1.82	1.82	1.82
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	LR
Rate of Return to Cap.	AGR	2.58	2.35	2.14	1.96	1.81	1.67	1.55	1.45	1.36	1.28	1.21	1.15	1.10	1.06	1.02	0.99	0.96	0.94	0.92	0.90	0.88	0.87	0.85	0.84	0.84	0.83	0.82	0.82	0.81	0.81	0.80	0.80	0.80	0.79	0.79	0.79	0.79	0.79	0.79	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
Rate of Return to Cap.	EXT	3.63	2.99	2.50	2.12	1.83	1.60	1.43	1.29	1.19	1.11	1.04	0.99	0.95	0.92	0.89	0.87	0.86	0.84	0.83	0.82	0.81	0.81	0.80	0.80	0.80	0.79	0.79	0.79	0.79	0.79	0.79	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
Rate of Return to Cap.	FOO	1.80	1.73	1.65	1.58	1.50	1.43	1.37	1.31	1.25	1.20	1.16	1.12	1.08	1.04	1.01	0.99	0.96	0.94	0.92	0.90	0.89	0.87	0.86	0.85	0.84	0.83	0.83	0.82	0.82	0.81	0.81	0.80	0.80	0.80	0.80	0.79	0.79	0.79	0.79	0.79	0.79	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
Rate of Return to Cap.	CLG	0.78	0.87	0.92	0.95	0.95	0.95	0.94	0.93	0.92	0.90	0.89	0.88	0.87	0.86	0.85	0.84	0.83	0.82	0.82	0.81	0.81	0.80	0.80	0.80	0.79	0.79	0.79	0.79	0.79	0.79	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
Rate of Return to Cap.	WWP	1.42	1.37	1.32	1.26	1.21	1.16	1.12	1.08	1.04	1.01	0.98	0.95	0.93	0.91	0.89	0.88	0.87	0.85	0.84	0.83	0.83	0.82	0.81	0.81	0.81	0.80	0.80	0.80	0.79	0.79	0.79	0.79	0.79	0.79	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
Rate of Return to Cap.	CHE	2.59	2.35	2.14	1.96	1.79	1.65	1.53	1.42	1.33	1.25	1.18	1.13	1.08	1.03	1.00	0.96	0.94	0.91	0.89	0.88	0.86	0.85	0.84	0.83	0.82	0.82	0.81	0.81	0.80	0.80	0.80	0.79	0.79	0.79	0.79	0.79	0.79	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
Rate of Return to Cap.	PHA	2.19	1.98	1.79	1.62	1.49	1.37	1.27	1.19	1.13	1.07	1.02	0.98	0.95	0.92	0.90	0.88	0.87	0.85	0.84	0.83	0.82	0.82	0.81	0.81	0.80	0.80	0.79	0.79	0.79	0.79	0.79	0.79	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
Rate of Return to Cap.	RUB	2.03	1.85	1.69	1.54	1.42	1.32	1.24	1.16	1.10	1.05	1.01	0.97	0.94	0.92	0.90	0.88	0.86	0.85	0.84	0.83	0.82	0.82	0.81	0.81	0.80	0.80	0.80	0.79	0.79	0.79	0.79	0.79	0.79	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
Rate of Return to Cap.	CEM	0.83	1.01	1.10	1.13	1.13	1.12	1.09	1.06	1.03	0.99	0.97	0.94	0.92	0.90	0.88	0.86	0.85	0.84	0.83	0.82	0.82	0.81	0.81	0.80	0.80	0.80	0.79	0.79	0.79	0.79	0.79	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
Rate of Return to Cap.	IRO	0.57	0.72	0.81	0.86	0.88	0.89	0.89	0.88	0.87	0.86	0.85	0.84	0.84	0.83	0.82	0.82	0.81	0.81	0.80	0.80	0.79	0.79	0.79	0.79	0.79	0.79	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
Rate of Return to Cap.	MEQ	0.04	0.17	0.28	0.36	0.43	0.49	0.54	0.58	0.61	0.64	0.67	0.69	0.70	0.71	0.73	0.74	0.74	0.75	0.75	0.76	0.76	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
Rate of Return to Cap.	AIR	- 0.55	- 0.38	- 0.23	- 0.11	- 0.00	0.09	0.17	0.24	0.30	0.35	0.40	0.44	0.48	0.51	0.54	0.56	0.59	0.61	0.62	0.64	0.65	0.67	0.68	0.69	0.70	0.70	0.71	0.72	0.72	0.73	0.73	0.74	0.74	0.75	0.75	0.75	0.75	0.76	0.76	0.76	0.76	0.76	0.76	0.77	0.77	0.77	0.77	0.77	0.77	0.78
Rate of Return to Cap.	WAT	0.62	0.81	0.92	0.99	1.03	1.04	1.03	1.02	1.01	0.99	0.97	0.95	0.93	0.91	0.90	0.88	0.87	0.86	0.85	0.84	0.83	0.82	0.82	0.81	0.81	0.80	0.80	0.80	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
Rate of Return to Cap.	CON	2.05	1.77	1.56	1.39	1.27	1.17	1.09	1.03	0.99	0.95	0.92	0.90	0.88	0.86	0.85	0.84	0.83	0.82	0.81	0.81	0.80	0.80	0.80	0.79	0.79	0.79	0.79	0.79	0.79	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
Rate of Return to Cap.	DIS	1.47	1.38	1.30	1.23	1.17	1.12	1.07	1.03	1.00	0.97	0.94	0.92	0.90	0.88	0.87	0.86	0.84	0.84	0.83	0.82	0.81	0.81	0.81	0.80	0.80	0.80	0.79	0.79	0.79	0.79	0.79	0.79	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
Rate of Return to Cap.	TRA	2.73	2.26	1.91	1.66	1.47	1.33	1.22	1.13	1.07	1.02	0.98	0.94	0.92	0.89	0.88	0.86	0.85	0.84	0.83	0.82	0.81	0.81	0.80	0.80	0.80	0.79	0.79	0.79	0.79	0.79	0.79	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
Rate of Return to Cap.	COM	2.30	2.05	1.84	1.66	1.52	1.40	1.30	1.21	1.14	1.09	1.04	1.00	0.96	0.93	0.91	0.89	0.87	0.86	0.85	0.84	0.83	0.82	0.81	0.81	0.80	0.80	0.80	0.79	0.79	0.79	0.79	0.79	0.79	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
Rate of Return to Cap.	PRS	1.86	1.67	1.51	1.38	1.28	1.19	1.12	1.07	1.02	0.98	0.95	0.92	0.90	0.88	0.87	0.85	0.84	0.83	0.82	0.82	0.81	0.81	0.80	0.80	0.80	0.79	0.79	0.79	0.79	0.79	0.79	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
Rate of Return to Cap.	PHE	1.37	1.19	1.09	1.02	0.98	0.94	0.92	0.89	0.88	0.86	0.85	0.84	0.83	0.82	0.82	0.81	0.81	0.80	0.80	0.80	0.79	0.79	0.79	0.79	0.79	0.79	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
Rate of Return to Cap.	OTH	1.45	1.40	1.34	1.28	1.22	1.17	1.12	1.08	1.04	1.00	0.97	0.95	0.92	0.90	0.89	0.87	0.86	0.85	0.84	0.83	0.82	0.82	0.81	0.81	0.80	0.80	0.80	0.79	0.79	0.79	0.79	0.79	0.79	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
Rate of Return to Cap.	HSS	1.41	1.21	1.10	1.03	0.98	0.94	0.92	0.90	0.88	0.86	0.85	0.84	0.83	0.82	0.82	0.81	0.81	0.80	0.80	0.80	0.79	0.79	0.79	0.79	0.79	0.79	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
Rate of Return to Cap.	RET	1.41	1.33	1.26	1.20	1.14	1.09	1.05	1.01	0.98	0.95	0.93	0.90	0.89	0.87	0.86	0.85	0.84	0.83	0.82	0.82	0.81	0.81	0.80	0.80	0.80	0.79	0.79	0.79	0.79	0.79	0.79	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
Rate of Return to Cap.	ELE	2.58	2.28	2.03	1.82	1.64	1.50	1.38	1.28	1.19	1.13	1.07	1.02	0.99	0.95	0.93	0.90	0.88	0.87	0.85	0.84	0.83	0.83	0.82	0.81	0.81	0.80	0.80	0.80	0.79	0.79	0.79	0.79	0.79	0.79	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
Rate of Return to Cap.	OGK	5.79	4.13	3.07	2.38	1.93	1.62	1.42	1.27	1.16	1.09	1.03	0.98	0.95	0.92	0.90	0.88	0.86	0.85	0.84	0.83	0.82	0.81	0.81	0.80	0.80	0.80	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
Rate of Return to Cap.	COAL	3.53	2.56	2.01	1.68	1.46	1.32	1.21	1.14	1.07	1.03	0.99	0.95	0.93	0.90	0.88	0.87	0.85	0.84	0.83	0.83	0.82	0.81	0.81	0.80	0.80	0.80	0.79	0.79	0.79	0.79	0.79	0.79	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
Output Price	AGR	1.02	0.94	0.88	0.83	0.78	0.74	0.70	0.67	0.64	0.62	0.60	0.58	0.57	0.56	0.55	0.54	0.53	0.52	0.52	0.51	0.51	0.50	0.50	0.50	0.49	0.49	0.49	0.49	0.49	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
Output Price	EXT	1.04	0.94	0.86	0.80	0.76	0.73	0.70	0.68	0.66	0.65	0.64	0.63	0.62	0.62	0.62	0.61	0.61	0.61	0.61	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
Output Price	FOO	1.22	1.19	1.16	1.14	1.11	1.09	1.07	1.05	1.03	1.02	1.00	0.99	0.98	0.97	0.96	0.95	0.95	0.94	0.94	0.93	0.93	0.92	0.92	0.92	0.92	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Output Price	CLG	0.77	0.77	0.77	0.77	0.76	0.76	0.76	0.76	0.76	0.76	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74
Output Price	WWP	1.16	1.14	1.13	1.12	1.10	1.09	1.09	1.08	1.07	1.06	1.06	1.05	1.05	1.04	1.04	1.04	1.03	1.03	1.03	1.03	1.03	1.03	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
Output Price	CHE	1.21	1.15	1.10	1.06	1.03	1.00	0.97	0.95	0.93	0.91	0.90	0.88	0.87	0.86	0.86	0.85	0.84	0.84	0.84	0.83	0.83	0.83	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81
Output Price	PHA	1.10	1.07	1.04	1.02	1.00	0.98	0.97	0.95	0.95	0.94	0.93	0.93	0.92	0.92	0.91	0.91	0.91	0.91	0.91	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Output Price	RUB	1.11	1.08	1.05	1.03	1.01	0.99	0.98	0.97	0.96	0.95	0.94	0.94	0.93	0.93	0.93	0.93	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91
Output Price	CEM	0.94	0.96	0.97	0.97	0.96	0.95	0.94	0.93	0.93	0.92	0.91	0.90	0.90	0.89	0.89	0.89	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87
Output Price	IRO	1.05	1.05	1.06	1.06	1.06	1.06	1.06	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05
Output Price	MEQ	0.77	0.80	0.82	0.84	0.85	0.87	0.88	0.88	0.89	0.90	0.90	0.91	0.91	0.91	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93
Output Price	AIR	0.43	0.46	0.48	0.50	0.52	0.54	0.55	0.57	0.58	0.59	0.59	0.60	0.61	0.61	0.62	0.62	0.63	0.63	0.64	0.64	0.64	0.64	0.65	0.65	0.65	0.65	0.65	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.67
Output Price	WAT	0.62	0.72	0.78	0.81	0.83	0.83	0.83	0.83	0.82	0.81	0.80	0.79	0.78	0.77	0.76	0.75	0.75	0.74	0.74	0.73	0.73	0.73	0.72	0.72	0.72	0.72	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Output Price	CON	0.81	0.75	0.71	0.67	0.64	0.62	0.61	0.60	0.59	0.58	0.57	0.57	0.56	0.56	0.56	0.56	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54
Output Price	DIS	1.03	1.01	0.98	0.97	0.95	0.93	0.92	0.91	0.90	0.89	0.89	0.88	0.88	0.87	0.87	0.86	0.86	0.86	0.86	0.86	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84
Output Price	TRA	0.85	0.77	0.72	0.68	0.64	0.62	0.60	0.59	0.58	0.57	0.56	0.55	0.55	0.54	0.54	0.54	0.54	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52
Output Price	COM	1.19	1.12	1.07	1.02	0.99	0.95	0.93	0.91	0.89	0.87	0.86	0.85	0.84	0.83	0.83	0.82	0.82	0.81	0.81	0.81	0.81	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79
Output Price	PRS	1.08	1.05	1.03	1.01	1.00	0.99	0.98	0.97	0.97	0.96	0.96	0.95	0.95	0.95	0.95	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94
Output Price	PHE	0.99	0.99	0.99	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
Output Price	OTH	1.18	1.16	1.13	1.10	1.07	1.05	1.02	1.00	0.99	0.97	0.96	0.94	0.93	0.92	0.91	0.91	0.90	0.90	0.89	0.89	0.88	0.88	0.88	0.88	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86
Output Price	HSS	1.14	1.13	1.14	1.14	1.15	1.16	1.16	1.17	1.17	1.17	1.18	1.18	1.18	1.18	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
Output Price	RET	1.07	1.06	1.05	1.05	1.04	1.03	1.02	1.01	1.01	1.00	1.00	0.99	0.99	0.99	0.99	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
Output Price	ELE	0.86	0.79	0.74	0.70	0.66	0.63	0.61	0.59	0.58	0.57	0.56	0.55	0.54	0.54	0.53	0.53	0.52	0.52	0.52	0.52	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51
Output Price	OGK	0.60	0.51	0.45	0.41	0.38	0.35	0.34	0.32	0.31	0.30	0.30	0.29	0.29	0.28	0.28	0.28	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26
Output Price	COAL	0.54	0.51	0.49	0.48	0.47	0.47	0.46	0.46	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44

Chapter 5

Thesis postlude

The purpose of this final chapter is to conclude the work contained within this thesis, and to identify areas for future research. We began this thesis by providing a general background to the work that we have carried out here, before outlining 15 research questions; for convenience these are reproduced here:

1. What was Scotland's CO_2 emissions total in 2004 under different accounting principles, and using different estimation methods?
2. What was Scotland's emissions embodied in its trading activities (exports and imports) in 2004?
3. What are the implications of different emissions accounting principles in terms of the policy incentives they provide?
4. What are the implications for Scotland of adopting their own territorial emissions targets?
5. Which sectors are making the biggest contribution to Scottish emissions in 2004, based on their direct pollution and on the emissions embodied in their supply chain?
6. What are the different environmental linkage measures that can be formed, and how useful is each measure?

7. What policy insights can environmental key sector, and in particular key linkage analysis, provide on the relationship between the economy and the environment?
8. What predictions might be formed about the sectors which, in the face of growth in export demand, would generate the greatest additional amount of pollution in Scotland?
9. What is the potential collective contribution of groups of sectors to emissions generation within Scotland in 2004, and how useful is this information?
10. What is the response of the Scottish economy to a uniform increase in export demand?
11. Which sectors would generate the greatest increase in emissions following a uniform export shock, and how do these compare with the carbon backward linkage ranking weighted by export final demand?
12. What are the implications for different emissions totals of a uniform growth in export demand?
13. Do the results for the changes in the emissions total with a pure export shock differ with the introduction of a supply constraint (e.g. no migration)?
14. How do the emissions per capita in Scotland differ with an export shock in the cases with and without flow migration?
15. How do the simulations carried out in Chapter 4 help inform policy, with particular reference to the compatibility of export led growth and different emission accounting principles?

The first two research questions were addressed by the empirical findings in Chapter 2, where we presented six sets of emissions totals for Scotland based on either the territorial or consumption accounting principle. The six results we present all consider a different aspect of the emissions-economy relationship in Scotland. The emission totals presented in this thesis have either not been calculated before for Scotland, or have only been calculated without the kind of explanation and transparency of the measures presented here.

We also presented the same six emissions totals re-calculated using UK pollution intensities for all sectors, compared to the earlier case where we used UK intensities for all sectors except the largest polluting sector (electricity production and distribution sector) for which we used the Scottish emissions intensity. The purpose of presenting both sets of results is to show the impact of assuming that Scotland's electricity is produced using UK pollution intensities, on each emissions total.

We demonstrated that the impact of altering the emissions intensity used for the electricity sector on the emissions totals calculated here is large, ranging from 29% in the DTA (OECD) case to 37% in the Type I and TELAS cases. The lower impact on the DTA (OECD) case is due to the use of a weighted pollution vector which weights the domestic pollution intensity (either Scottish or UK) alongside the pollution intensity of sectors in different regions that Scotland imports from.

This is a large impact, and demonstrates the importance of incorporating region specific data. This analysis is also helpful in understanding a set of consumption emissions totals for Scotland derived by researchers at the University of Leeds on behalf of the Scottish Government[1]. When we compare our results to the estimates produced by the University of Leeds we can see that their estimate of consumption emissions in Scotland in 2004 is 74,595 kT CO_2 this contrasts with our estimate in the DTA (OECD) case of 77,429kT CO_2.

We discussed earlier the approach that the University of Leeds researchers employed in estimating the emissions embodied in imports from ROW. While it is not clear exactly how they estimated these emissions, the fact that we only get close to their total when we assume a UK pollution intensity for the electricity

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[1] Available online at: `http://www.scotland.gov.uk/Resource/0039/00392289.xls`

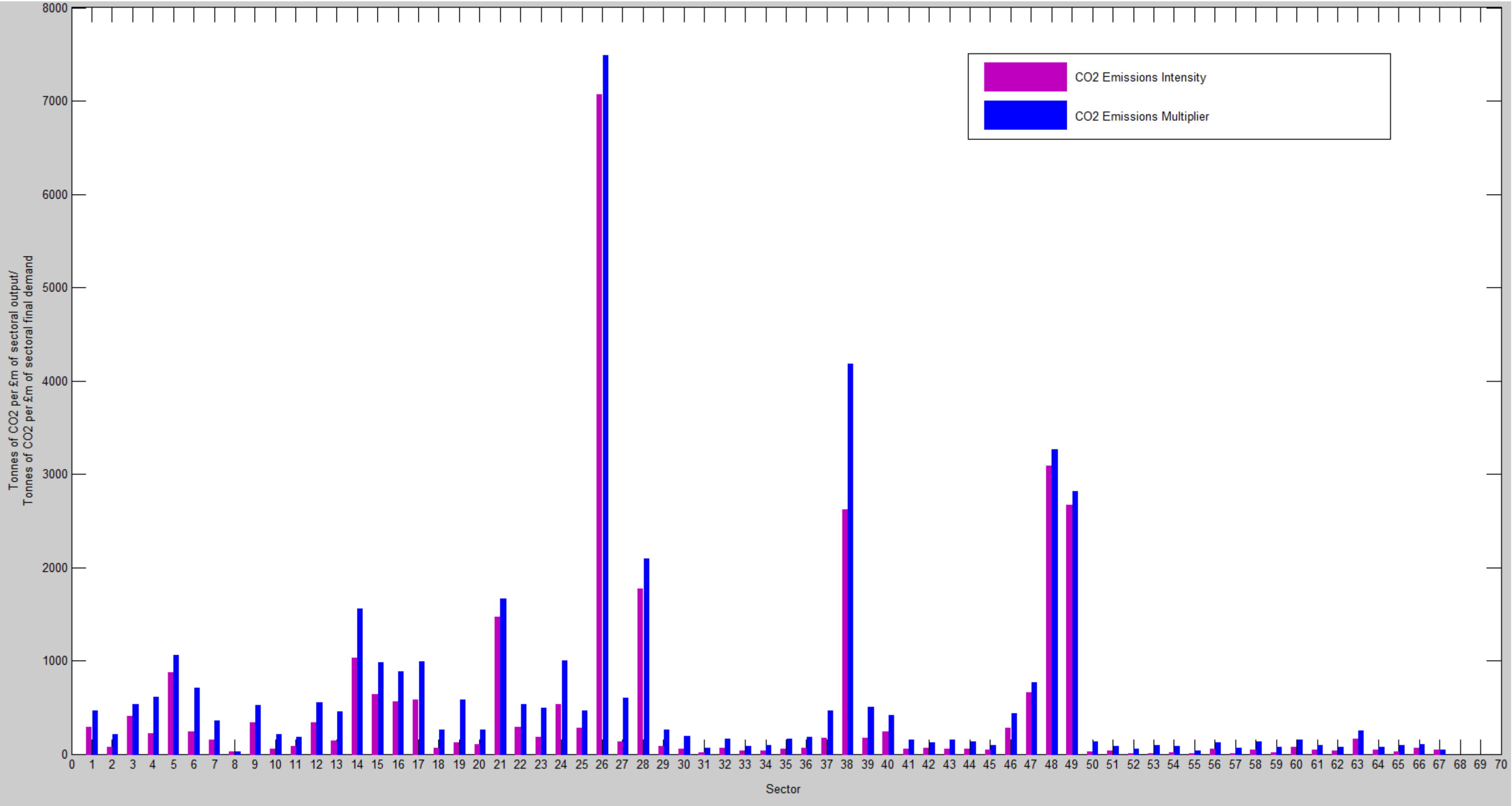
sector in Scotland suggests that they are likely to be using a UK pollution intensity for all sectors. For the electricity sector the UK CO_2 intensity is much larger than the reported Scottish intensity. This suggests that the University of Leeds researchers' estimates are around 29% too large.

We also examined the implied emissions trade balance (emissions embodied in exports - emissions embodied in imports) for each of our consumption emissions totals. This shows that according to both the DTA and DTA (OECD) measures Scotland is running an emissions trade deficit with the rest of the world, that is to say that the emissions embodied in imports is greater than the emissions embodied in exports. Our estimates of Scotland's emissions trade balance range from a deficit of around 12.27 million tonnes of CO_2 in the balance of emissions embodied in trade (BEET) case to 12.17 million tonnes of CO_2 in the DTA(OECD) case.

We then looked at how individual sectors generate and support emissions in Scotland. We established which sectors were the largest direct emitters of CO_2 emissions in Scotland, the top 5 from Figure 5.1 were: 26 - Cement and clay, 48 - Water transport, 49 - Air transport, 38 - Electricity production and distribution and 28 - Iron and steel. We then assessed which sectors had the most CO_2 intensive supply chain (known as the CLBLI measure based on the input-output model), the top 5 were: 26 - Cement and clay, 38 - Electricity production and distribution, 48 - Water transport, 49 - Air transport and 28 - Iron and steel.

In discussing environmental linkage and key sector measures we noted that much of this literature lacked a consistent and coherent discussion and motivation for the different linkage measures that were used, in particular when using the forward linkage measure based on the Ghoshian input-output model. We attempted to address this gap in the literature and took each linkage measure in turn and assessed its usefulness in an environmental context, with particular emphasis on whether there were any obvious policy uses for these measures. This included assessing how additional information, in the form of a sectoral level

Figure 5.1: Sectoral CO_2 Intensities v. Sectoral Type I output-CO_2 Multipliers



weight, could be introduced into the ranking of sectors to provide additional information and insight.

We considered a number of different types of information to introduce, and the usefulness of each of these. In terms of this thesis, perhaps the most useful of these measures was the carbon Leontief backward linkage index, weighted by the share of each sector's export demand in total export final demand (CLBLIwe). We argued that the CLBLIwe measure provided some indication of where, in the face of a general increase in export demand, the greatest additional environmental burden would be supported. Note the distinction here between generated emissions and supported emissions.

What the CLBLIwe provides is a measure of the CO_2 content of each sector's supply chain weighted by their proportion of total export final demand. This means it focuses on the supported emissions, not on the directly generated emissions. The sectors which are ranked highly by this measure would be the sectors predicted to generate the greatest additional environmental impact through supporting emissions in the economy following a general increase in export demand.

These sectors, taking the top 5, were: 4 - Coal extraction, 5 - Oil and gas extraction, 7 - Food and drink, 14 - Coke, refined petroleum & nuclear fuel and 15 - Industrial gases and dyes. The linkage and key sector analysis in this thesis was carried out at the 67 sector level, while our CGE model operated at a more aggregated, 25 sector, level. We therefore had to aggregate sectors together in moving to the CGE analysis. Looking at the sectoral aggregation scheme in Table 4.2 we can see that only two of the top 5 sectors according to the CLBLIwe measure are not aggregated up with other industries, these are Sectors 7 - Food and drink and 4 - Coal extraction[2].

Focussing on these two sectors (7 and 4) we look at whether these sectors indeed see their supported emissions grow significantly following a uniform ex-

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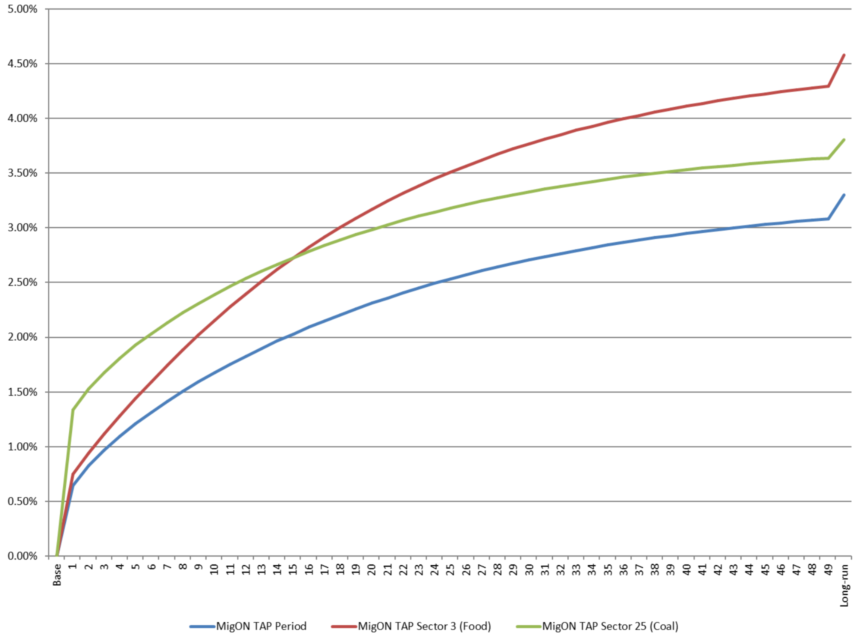
[2] While Sector 7 is shown as being aggregated up with Sector 8, Sector 8 has no output, so in effect Sector 7 is not aggregated going from the 67 sector aggregation to the 25 sector aggregation.

Figure 5.2: % Change in emissions supported by Sectors 4 & 7 against % change in TAP emissions total MigON

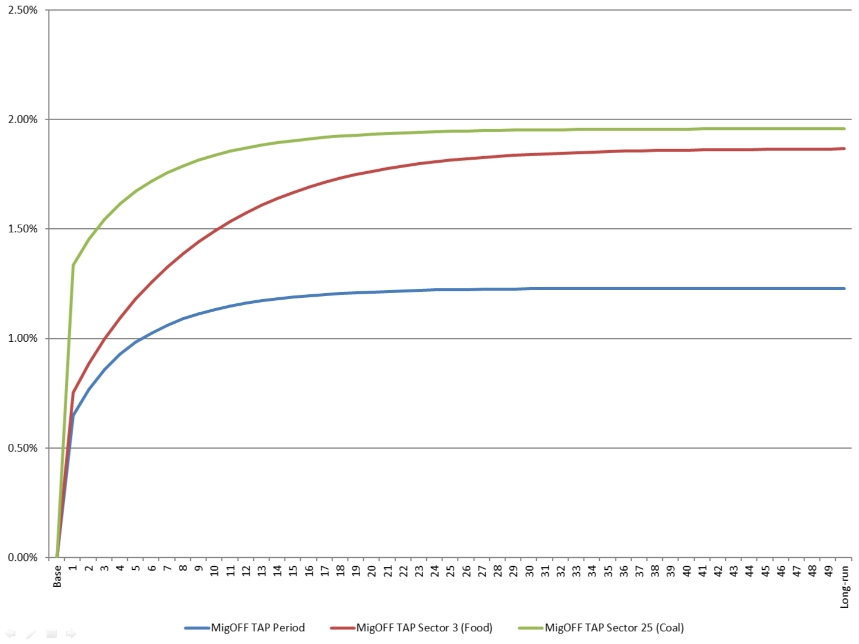


port shock. Since we do not have results for all 67 sectors to compare against, we instead compare the increase in supported emissions in these two sectors to the overall increase in territorial emissions. We focus here on the base case elasticities in both the migration on and migration off cases.

Figures 5.2 and 5.3 chart the % increase in the emissions supported by Sectors 7 and 4 against the overall increase in territorial emissions in the migration on and migration off case respectively. Figures 5.2 and 5.3 demonstrate that the emissions supported by these two sectors increase more, in both the migration on and migration off cases, than the overall increase in territorial emissions. This means that these sectors are making a more than proportional contribution towards the increase in territorial emissions, suggesting that the CLBLIwe is perhaps a good predictor of the sectors whose expansion following an increase in export demand will generate the greatest additional volume of emissions.

Aside from sectoral linkage analysis we used the hypothetical extraction approach to look at the impact on Scottish output and CO_2 emissions of hypo-

Figure 5.3: % Change in emissions supported by Sectors 4 & 7 against % change in TAP emissions total MigOFF



thetically extracting each sector, or group of sectors, from the Scottish economy. This was useful in illustrating the unique importance of the electricity sector in generating and supporting Scottish emissions. The analysis based on sectoral output was also interesting as it illustrated that in contrast to the CO_2 results, there were a broader range of sectors which were important.

Moving to the hypothetical extraction of key groups allowed us to take into account, in assessing sectoral importance for output and CO_2 emissions, the degree of sectoral interdependence. This analysis further illustrated the importance of the electricity sector in determining Scottish emissions by demonstrating that no four sectors, which did not include the electricity sector, could reduce Scottish emissions by more than 19.44% if hypothetically extracted from the Scottish economy.

We then extended the analysis in this thesis using a CGE model. We considered a central case of a 5% increase in Scottish export final demand from the rest of the UK (RUK) and the rest of the world (ROW). This central case was analysed as a pure demand shock case with no supply constraints (where there was flow migration), and in a model with no migration (the migration off case). Our economic results for these simulations were consistent with the existing literature.

Our environmental results were constructed by recreating the demand driven input-output model, including import matrices, in all periods after the introduction of this shock to export demand. Having done so we estimated the emissions generation by each sector based on their use of fuel inputs in each case, and used this to calculate the emissions intensity (tonnes of CO_2 per £m of output) of each sector in each period.

We saw from these results that in the migration on cases both the CAP and TAP emissions totals increased more than in the migration off case (Figure 4.9). In percentage terms (Figure 4.11) this was also clear. Interestingly in percentage terms the consumption emissions in the migration on case increased more than the TAP emissions in the migration off case. We also considered the impact on the difference between the TAP and CAP emissions totals, in percentage terms, in both the migration on and migration off cases (Figure 4.10), this shows that the emissions trade balance (emissions embodied in exports - emissions embodied in imports) reduces in percentage terms following an increase in export demand in both the migration on and migration off cases (although by more in the migration on case).

In order to better consider the environmental impact of this increase in export demand in both the migration on and migration off cases we looked at our results in terms of per capita emissions (CO_2 per person) in Figure 4.12. TAP and CAP emissions per capita both increase more in the migration off case than in the migration on case. We discussed why this would be in Chapter 4. We also looked at the evolution of TAP and CAP emissions per capita in % terms (Figure 4.13).

This showed that TAP emissions per capita increased more than CAP emissions per capita in the migration off case, and that while TAP emissions per capita increased in the migration on case, CAP emissions per capita fell in the migration on case. Figure 4.14 showed why this was. In Figure 4.14 we can see that the growth of consumption emissions is outpaced by the growth in population, leading to a decrease in CAP emissions per capita. Figure 4.15 shows the same information as Figure 4.14, but this time for the migration off case.

The work presented in Chapter 4 raised questions about the compatibility of Scotland's current environmental and economic growth policies. We saw from Chapter 2 that Scotland currently has a greater volume of emissions embodied in its imports than it does in its exports. From Chapter 3 we also understand how important emissions from the electricity sector are going to be in determining the path of Scotland's territorial emissions.

The current drive significantly to increase the proportion of renewable energy in Scotland in the coming years is likely to be important in driving down territorial emissions and helping to meet the Climate Change (Scotland) Act targets. However, as we discussed, Scotland also has a commitment to reducing the emissions embodied in what it consumes. It is less clear the extent to which gains in decarbonising the electricity sector in Scotland will impact on Scotland's consumption emissions.

Arising from the work in this thesis there are a number of areas for future work, these include:

- Determining the degree of decarbonisation of the electricity sector that would be needed to meet both Scotland's TAP emissions targets as well as to reduce our CAP emissions.

- Incorporating and modelling the abatement of emissions in AMOSENVI.

- Using an interregional model to examine the impact of the unilateral imposition of environmental policies in Scotland on the rest of the UK; both in terms of the economy and environmental indicators.

- Constructing a carbon tax policy response function for Scotland and the rest of the UK to determine the best response of both Scotland and RUK to the tax decision of the other.

The focus of this thesis has been on looking at how the economy and the environment interact in Scotland, how these interactions can be measured and in the final chapter how economic policies impact on the environment. The areas of future work identified here focus more on the role of environmental policies in this mix, since policies do not stand in isolation. Some of these areas of future work will utilise other variants of AMOSENVI, while others will require additional development of the model.

Scotland is committed to decarbonising its electricity sector, and much is made of what this will mean in the context of Scotland's impact on climate change. There is another side to this issue, which we have tried to highlight in this thesis, which is that it is not just the supply of goods which embody pollution which is important, but the demand for these goods as well. This is particularly important when we are talking about consumption emissions. Given the openness of the world economy there is only so much any individual region or country can do to affect their consumption emissions from the supply side. In future research we will try to focus on the impact of different carbon tax and abatement regimes on consumer behaviour and import demand, and determine how demand side changes can help reduce Scotland's emissions.

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