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Reconsidering environmental attribution and resource costs of common pool resources: applications of environmental input-output (IO) analysis

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Declaration

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.'

Signed:

Date:

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Dedication

This thesis is dedicated to the memory of my father, Professor Samuel Olusegun Alabi (**S.O**). I wish you were here to see this come to reality. Thank you so much for being a great teacher and teaching me that hard work doesn't kill and it always pays in the end. I love you always.

Table of Contents

List of Tables

List of Abbreviations

CPA: Classification of Products by Activity
EU: European Union
FTE: Full Time employment
GDP: Gross Domestic Product
GVA: Gross Value Added
IOC: Input-Output Category
ISIC: International Standard Industrial Classification
LCA: Life cycle analysis
NACE: European Statistical Classification of Economic Activities
QNAS: Quarterly National Accounts Scotland
SNA: Standard National Accounts
SEPA: Scotland Environmental Protection Agency
UK: United Kingdom
UN: United Nations
WERU: Welsh Economy Research Unit (Cardiff University)
WIO: Waste IO tables
ZWS: Zero Waste Scotland

Definition of key terms in this research

In order to understand and clarify the terms used in my thesis, the following are here-by defined

1. **Social cost/resource costs**: the total cost from the production of a good and service, including both the private cost and any production externality
2. **Social opportunity cost**: The amount of other goods, which has to be forgone because resources are used to make some particular good. When any goods or services are produced, the resources used to make them are not available for other purposes (Field and Olewiler, 2005; Perman, 2003)
3. **Leontief generalised model/full (original) Leontief environmental IO model:** This is a model developed by Leontief (1970). It is a contribution of constructing a "generalised " IO that links pollution generation directly to economic activity and suggest cleaning behaviours (Miller and Blair, 2009).
4. **Conventional environmental IO model:** What I refer to as a conventional environmental IO model, are model that apply the environmental IO model but doesn't go as far as to consider the resource cost implications of using the environmental (Author's definition)
5. **Unadjusted IO accounts:** Standard economic environmental IO accounts (Leontief (1936)
6. **Adjusted IO accounts**: Initially developed by Allan et al. (2007), it is an IO account that incorporates resource costs implied by environmental 'goods, or 'bads' generation) in monetary terms.
7. **Multiplier**: is the output multiplier for any given industry, which tells us the amount of output (generally reported in £million) that is generated

throughout the economy (across all industries) per £1million of final consumption demand for that industry's output (Miller and Blair, 2009)

8. **Partial consumption-based account**: A home region dimension of a footprint analysis that allows industrial waste generation to be consistently attributed to the respective final demand categories (Turner et al., 2014)
9. **Environmental 'bads':** The by-products of materials and resources input no longer required by the economy are returned by the 'Polluter' to the environment (e.g. waste, pollution)
10. **Environmental 'goods'** User' sources materials or resource inputs required for economic processes from the environment (e.g. water resources and minerals)
11. **Type I** multiplier; are variant of the output multiplier that captures the direct effect of the £1million of final demand plus indirect effects in the industry's up-stream supply chain (Miller and Blair, 2009).
12. **Type II** multipliers incorporates the additional, induced, impacts of household consumption financed through income from employment in industrial production of final demand plus indirect effects in the industry's up-stream supply chain output (Emonts-Holley et al., 2015; McGregor et al., 2008; Miller and Blair, 2009)

Abstract

In this thesis, I apply environmental input-output (IO) methods to evaluate some impacts of economic activity on the environment and the associated economy-wide implications of using the environment to meet some economic needs. The core of this thesis comprises of three independent but related chapters or papers (Chapter 2, 3 & 4). Each of these core chapters focuses on developing methods to answer key policy questions so that policy makers may be provided with a better understanding of the impacts of economic activities on the environment. In the first core chapter (Chapter 2), the environmental IO approach is considered as a means of examining the nature of externalities via pollution generation and of attributing, as a case study, physical waste generated to production and consumption economic activity. The chapter addresses the policy-relevant question of what economic sectors may ultimately be considered responsible for waste generation and the final consumption patterns, which drive that production and in turn waste pressures in Scotland. In the second core chapter (Chapter 3), the environmental IO model is applied to model and incorporate the resource implications of negative externalities from waste generation into economic processes. It builds on a previous but inconclusive study on this issue, here using improved data. The chapter addresses a key policy issue regarding identifying the implications if the direct polluter pays or does not pay for waste management implied by their waste generation and, in either case, who ultimately bears the cost for the provision of

waste management services within the economy. In the third core chapter (Chapter 4), the environmental IO model is applied in a novel way to consider the case of supplying a physical resource like water (as opposed to providing a clean environment as in the event of pollution or waste generation). The chapter addresses key policy issues regarding the causes and implications of the deviation between actual expenditure for the output of the water sector and actual physical water use. More generally, this thesis makes empirical and analytical improvements to the application of the Leontief, (1970) environmental IO model, a seminal theoretical contribution in terms of the resource cost of environmental protection and provision of common pool resources.

Chapter 1: Introduction to the research, nature of the problem and the role of IO in addressing economic-environmental issues

1.1 Background, context, rationale and significance of the thesis

Environmental problems (e.g. resource depletion, pollution generation etc.) are caused by different types of economic activity, the impacts of which may be mitigated or controlled through a combination of incentives, strategies, regulations and good policies (Bithas, 2011; Füssel, 2007; van den Bergh, 2010). Nonetheless, using the environment to meet different economic needs will have far-reaching economy-wide implications that have not been given sufficient attention in the literature and policy debate. In this study, my aim is to address some particular types of impacts of economic activity on the environment, focussing on some economy-wide implications of using the environment to meet different economic needs that we may begin to analyse using environmental input-output (IO) methods. This is with the particular objective of refining environmental IO approaches to provide key information and outcomes where it may be argued that policy action may require reconsideration of how the responsibility for environmental issues may be attributed, particularly where the resource costs of providing common pool resources is a concern.

Before, I continue with the discussion on the background to this study, I give an overview of what this chapter covers. In this first chapter, I introduce the thesis and discuss the background, objectives and role of IO in addressing economic-environmental issues. More generally, the chapter highlights and discusses the diversity, transparency and appropriateness of environmental IO methods to examine economic-environmental issues and ultimately its strength in informing policy makers or policy community. The chapter is set out as follows: Section 1.2, highlights why I have chosen the environmental IO model as the method in this research. The case studies employed to address the research objectives of this study are discussed in Section 1.3. Section 1.4 discusses the role of the IO framework in addressing economic-environmental issues. I discuss the significance and originality of the research in Section 1.5. In Section 1.6, I summarise the objectives and specific aims of the thesis. Finally, I give an outline of the structure of the entire thesis and highlight the main results or findings in Section 1.7. This section continues with the discussion on the background of the research.

Let us continue the discussion by setting out what can be considered as a generic and fundamental problem with how economies actually work. Effective running and functioning of any economy relies on the extraction of natural resources and in turn the generation of pollution to meet various economic needs that may enable the possibilities of long-term and sustainable economic growth (Solow, 1974). However, this economic process is problematic, in that it often neglects the full social costs of using resources from the environment and maintaining a pollution free environment. Primarily, economic activity affects the environment in two broad ways. First, the 'User' sources materials or resource inputs required for economic processes from the environment (Pearce et al., 1993). Second, the by-products of materials and resources input no longer required by the economy are returned by the 'Polluter' to the environment in the form of waste or pollution (Pearce et al., 1993). These two types of impacts on the environment have resource costs and implications. However, the 'User' and 'Polluter' often externalises these costs and are not held liable and accountable for generating adverse effects for the environment. Instead, the cost or burden is shifted to a third party (e.g. Government) that is not involved in the economic activity themselves (Gillingham and Sweney, 2010).

The unpaid cost reflects the failure of the market system to put an appropriate value on 'the environment', even though the environment serves economic functions and provides other benefits (Garrod et al., 1999; Turner, 1999). Some argue that this market failure exists precisely because the environment is considered a free asset, or an example of a common pool resource, that is the benefits the environment provides are intermediate between those provided by 'public' and 'private' goods (Stiglitz, 2000). Consumption is rival in that utilizing the resource imposes costs on other users. However, due to ineffective or incomplete property rights, the use of the resource is not fully excludable. As a result, the 'User' and 'Polluter' does not have to pay the full cost of his/her use, which is not optimally determined through the market mechanism. Moreover, where there is no market for environmental goods they will be either under-priced or have a price of zero (Turner, 1999). The consequences will be an inefficient or unfavourable allocation of resources where environmental goods and services are overused or overexploited. This, in turn, causes various environmental problems that may have adverse effects on the economy, society, and human health.

Governments are aware of this type of market failure associated with using the environment. They intervene by adopting various mechanisms, including using public expenditure to replenish resources and reinforce market processes (Allan et al., 2007). Alternatively, they may impose an environmental tax on production and consumption, or a subsidy for alternative items (Pigou, 1920). However, well-informed policy to address this type of market failure requires development of empirical models, in addition to (and in application of) theoretical models. Specifically, an empirical modelling framework is required to actually track the economic and environmental effects of both environmental and economic policies and other disturbances in particular economic settings. More generally, the empirical framework should utimately be able to capture the full social cost and the economy-wide implications of using the environment to meet economic needs. Environmental IO modelling builds on micro foundations to meet these requirements. These models are designed to incorporate environmental problems and activities (waste, pollution generation and/or natural resource use) in an IO framework. Several approaches to do this have been developed by a number authors, amongst them are Daly (1968); Isard (1969); Leontief (1970) and Victor (1972).The following section gives an overview of the type of environmental IO model employed in this study and the peculiarities of the model.

1.2 Why the Leontief (1970) environmental IO model

In this thesis, I apply and further develop the Leontief (1970) environmental IO method for detailed analysis of the impact of economic activity on the environment. In addition, I consider the economy-wide implications of using different types of environmental services to meet various economic needs. The features of the IO framework justify their use here. They include the incorporation of sectorally disaggregated economic accounts, where different input purchases to each industrial sector and the subsequent uses of the output of those sectors are separately identified. Linked to this, the use of physical resources and the generation of pollution can be related to inputs and outputs in value terms. A central contention is that environmental IO analysis can be applied to identify both the direct and indirect 'User' and/or 'Polluter', and it offers a comprehensive, rigorous, and transparent way to assess environmental impacts of various production and consumption activity of an economy. Due to these characteristics, the IO method is an excellent tool for analysing priority environmental problems and has multiple potential uses (see Section 1.4 below) that may add to the existing analytical capacity available to policymakers.

More generic developments of the Leontief (1970) environmental IO model focusing on resource use and pollution generation can be seen in studies such as Allan et al. (2007); Arrous (1994); Leontief and Ford, (1972); Luptacik and Böhm (1999); Qayum (1991); Schäfer and Stahmer (1989); Weisz and Duchin (2006). However, there has been less research using the Leontief (1970) environmental IO model in considering full social and resource costs and the economy-wide implication of economic-environmental interaction. In this study, I address the aforementioned gap by providing further insight on how the analysis in this study is beneficial for different types of externalities (e.g. waste generation) as well as resource uses. Moreover, environmental IO models can be configured for application at different spatial scales and as a foundation to other and/or more flexible and advanced macroeconomic tools such as the Social Accounting Matrix (SAM) and Computable General equilibrium (CGE) models. I discuss these prospects in more detail in the final chapter (Chapter 5).

More generally, in this thesis, I consider the role of environmental IO methods in examining the impacts of economic activity on the environment, with the clear objective of refining these approaches to provide key information and outcomes that may support various environmental protection and resource management policies at regional level. I do this, by carrying out the analysis in this study in a progressive way. Specifically, I apply and extend the environmental IO model in the core chapters (2-4) of this thesis using the case of physical waste generated as a (local) pollutant to be managed or 'cleaned' and the case of physical water (public water) to be supplied as illustrative examples to consider common pool resource problems. I focus on case studies of the Scottish and Welsh regional economies, where there is relevant devolved responsibility in each case. The following section, discusses in more detail the relevance of this study to the case regions.

1.3 The case studies in this research

As aforementioned, in this research, I focus on regional economies in the UK (Scotland and Wales). I make this choice for three main reasons. First, since 1999, UK governance has been transformed by devolution[1]. Devolution is a process designed to decentralise government decision-making and actions, giving more power and responsibility in part to devolved authorities so that the singularity of regional economies is reflected and local factors are better recognised in decision-making. In the UK, this meant that responsibility for sustainable economic development and growth is a central priority of her regional economies. As a result of

[1] The devolution of powers to Scotland, Wales and Northern Ireland is summarised and available at: https://www.gov.uk/guidance/devolution-of-powers-to-scotland-wales-and-northern-ireland

which, policymakers need tools and methods to weigh the cost, benefits and trade-off of various (economic and environmental) policy issues.

Secondly, environmental issues cut across many areas of policy such as environmental protection, conservation of resources, human wellbeing, and sustainable development and are directly related to many local level and/or regional matters such as air pollution, waste generation, water quality and availability. In the UK, regulations for these issues have been significantly shaped by policies that were introduced by the European Union (EU). However, with the UK's recent vote to leave the EU[2], the UK is faced with either retaining EU environmental standards or going beyond EU standards, following the triggering of Article (50)[3] of the Treaty on the European Union and the final outcomes of official negotiations (Environmental Audit Community 2016)[4]. On this basis, the UK's devolved governments may now have stronger influence, power and responsibility over the formulation and design of its environmental policies in the coming years. As such, policy makers need to be adequately informed and gain a better understanding of regional environmental issues and future policies.

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[2] On Thursday 23 June 2016, the United Kingdom voted to leave the European Union. The details of the referendum are available at https://www.gov.uk/government/topical-events/eu-referendum

[3] Article 50 is the formal mechanism for leaving the European Union it is available at https://www.gov.uk/government/collections/article-50-and-negotiations-with-the-eu

[4] EU and UK Environmental Policies, published by the House of Commons Environmental Audit Committee is available at http://www.publications.parliament.uk/pa/cm201516/cmselect/cmenvaud/537/537.pdf

Thirdly, economic IO analysis and its basic environmental extensions are already commonly employed accounting and modelling frameworks that UK national and regional policy makers tend to understand and are often conversant with informative content. This is especially true given that IO tables are a standard part of national accounts at the UK and Scottish levels (UK Blue Book[5] and Quarterly National Accounts Scotland (QNAS)[6]. For Wales, the Welsh Economy Research Unit (WERU) at Cardiff University has developed Welsh IO framework over the years. While not part of official regional/national accounts, this IO framework has been used in various policy relevant analyses, with the support of bodies such as Natural Resources Wales and the Welsh Assembly Government (for example see Munday et. al. (2009)[7], (2015)[8])

In the context of applying IO methods and analysis to support local policy, this is also relevant because regional governments continuously address a number of issues driven by economic-environmental interaction. For instance, the Scottish Government perform routine exercises (i.e. multiplier analysis and effects) using the IO framework, and constructing it as a part of QNAS, to understand how the economy

[5] UK National Accounts: The Blue Book (2015) Edition available at https://www.ons.gov.uk/economy/grossdomesticproductgdp/compendium/unitedkingdomnationalaccountsthebluebook/2015-10-30

[6] Quarterly National Accounts Scotland available at http://www.gov.scot/topics/statistics/browse/economy/QNA2016Q3

[7] Munday, M. Roche, N & Roberts, A. 2009. A review of the economic evidence on the determinants and effects of foreign direct investment [Online]. Available at: http://gov.wales/docs/caecd/research/090617-foreign-direct-investment-en.pdf

[8] Munday, M. Jones, C & Roche, N. 2015. The Economic Impact of the Communities and Nature Environment for Growth (E4G) Strategic Project. Available at: https://naturalresources.wales/media/3806/final-report-on-the-economic-impact-of-the-communities-and-nature-environment-for-growth-e4g-project.pdf

functions over time. From 1998-2014 and on an annual basis, the Scottish Government determine the amount of potential employment that will be created in the economy because of an increase in the final demand for any production sector's output (usually calculated as full time equivalent (FTE) jobs created). This measure is referred to as output-employment multiplier or 'employment effects' (Scottish Government, 2014)[9].

The Scottish Government also employs basic environment IO analysis for carbon accounting linked to public budget decisions by conducting high-level assessment of impacts of government spending on emissions (Scottish Government, 2017)[10]. In Wales, WERU has been involved in contributing to the almost annually published Welsh Economic Review. The review provides an authoritative and objective analysis of the Welsh economy in a manner that promotes understanding and informs decision makers[11]. Members of WERU write core sections of the Review. The Welsh IO framework has also been a basic for economic-environmental modelling (Munday and Roberts, 2006; Munday et al., 2013). It is commonly used to assess the environmental consequences of tourism spending in the region, particularly when spending is connected to major events (Collins et al., 2009; Jones, 2012; Jones and Munday, 2007; Roberts et al., 2016)

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[9] The Scottish government routine exercise of multipliers is available at http://www.gov.scot/Topics/Statistics/Browse/Economy/Input-Output/Mulitipliers

[10] High level carbon assessment of Scottish draft budget conducted annually from 2010-2017 is available at http://www.gov.scot/Topics/Statistics/Browse/Economy/Input-Output/CarbonAssessment

[11] Welsh Economic Review available at https://publications.cardiffuniversitypress.org/index.php/WER/index

In view of the above discussions, the awareness and interest of policy analysts and decision-makers in the UK, as well as the wider regional and environmental IO research communities, there is a clear opportunity for this study to contribute by demonstrating other ways that the IO method and framework may play a role in supporting regional policies on economic-environment issues. Having discussed the background of the research, why I have chosen the method applied in the thesis and the case studies used in this study in the previous sections, the following section considers the role and use of the IO framework in addressing economic-environmental issue.

1.4 Role of IO in addressing economic-environmental issues

Initially developed by Leontief (1936), IO analysis provides a comprehensive snapshot of the structure of inter-industry linkages in an economy. It facilities the calculation of the added value that each sector contributes to the final output and gross domestic product (GDP) generated by an economy, as well as providing in monetary terms for any given year, insight into the value of economic transactions between different sectors (Miller and Blair, 2009). IO tables are the required key component used for IO analysis. In most countries, IO tables are constructed, produced, and published regularly or periodically, e.g.

officially by the Office of National Statistics (ONS)[12], the Scottish Government[13], or sponsored in the research community, such as by Welsh Economy Research Unit (WERU).

National or regional IO tables are conceptually reconcilable with United Nations system of national accounts (SNA)[14]. SNA is used as a basis for IO analysis; it describes a coherent, consistent, and integrated set of macroeconomic accounts in the context of internationally agreed definitions, classifications, and accounting rules developed by United Nations. The most commonly used commodity and industry classifications for the construction of IO tables, where environmental or resource variables are reported using the same classification for 'Users' and 'Polluters', are International Standard Industrial Classification (ISIC)[15], European Statistical Classification of Economic Activities (NACE)[16] and European Statistical Classification of Products by Activity (CPA)[17]. These industry and product classifications facilitate comparison

12 For example, see IO data publications by ONS in supply and use tables, with annual tables from 1994 to 2014 available at: https://www.ons.gov.uk/economy/nationalaccounts/supplyandusetables/datasets/inputoutputsupplyandusetables

13Scottish Government publish Supply Table, combined use and industry-by-industry, with annual periodic tables from 1998-2013 available at http://www.gov.scot/Topics/Statistics/Browse/Economy/Input-Output/Downloads

14 The United Nations system of national accounts is available at http://unstats.un.org/unsd/nationalaccount/sna.asp

15 For the United Nations International Standard Industrial Classification (ISIC), see http://unstats.un.org/unsd/iiss/International-Standard-Industrial-Classification-of-all-Economic-Activities-ISIC.ashx

16 For European Union Statistical Classification of Economic Activities (NACE),see http://ec.europa.eu/eurostat/statistics-explained/index.php/NACE_background

17 European Union Statistical Classification of Products by Activity (CPA) is available at http://ec.europa.eu/eurostat/ramon/nomenclatures/index.cfm?TargetUrl=LST_NOM_DTL&StrNom=CPA_2008&StrLanguageCode=EN&IntPcKey=&StrLayoutCode=HIERARCHIC

of economic and environmental impacts across and between regions and countries based on IO analysis (McDonald and Patterson, 2004).

As I explained in the beginning of this section, conventional economic IO tables are constructed in monetary (value) terms and are used to consider inter-industry linkage within an economy and sectoral contribution to final demand. However, authors such as Daly (1968), Isard (1969), Leontief (1970) and Victor (1972) have demonstrated that physical interaction between the economy and the environment involving material flow, resource use and/or pollution generation can also be placed within the IO framework using environmental variants of standard economic IO analysis. More generally, environmental IO modelling is an extension of the conventional demand-driven IO analysis, it introduces a physical environmental dimension to the conventional monetary analysis (Miller and Blair, 2009).

In this study, economic and environmental IO tables and models based on them are considered to have two main roles in addressing economic-environmental issues and supporting economic and environmental policy. First, the role of descriptive and accounting analysis for any given accounting year that IO accounts are reported for. Second, the role of impact analysis for scenarios of marginal changes in activity. Both involve using environmental variants of the IO multiplier analysis that constitutes the core of IO methodology. More generally, in the conventional demand-driven economic set-up, IO multipliers are used to measure the economy-wide impacts of final demand for the output of specific sectors of the economy (Miller and Blair, 2009).

The multiplier impacts include 'direct' input requirements that account for intermediate input purchases of goods and services from various industries and which are directly reported in IO tables. However, through simple mathematical manipulation of the IO data (see Chapter 2), multipliers also capture the 'indirect' input requirements accounting for the fact that any supplying sector must purchase its own intermediates and any sector supplying that sector must do the same, and so on (i.e. 'rounds' of the multiplier). In addition, a multiplier may incorporate 'induced' input requirements accounting for the fact that all industries in the direct and indirect elements of the supply chain employ people who then spend their wage income on a range of economic outputs, triggering more rounds of inter-industry transactions. Let us discuss the aforementioned roles in more detail using examples from the literature.

1.4.1 Use of IO for accounting analysis

Traditionally, one basic way the analysis of multipliers can be applied in contest of accounting analysis is by understanding the pattern of interdependences and inter-linkages between industries through identifying key or leading sectors in an economy (Chenery and Watanabe, 1958; Hirschman, 1958; Rasmussen, 1956). Fundamentally, there are two basic types of inter-industry linkages, namely, backward and forward linkages (Miller and Blair, 2009). Consideration of backward linkages focuses on the fact that any industrial activity requires further domestic production and supply of inputs via its up-stream supply chain. Whereas, the consideration of forward linkages focuses on the opposite direction. It considers how any individual industrial activity induces the utilisation of its output by other (down-stream) domestic production activities (Miller & Blair, 2009). These linkage measures reflect the nature and processes of economic activity and signify the extent to which a sector can be a source of growth to the economy (see for example Cai & Leung, 2004; Cella, 1984; Chenery & Watanabe, 1958; Dietzenbacher, 2002; Dietzenbacher & der Linden, 1997; Hirschman, 1958; Midmore et al., 2006; Miller & Blair, 2009; Rasmussen, 1956; Strassert, 1968)

By augmenting economic IO tables with information on physical resource(s) use and/or pollution generated (or produced per unit of output), the environmental IO method can be similarly used to attribute environmental impacts to production and consumption activities within an economy for a given time period (usually the accounting year which the IO data is reported for). This framework can be used to address policy issues such as which elements of an economy's activity (production and/or consumption) may ultimately be the key cause or driver of environmental pressures. Using IO accounting analysis to identify what production and consumption patterns are responsible for environmental pressures can be considered as a dual approach with complementary perspectives on the structure of pollution generation and/or the problems of resource use in a given accounting period. It provides necessary information to focus policy actions in the neediest areas and in the areas where it is likely to have the most impact. Examples of applying environmental IO for descriptive and accounting analysis based on average multiplier relationships existing in a given accounting year can be seen in a range of studies (for example see Barrett et al., 2013; Minx et al., 2009; Mózner, 2013; Turner and Katris, 2017; Wiedmann et al., 2010). The applied work in Chapter 2 of this thesis builds on studies using this type of applications (e.g. for waste, Jensen et al. (2013)).

1.4.2 Use of IO for modelling analysis

Another common way that economic and environmental IO analyses are used is to employ the average multiplier relationship as explained in the previous sub-section in examining the potential impacts of marginal changes in demand patterns in an economy on economic and environmental variables. By this I mean, estimating the wider economic impacts of a particular activity as a representation of marginal rather than just average economy-wide impacts of a given change in final demand for specific production sectors (Miller and Blair, 2009). In this way, the multipliers are used to measure activity levels in terms of output, wage income, value-added, employment and/or other variables of interest that is likely to be generated throughout an economy for each monetary unit (usually £1 or £1million) of final demand (see, Fraser of Allander Institute, 2017[18]; Lisenkova et al., 2010; Scottish Enterprise, 2008).

The IO methods can also be configured to consider price and supply multipliers (Ghosh 1958). However, it is important to note, that the IO framework has limitations if there is a need to model changes in activity, particularly where these are likely to induce changes in prices and supply conditions and/or where regulatory or market constraints are involved. This will require a set of assumptions regarding supply conditions; technology and the role of prices that prove restrictive in IO setting. As such, price and in particular, supply multipliers are less commonly applied in the context of policy analyses. More generally, I acknowledge that in such cases other advanced macroeconomic models that are appropriate for considering price, supply and technology changes are more appropriate. One of these is the Computable General Equilibrium (CGE) model. CGE models can be developed using multisector data sources such as IO tables and Social Accounting Matrix (SAM) (see Hanley et al., 2009; Seung et al., 1997; Tol, 2008). However, I argue that there are still key merits in applying environmental IO methods, in its original form, in that it gives us a useful starting point to consider the basics and fundamental issues before ultimately moving to other advanced models like CGE that may facilitate extension of research.

[18] Examples of IO multipliers employed to study the Scottish economy are available at https://www.sbs.strath.ac.uk/economics/fraser/20170420/Exports-and-Employment- Scotland.pdf

Moreover, there are number of studies that have convincingly argued that the supply IO system is only useful if restated and reinterpreted as price IO system (Dietzenbacher, 1997; Oosterhaven, 1988). For this study, I argue that, the multiplier changes and impacts are small or on small sectors (i.e. water and waste) and thus supply constraint is less important for the analysis I do in this current research. Hence, in this study (Chapter 3 and 4), I have only employed the price IO system through consideration of price multipliers, to consider which types of industries and consumers ultimately bear resource costs that may not be fully incorporated in the market prices of some industrial outputs. It is important to note that with the price IO system I only consider where price pressure is located and not price changes. Crucially, the IO framework is demand driven-driven by change on the final demand side of the economy and thus the demand driven system is silent in price and supply constraints. Ultimately, IO methods, allows us to consider supply or demand or price and quantity.

From the above discussions, it is clear that IO methods are useful and suitable tools to study the interdependences and relationships between the economy and the environment. In this respect, the models and analysis may help to support existing economic and environmental policies and/or inform new policies. However, this thesis contends that the application and value of the IO approach for this purpose have not been fully assessed in the literature with a view to informing policy decisions or in considering market failure issues. This leads us to the discussions of the originality and significance of the study.

1.5 Originality and significance of the study

This study gains significance and originality on the basic that while the Leontief environmental IO analysis is regarded as an important and insightful tool its most common use is for descriptive and impact type analysis as I discuss in the previous section. In most cases, the environmental IO methods has been extensively used in the literature with the main objective of distinguishing between two major accounting approaches for pollution generation and thus responsibility for reduction. These are; (1) production-based principle/account (Munksgaard and Pedersen, 2001) and (2) consumption-based principle/account (see Wiedmann, 2009; Wiedmann et al., 2006). In contrast to the two major principles above, there is another view for a shared responsibility principle which centres on allocating responsibility for environmental impact equally between the producer and consumer (for example see Andrew and Forgie, 2008; Ferng, 2003; Gallego and Lenzen, 2005; Lenzen et al., 2007; Mózner, 2013). A number of studies have used one or both of these aforementioned principles to analyse national, regional, multiregional trends in greenhouse gas emissions and other footprint type issues (e.g. land, material, and ecological flows) (Gu et al., 2014; Hubacek and Giljum, 2003; Liu, 2012; Nakamura and Nakajima, 2005; Steen-Olsen et al., 2012; White et al., 2015; Wilting and Vringer, 2009).

It can be argued that most of the aforementioned studies have missed or overlooked the application and role of the environmental IO model in the assessment of resource costs imposed by economic-environmental interaction that are not directly reflected in the market system (Allan et.al., 2007). To be specific, the previous studies neglect measuring pollution generation and/or resource use associated with different economic activity to account for potential system and economy-wide implications of managing resources and/or pollutants in the context of the implied social or resource costs that are often not internalised by the 'Polluter' or 'User'. For example, once categorised as a negative externality, the impact of pollution could be reduced through the operation of abatement sectors (for example see Allan et al., 2007; Leontief, 1970; Leontief & Ford, 1972; Weisz & Duchin, 2006). My thesis focuses on filling the aforementioned gap at least at region level.

Another strength and significance of this study is on the fact that it allows us to look at fundamental issues in more details than have been previous considered by researchers and even policy makers. It seems to be the case that researchers and decision makers miss or jumps steps when addressing economic-environmental issues and may overlook key questions. For instance, what is the distribution and structure of waste generation? what would the economy look like if the 'Polluter' or 'User' pays for cleaning the environment and managing natural resources? These are some of the issues I address in this study, which I believe make this research distinct, from existing studies as to the best of my knowledge these issue have only been considered in one or two studies prior to this research. Therefore, I attempt to provide additional and relatively new information to economic-environmental literature and policy debate, through a closer examination of the connection between economic activities and processes and the resource costs implications of using the environment. The following section outlines the specific aims and objectives of the thesis

1.6 Some specific aims and objectives of this study

The overall aim of this current research is to provide useful information and insight that may strengthen economic-environmental policy in UK regional economies. Through research centred on addressing the issue of market failure and suggesting ways of incorporating/internalising externalities into economic processes and considering the economy-wide implications in this regard. I identify three inter-related areas of analysis that may be useful in considering pathways to economic growth in regions that promote environmental protection and natural resource management. Each of the inter-related areas constitutes one of the research objectives and achieving the overall aim of this study involves the following specific objectives:

1. To consider how IO 'multiplier' analyses may be used to develop understanding of the structure and drivers of regional waste generation. This process will involve consideration of total regional

waste generation both in terms of direct generation but also generation of domestic waste embedded in local supply chains that serve domestic final consumption demands. In developing the analytical framework, I draw and reflect upon key developments in applying IO to regional waste problems (e.g Court, 2012 and Jensen et al., 2013 studies for Wales).

2. To extend the application of the Leontief (1970) environmental model and promote the value of redoing analysis by revisiting an earlier but incomplete study by Allan et al. (2007). Their study operationalises the environmental IO model to incorporate the average cost of disposing of a physical unit of waste to identify the demand for waste disposal services implied by the physical waste generated. This study builds on the Leontief (1970) and the Allan et al. (2007) models as foundation and appropriate approach to incorporating the resource cost of waste management in Scottish IO accounts.

3. To develop IO methods through which the full resource costs of water supply and use may be examined. This step is necessary where the market system cannot be relied upon to allocate water among competing uses - in terms of both different types of industrial and domestic users, and the ecological and amenity functions of water courses – in a way that is socially efficient.

The underlining aim of this thesis is determining if environmental IO methods and the seminal Leontief (1970) environmental model in particular can be developed to improve the understanding of economic-environmental interaction and support already existing or new policy decisions at least regional levels.

1.7 Structure of the study

The thesis is organised into five chapters. Chapters 2 to 4 are the core chapters, while Chapters 1 and 5 respectively provide an Introduction and Conclusion. Chapters 2 and 3 focus on more traditional ways to apply the environmental IO analysis, but with new empirical applications to test and augment the existing method for considering externalities and common pool resource issues in the context of pollution generation, specifically focusing on physical waste. Chapter 4 forms a core contribution of this thesis and a novel contribution to the economic-environmental type analysis. Each core chapter of this thesis (Chapters 2-4) focuses on developing methods to address key policy issues, so that policy maker may be provided with a better understanding on how economic activity affects the environment.

This study starts proper in Chapter 2, which is titled 'Examining the nature and structure of a local pollutant: the illustrative case of waste generated in Scotland'. As a first step in applying the environmental IO model in this study, I consider the structure of the waste problem within Scotland to develop better understanding of waste generated in the region, and to consider how this information may help to improve waste management & prevention activities. Employing environmental IO methods along these lines may aid the process of monitoring the progress on waste prevention and zero waste plans of Scotland. Through this system, I consider both the industrial source of waste in terms of waste generation and the type of final demand driving waste generation. The latter can be considered both in terms of (a) what is consumed (industry outputs) and (b) who consumes (sources of final demand). This will lead to identifying the main drivers of waste generation, permitting focus on production and consumption activity that are of particular concern. A second priority here is to understand the economic processes and drivers underlying hazardous waste production in the region. More generally, this type of analysis in Chapter 2 may assist policy makers in identify the interplay between the production of hazardous waste and the consumption of industry goods that have directly and/or indirectly resulted in hazardous waste production which will facilitate the necessary treatment options

In Chapter 2 the key research findings are, in the first instance are that only a few industries are accountable for most of the waste generation in Scotland. Secondly, when I consider the production side of the economy and in turn, waste generation that occur in order to meet final demand, gross fixed capital formation, household, and Government final demand types have greater impacts in waste generation in Scotland than what previous studies have found. Thus, it can be argued that rather than only regulating and posing restrictions on producers, focus might be directed towards curbing final consumption goods that are directly or indirectly produced by waste intensive industries. Overall, the conclusions from Chapter 2 may be useful if regional policy makers attempt to consider waste reduction through consumption-focused polices as well as production-based ones

The research continues in Chapter 3. Chapter 3 is titled 'Examining the economic implications of incorporating the resource costs of supplying a clean environment (waste free) in Scotland'. In this chapter, I build on a previous Scottish study by Allan et al. (2007). Allan et al. (2007), took a first attempt at this by operationalising the full Leontief environmental model based on the Scottish IO accounts of (2007). However, these authors encounter a number of issues in developing the model. One core issue was a lack of compatible industry-environment data. This severely hindered a thorough and accurate enumeration and analysis of environmental problems at the Scottish level. Other issues also revolved around difficulty in explaining and interpreting some of the results obtained at the time. But currently due to the improved quality of data now available (Scottish IO tables 2011) and better knowledge of the subject area it provides an opportunity to produce more accurate results and finding on environmental issues of Scotland that will contribute to the IO field and provide useful information for policy makers. Hence the focus in this Chapter 3 is to revisit the Allan et .al (2007) to address some of the unresolved issues in their study. This will involve focusing on the activity of the waste disposal sector (IOC 49) in the IO system in terms of the distribution of resource costs involved in internalising the externalities of waste generation. Secondly, the Scottish IO tables (2011) will be extended with waste coefficients to consider direct, indirect and induced impacts on waste generated throughout the economy that may be related to final consumption demand for the output of each industry reported in the IO tables. With a primary aim to generate the full Leontief environmental set of accounts for Scotland with waste generation and the waste management sector separately identified.

In chapter 3, the main result is that production sectors appear to only partly and unsystemically pay for the waste cleaning and management. In effect, some sectors seem to be charged more for waste disposal services than others. I also find that the demand reflected by the multiplier calculation cannot be mapped onto the resource cost implied by waste generation of each sector. On this basis, I consider the average cost per physical unit of waste to identify the demand for waste disposal services implied by the physical waste generated by a sector. Hence, I find that the production side of the economy is subsidised in terms of direct payment for waste management services by 'Waste Management', 'Public Administration', and 'Health' sectors in particular.

The final core chapter (Chapter 4) provides an extension of the method used in the previous chapter (Chapter 3). Chapter 4 is titled 'Augumenting the environmetal IO model to consider the economy-wide implications of water supply and use. I explore how the Leontief (1970) model and the further methodological developments of Allan et al. (2007) used to operationalise it may be applied to the case of supplying a physical resource like water (as opposed to providing a clean environment for example in the event of pollution or waste generation) and for the economy of Wales. This analysis is set in the context of providing common pool resources where the 'Users' typically do not pay the full cost for their resource use (and it is not possible to fully exclude use). Chapter 4 addresses key policy issues regarding the causes of the deviation between actual expenditure for the output of the water sector and actual water consumption in Wales. Another key policy issue is understanding how water usage in one industry connects to water usage embedded in supply chains. In Chapter 4, I find that, the production side of the economy is heavily subsidised by household. As a result, household are paying far beyond that which is implied by their demand. I argue that policy makers and regulators require such analysis and information in order to understand the demand and supply of UK regional water resources and their role in supporting economic expansion whilst simultaneously adopting appropriate strategies for achieving water sustainability.

Finally, Chapter 5 provides an overall conclusion of the work and analysis conducted throughout this thesis and a reflective assessment of the specific results obtained in the three analytical chapters. Additionally, I identify major contributions and highlight some recommendations and directions for future research initiatives.

Chapter 2: Examining the nature and structure of externalities via pollutants: an illustrative case of waste generation in Scotland

2.1 Introduction

As I explain in Chapter 1, economic actions by the 'Users' or 'Polluters' exert negative impacts on the environment and cause the generation of environmental 'bads' (e.g. air pollution, carbon emissions, waste, resource depletion etc.). Thus, two natural questions arise: (1) who are the 'Users' or 'Polluters'; (2) how can we examine the nature and structure (direct and indirect) of economic-environmental interactions and connections? One way the environment IO method can be used is to assess and examine the nature of externalities via pollutants in the economic system. Specifically, it can be used for accounting purposes to attribute various environmental 'bads' to production and consumption activities at any given point in time (usually the accounting year the IO data are reported for). This is a traditional approach that has been used extensively in the literature to examine pollution generation, resource use and other environmental problems (Llop, 2008; Minx et al., 2009; Tukker et al., 2009; Feng et al., 2012; Munday et al., 2013; Chen et al., 2016).

In this chapter, I focus on investigating which production sectors are directly responsible for waste generation in a single region and determining the final consumption demands that ultimately drive production and its related waste pressures in Scotland. In the first instance, I calculate the amount of waste directly generated in various production activities in Scotland under what is commonly referred to as a 'production based principle/account' (Munksgaard and Pedersen, 2001). This approach accounts for environmental pressures and impacts caused by production of national goods and services, so that responsibility for its reduction is allocated to the 'direct polluter' (i.e. the industry generating waste due to its production process).

However, production is driven by consumer demand, such that producers mainly generate or contribute to environmental pressures, because human consumption activities create demand for their outputs (Andrew and Forgie, 2008). Thus, as another or second instance, I also attribute total waste generated in production to various types of consumer demand (in particular intermediate or final demand), whose demand for a particular output directly or indirectly may be driving this waste generation. In this respect, I apply a less commonly used approach, partial consumption based accounts (Turner, 2014) that accounts for environmental pressures (e.g. waste) that is supported by final demand for each sector's output, rather than the direct waste generation associated with the production of that output. Partial consumption accounts is regarded as important for policy because it reattributes the cause of environmental pressures or impacts to the 'indirect' polluter (i.e. the type of consumer demand for production output and in turn waste generation) (Jensen et al., 2011; Turner et al., 2011).

In this chapter, I use the above-mentioned national accounting principles (i.e. production based account and partial consumption accounts)) for two main reasons. First, this type of environmental IO accounting provides information that will prove useful if local policy makers attempt to control waste generation through production perspective policies as well as consumption perspective policies. The argument for the use of these accounting approaches is also relevant, when we consider responsibility issues in terms of what governments' have jurisdiction over (Turner et al. 2011). For, instance, we know that local policy makers do not have the authority and power to influence or restrict the input used in producing goods and services outside territorial boundaries that is imported for local consumption (Turner et al. 2011).

Secondly, this chapter is linked to previous work in relation to regional policy makers who were interested in understanding local impact associated with production and consumption activity. In 2015, the Centre for Energy Policy (CEP), University of Strathclyde carried out a preliminary illustrative analysis using environmental accounting methods based on IO framework to informally inform the thinking and understanding of policy analysts in the Scottish Government and Zero

Waste Scotland (ZWS). CEP focused on determining both the direct industrial source of waste generation and the final demand drivers, both in terms of the industrial outputs consumed and types of consumer (domestic, external, and capital demands). Through my role as CEP PhD student, I participated in this work by conducting analysis and simulations with my supervisor and Director of CEP, Professor Karen Turner, and have had agreement of parties to use resulting datasets and findings in my thesis. More generally, due to the quality of the dataset provided by the Scottish Government and ZWS, I became interested in conducting the analysis in Chapter 3, which is revisiting a previous but incomplete Scottish study by Allan et al. (2007) on the (absolute and distribution of absolute) resource costs involved in 'internalising' the externality of waste generation.

The remainder of the chapter is as follows. In Section 2.2, I will begin by discussing some issues for policy in the context of measuring and examining the environmental impacts caused by different economic activity. This is followed by a review of studies that have applied environmental IO model to consider various environmental impact attribution scenarios, including studies that consider various dimensions of the waste problem (e.g. Jensen et al., 2011; Liao et al., 2015; Nakamura and Kondo, 2002; Salemdeeb et al., 2016) (Section 2.3). The data used for communicating key elements of the waste generation in Scotland is described in Section 2.4. In Section 2.5, I describe the method employed in this chapter that is focused on enumerating the extension of conventional economic IO model to demand driven environmental IO model and applying it to account for waste generation associated with economic activity. In Section 2.6, the empirical results are presented and discussed. In Section 2.7, I reflect on the chapter and I raise some practical issues in future consideration of footprint type analysis. Finally, I discuss the conclusions of the chapter in Section 2.8.

2.2 Issues for policy

Waste creates both direct and indirect environmental and health impacts (Huysman et al., 2015; Kellenberg, 2012; Pires et al., 2011). For this reason, governments worldwide have continued to introduce various strategies and plans to reduce the amount of waste caused by different types of economic activity. The commonly discussed strategies and/or plans include, but are not limited to; the EU Waste framework directive, zero waste strategies, EU waste hierarchy, and integrated waste management (Beylot et al., 2016; Osmani, 2012; Rocco et al., 2016; Song et al., 2014; Zaman, 2014). More generally, waste management is now discussed and considered with the overarching objective of how to use natural material resources more efficiently, avoiding waste and where possible using unavoidable waste as a resource (Cobo et al., 2017; Huysman et al., 2015; Schreck and Wagner, 2017).

However, it can be argued that despite the application of a number of market-orientated instruments, strategies and programmes to promote waste reduction and minimization behaviour, what may seem to be the core challenge is that the policy objectives and measures to encourage waste reduction are not supported with the appropriate empirical framework. For instance, with most waste polices and strategies, government have placed more emphasis on moving from safe disposal of waste to beneficial reuse of materials as I mentioned above but little or no consideration of a fundamental and crucial issue of what is the distribution of waste and the structure of waste generation. In addition, there has been more consideration of the direct polluter (industrial source of waste in terms of waste generation) with limited or even no clear consideration of the indirect polluter (type of final demand driving waste generation).

Essentially, there are remarkably few empirical studies that consider the responsibility for waste generation using footprint type IO accounting methods. An advantage, of footprint type IO accounting is that it permits the consideration of the distribution of direct waste generation across the different IOC sectors. In addition, it can be applied to reallocate waste from where it is directly generated in the production of output to the demand source ultimately driving that output. This may be useful in answering key policy questions of which economic sectors may be considered responsible for waste generation by determining consumption patterns of different types of final consumers. In turn, this may cause policy makers to reconsider how responsibilities for environmental problems are assigned and ultimately who is considered as the 'Polluters'. In addition, it may help policy makers in monitoring, assessing, and considering how their decisions and policies influence waste generation.

To demonstrate the above argument, I propose that the traditional attribution environmental IO approach that is commonly used for carbon emission accounting, which follows the production based principles (Munksgaard and Pedersen, 2001) and partial consumption-based principles (Turner et al., 2014), can be applied to the case of waste. Waste is a pollutant that – in contrast to carbon – has greater impacts within the local economy as opposed to impacting globally via international supply chains. In this context, I propose that applications of the environmental IO method in this way may also depict the benefit of employing production based and partial consumption based account that focus on domestic supply chain activity. In the following Section (Section 2.3) I proceed with some examples of studies that attempt to apply the environmental IO model to consider various waste issues.

2.3 Examples of studies applying environmental IO analysis to consider responsibility for waste generation

There is a growing literature on the use of the environmental IO model to consider various dimensions of the waste problem (Beylot et al., 2017; Delahaye et al., 2011; Duchin, 1990; Kondo & Nakamura, 2005;

Munksgaard et al., 2005; Reynolds et al., 2016). These dimensions have been largely centred on considering waste reduction in the form of either reuse, recycling and recovery that promote sustainable society and green consumption (Duchin, 1990; Li, 2012; Nakamura & Yamasue, 2010; Ni et al., 2001; Xu & Zhang, 2009). This may perhaps reflect the fact that waste policies and strategies tended to focus on moving from the high dependence on the use of landfill to the use of the EU waste hierarchy that prioritize waste treatment option. Recently, focus is now shifting to resource efficiency and circular economy approaches in waste management, where waste is used as a resource input rather than a pollution output (Li, 2012; Bastein et al., 2013; Ham et al., 2013; Agrawal et al., 2013)

In this section, I present a survey of the literature by looking into the different ways IO methods have been employment to address various waste problem. For instance, in Duchin (1990), the environmental IO method was used to examine the impact of technological change on multiple waste treatment systems. In addition, the author evaluated the physical and economic feasibility of alternative strategies for dealing with biological waste. In a pioneering contribution, Nakamura, (1999) and Nakamura & Kondo, (2002) develop a waste IO modelling approach, to analyse the interactions between waste emissions and economic activity for the Japanese economy. Their model is used to evaluate the effects of alternative waste disposal and recycling options on the levels of industrial production. Their later work by Nakamura & Kondo (2009) provides a comprehensive literature of the extended use of waste IO models, for example in terms of analysis of sustainable consumption, life cycle, materials flows analysis and linear programming (for example see Takase et al., 2005; Nakamura & Kondo, 2006; Kondo & Nakamura, 2004; Nakamura & Nakajima, 2005). Choi et al. (2010) demonstrates how to use the baseline IO model and environmental IO accounts to analyse geographical e-waste recycling systems for end-of-life commodities.

A key advantage of studies that use waste IO model is that it captures the integration of waste generation and management options so that waste can be tracked through the economic system from origin to destination. While, the above-mentioned studies constitute a necessary part of the broader or wider evidence base in considering the economy-waste-environmental nexus, such analyses do not attempt to consider demand drivers of waste generation aligned with national accounting principles. There are other studies that consider that the disposal and treatment of waste cause the generation of several greenhouse gases that can potentially contribute to global climate change (see Dietzenbacher, 2005; Finnveden et al., 2007; Williams, 2013). These authors argue that the most significant greenhouse gas produced from waste is methane. Methane, is a chemical compound, released during decomposition of organic matter in landfills (Mühle et al., 2010). Other forms of waste disposal and treatment also produce greenhouse gas, in the form of carbon dioxide (Dijkgraaf and Vollebergh, 2004). However, these studies are not based on the IO framework, rather based on assessment approaches and integrated waste management options. In this study, I focus on physical waste generation and not pollution components associated with waste generation.

Among the previous studies, several of them consider international dimensions to waste management, that is where waste (such as hazardous waste) is shipped internationally for management in different geographical locations (for example see Alberini and Bartholomew, 1999; Baggs, 2009; Fikru, 2012; Fischer et al., 2008; Kellenberg, 2012). However, in the case of a local pollutant (e.g. waste), the impacts primarily lie at the local level and so they may not require international trade component of any kind. In the context of waste treatment and green accounting, Allan et al. (2007) consider resource cost and economy-wide implication of waste management. Specifically, they identify the sectors that pay or do not pay the actual cost for waste cleaning services implied by the waste generated and consider sectors that ultimately bears the cost of managing waste. The analysis in the following chapter (Chapter 3), builds on this study. Other studies consider that there is a need to develop physical IO systems in order to properly assess waste flows in IO framework (Dietzenbacher, 2005; Hubacek & Giljum, 2003; Weisz & Duchin, 2006; Xu & Zhang, 2009).

Some studies that have explicitly attempted to apply the environmental IO model to attribute responsibility of waste generation to different economic activity are scarce and limited. I review some existing examples here. Jensen et al. (2011) apply a regional IO framework and data derived on waste generation by industry to analyse different aspects of regional waste accountability. In addition, they estimate a series of industry output–waste multipliers, using different methods for waste attribution from production and consumption perspectives. As a case study, their paper focuses on Wales, a region of the UK. Court (2012) argues that although multiple modelling techniques can be employed to relate environmental impacts and pressure to economic activity, it is important to select a method that is transparent, easily interpreted, and consistent with economic-environmental policy objectives. For these reasons, the author applies environmental accounting methods based on an IO framework as a means to examine the relationships between economic activity and hazardous waste generation. The author accounts for hazardous waste generation not only in terms of direct generation and intensity (hazardous waste generated per unit of output), but also in terms of indirect and total generation intensity by industry, as well as generation attributed to final demand for an industry's output. The results in the study are analysed from multiple perspectives and discussed in terms of policy relevance.

Court et al. (2014) also focus on hazardous waste. However, they use an approach similar to Jensen et al. (2011) and they apply the IO framework to attribute hazardous waste streams to regional production and consumption activity, and to connect these same waste streams to different management options. These authors raise the point that a method which uses the IO framework provides useful intelligence for decision-makers seeking to connect elements of the management of the waste hierarchy to production and to different patterns and types of final consumption (including domestic household consumption). Other studies attempt to determine the direct and indirect waste generated along the supply chain, in order to identify what industries create high demand for incineration and landfill waste management options (Lee et al., 2012; Liao et al., 2015). On the other hand, Salemdeeb et al., (2016) examine the direct and indirect waste arising across the UK supply chain using waste IO table developed by (Nakamura, 1999; Nakamura & Kondo, 2002).While, Delahaye et al. (2011) introduce Dutch waste accounts that show the origin, destination, and treatment methods of waste types categorized according to the adopted European waste regulations. Generally, in the existing and vast literature on IO methods, there are only limited attempts to apply attribution analysis for waste accounting at regional level and within the context of considering appropriate IO measures when the focus is on a local pollutant as physical waste. My contribution in this chapter is to fill in such gaps in the IO literature, at least at a regional level through the methodology set out in this chapter.

2.4 Data for the allocation of waste generated to production and final consumption demand

As I explained in the introduction to this chapter, the Scottish Government and ZWS provided the data used in this chapter and the next chapter. However, the data is used differently in both chapters. The dataset forms a crucial part of the analysis and ultimately contributes to the accuracy of the findings and outcome in this chapter. Let us discuss the dataset in more detail. The Scottish Government produces and publishes IO data periodically. The dataset comprises of Scottish Supply tables, Use tables and Symmetric IO analytical tables that has been produced annually from 1998-2014[19]. The 2014 data, is the most recent IO data published. In this chapter and the next (Chapter 3), I employ the industry-by-industry Scottish analytical IO table of 2011.

The 2011 IO table reports transaction data for 97 IO categories (IOC) mapped to the Standard Industrial Classification (SIC) of 2007 (see Appendix 1a for sectoral breakdown). The IO table reports where each industry sold its output, across the 97 Scottish industry categories (intermediate sales) and different types of final consumption (including household and government demands, capital formation and exports, etc.). In addition, it reports where each industry bought its inputs, again across all 97 Scottish IOC (intermediate purchases), as well as imported goods and services, net taxes on products/production, payments to labour, and other value added (generally capital, and land, equating as 'gross operating surplus').

In terms of the waste data, we have established that the production of waste creates both direct and indirect environmental impacts and a range

[19] IO tables available for download at http://www.gov.scot/Topics/Statistics/Browse/Economy/IO/Downloads

of strategies are available to reduce the generation of waste by industry and households, and to select waste treatment approaches that minimize environmental harm. However, evaluating these strategies requires reliable and detailed data on waste generation and its management. SEPA and ZWS collect and report robust data on Scottish Business Waste Arising annually from 2011-2015. The dataset covers tonnes of 33 different types of waste generated by 29 industrial groups in Scotland. It consists mainly of waste from households, commercial industries and construction and demolition for each of the 32 local councils in Scotland as well as the entire region. This aligns the data with the sources of waste that is targeted by policies, landfill restrictions, and other involvements designed to optimise resource utilisation and waste prevention based on the objective of the Scotland Zero Waste Plan (ZWP)[20] under Scotland's Climate Change Act (2009).

In this chapter and the next (Chapter 3), I use Scotland Business Waste Arising data produced by SEPA AND ZWS for the accounting year 2011 reported in tonnages. Tonnes are the common measurement for waste. However, it is important to note that the statement of the system or method does not depend on the unit but consistency with SIC. The system can be used with other physical pollutants, units and other currencies but the main thing is to ensure consistency. To my knowledge, 2011 is the most recent year where comprehensive national waste data is available in

[20] Scotland's Zero Waste Plan (2010) Available at http://www.gov.scot/Topics/Environment/waste-and-pollution/Waste-1/wastestrategy

Scotland. Specifically, I consider the data as comprehensive because it is reported in sectoral breakdown that is consistent with the SIC used in developing the economic accounts.

In preparing the dataset for analysis, the Scottish Government IO team in collaboration with CEP and ZWS, have mapped waste generated in each sector per £1million of sectoral output, i.e. direct waste intensities to each of the 29 groupings using output data from the IO account. These waste intensities were then applied to each of the sub-sectors of IOCs that belong to each grouping (e.g., the third grouping in the Scotland Business Waste Arising data is 'Food & Drink' and this maps to IOCs 9-18). This means that sectors in the same IO group share the same waste coefficient across the economy. Thus, the waste generated is reported for each of the 97 sectors in the IO tables, which gave 33 (K, types of waste) rows by 97 columns (N, Scottish IO industries) matrix of direct waste intensities figures. More generally, we are using the data in this way to show that the IO multiplier analysis can be used for more than just direct and total multiplier analysis as I show in Section 2.6.

2.5 Extending the conventional demand driven IO model to consider economic-environmental issues

2.5.1 Waste generated and the demand-driven environmental IO model

In this section, I describe the way in which environmental 'bads' (e.g. physical waste) is incorporated into the standard demand driven IO model. Essentially, I show how the IO methods are developed in order to examine and assess the relationship between economic sectors and waste generation (i.e. direct waste generation), inter-industry waste generation relationship (indirect waste generation) and Type I output waste multipliers (direct and indirect).

Let us begin with the standard IO identity originally stated in Leontief (1936, 1941). Note that the symbols in the equations in this thesis refer to either vector, matrices, or scalar. A bold lower case character denotes a vector, e.g. $\mathbf{x}$. A bold upper case character, such as **A**., denotes a matrix. All non-bold characters are scalars, such as a_{ij}. With this notations in mind, let us consider an economy divided into N number of sectors. Each sector produces output that goes to satisfy final demand and to meet intermediate demand that serves as input to other sectors. Thus, we can then write the basic demand driven IO equation that describes the way in which a sector's output is distributed to final demand and other sectors as:

$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-\mathbf{1}}\mathbf{y} \qquad (2.1)$$

Where the N × 1 vector of total output is $\mathbf{x}$, $\boldsymbol{y}$ is the N× 1 vector with each element representing final demand (e.g. households, governments, capital and exports). **A** is the N ×N matrix of input-output coefficients (direct requirement) matrix with elements a_{ij} (where j=1,...M and M=N) that describes the amount of intermediate demand for output from sector i used by sector j,per unit of output X_j from sector j .$\mathbf{I}$ is the identity matrix of the same order as the $\mathbf{A}$ matrix. In equation 2.1, the Leontief inverse is $(\mathbf{I}-\mathbf{A})^{-1}$. It is a NxN matrix with elements l_{ij} , describing the amount of output generated in each sector i per unit of final demand for the output of sector j.

Recall that in this chapter, we are interested in waste generation, thus let us consider how we can set-up and extend the basic driven framework in equation 2.1, so that we can calculate or determine total waste generation in production. This is done by introducing the statement in equation in 2.2

$$\mathbf{W^X} = \mathbf{\Omega x} \tag{2.2}$$

Where $\mathbf{W^x}$ is a Kx1 vector, with elements, w_k^x and K=1,…,K representing the total waste generated by all production activities in the economy. $\mathbf{\Omega x}$ is a K×N matrix where element $\omega_{k,i}$ representing the ratio of waste type K per unit of total output in sector i. Thus, with the production-based account, the standard IO attribution (Leontief 1970, Miller and Blair 2009) can be employed, such that the equation (2.1) is extended to:

$$\mathbf{W^y} = \mathbf{\Omega}[\mathbf{I}-\mathbf{A}]^{-1}\mathbf{y} \tag{2.3}$$

In equation 2.3, $\mathbf{W^y}$, is a K x 1 vector, with elements w_k^y,being the total waste generation k directly and indirectly required to satisfy total final demand **y**, in the economy

It is of importance to note that the equations above are conventional or standard Type I equations. By this, I mean that in the Type I set up, all sectors are identified as production sectors in the IO accounts for the region in question. However, it is possible to endogenise activities reported as final consumption sectors in the IO accounts and reconfigure the **y** vector and **A** matrix. For example, it is common to carry out Type II analysis, where household consumption is endogenised by substracting household final consumption expenditure from each vector **y,** and adding an additional column and row of input-output coefficients to the **A**-matrix (Emonts-Holley et al., 2015; McGregor et al., 2008; Miller and Blair, 2009)

However, in IO framework, this involves removing household consumption as a driver of waste or pollution. This would seem to be inconsistent with the popular view that human behaviour lies at heart of environmental problems (Jensen et al., 2011; Turner et al., 2011). More generally, the income from employment associated with final demand for one unit of any sector's output affects the total level of household expenditure and thus pollution in the economy. This is because households are responsible for generating domestic waste both directly by purchasing and burning fuels and indirectly by purchasing locally produced goods and services, which entails waste generation in their production and they may do so to greater degree if income from employment grows. For this reason, in Chapter 3, I do consider Type II multipliers. However, for the attribution analysis here I maintain the traditional Type I focus.

2.6 Empirical results and discussion

2.6.1 Production based accounts

Let us recall that this chapter focusses on addressing a policy-relevant question of what economic sectors may ultimately be considered responsible for waste generation (as an example of a pollutant with local impacts) and the final consumption patterns, which drives that production and in turn waste pressures in Scotland. Thus, in this section, I present the finding from the IO waste accounting analysis. First, I focus on an analysis that examines waste generation in Scotland supported by industry level activities. This is then extended to consider Type I output-waste multipliers that captures direct and indirect waste generation in each sector per £millions of final demands. Finally, I consider the final demand sectors that drive waste generation in the direct waste intensive sector as a result of their demand for that sector's output. In addition, I signpost to Chapter 3 and consider what type of final consumption types may ultimately bear the cost for the provision of waste management services within the economy. Note that I have done the analysis and have the results for the full ninety-seven sectors for the accounting year 2011, but I do not present the full results here; this is mainly to keep consistent spacing and legibility of the tables throughout this chapter, as the results are quite voluminous and may run over two pages. In this Section, I present the results for the top twelve waste intensive sectors (see Appendix 1a for full 97 industry classification), but I refer to Appendix 2a where appropriate to give clearer explanation of the results.

Recall that under the production based accounts the idea is that, environmental impacts are directly caused by production activities, so that waste generated in an economy is directly related to the output of the production sector or a production sector's use of particular factors of production (inputs) from other production sector. Let us now examine Table 2.1 that presents the top twelve largest waste generation industries (that account for over 1% of total waste generation) in Scotland in 2011. In Table 2.1, the first column of results reports the direct total waste intensity per output in the different sectors. The second column reports the total physical amount of waste generated. The third column reports each of these entries (i.e. total waste generation) as a percentage of total industrial waste generation across the ninety-seven Scottish industries. The final column of the result, reports the percentage share of total direct waste generated by the top twelve sectors. The results are ranked from highest to lowest in terms of total waste generation.

The top twelve waste intensive industries are: 'Construction', 'Electricity', 'Retail', 'Wholesale' 'Mining', 'Spirit & Wine', 'Agriculture', 'Food Services', 'Water & Sewerage', 'Education', 'Fabricated Metal', and 'Health' with the largest waste generation. Of the total waste generation of all nine-seven sectors (10,590,928 tonnes), the top twelve waste intensive sectors account for around 8,588,601.89 tonnes (81.09%). Evidently, the 'Construction' industry waste generation 6,051,440 tonnes (70%) is ranked highest across the top twelve waste intensive industries. In fact, the 'Construction' sector remains the largest waste generator and accounts for over 57% of the total waste generation by all ninety-seven Scottish industries.

There are several possible explanations for the 'Construction' sector's result. First, from the base year data, the 'Construction' sector contributed £18,950 million in economic output to Scotland. This is the largest output across intermediate sectors. These figures reflect the importance of the 'Construction' sector to the Scottish economy and a possible reason for the sector's waste intensity. Secondly, the 'Construction' sector reported in the IO accounts covers SIC codes 41-43, which comprise of construction of buildings, civil engineering and specialised construction services (the later including demolition, site preparation, electricals, plumbing and plastering etc.). Therefore, it can be argued that the type of activities of the 'Construction' sector contribute to the level of waste generation in Scotland. In fact, from the underlying dataset, 'Construction and Demolition', 'Soil Waste' and 'Metallic Ferrous' are the largest waste-type generated by the 'Construction' sector and the most difficult waste types to dispose and reuse. Policies and strategies shaping waste management and reduction should consider the 'Construction' sector as the main driver of industry-level waste generation.

Table 2.1 Top 12 (out of 97) Direct waste intensity, total waste generation and percentage share of total waste generation in Scotland in 2011

Sector number	Sector name	Direct intensity (tonnes per million of output	Total direct waste generated (tonnes)	Share of total direct waste generated (10,590,928)	Share of total direct waste generated (top 12 8,588,602)
1	Construction	319	6,051,440	57%	70%
2	Electricity	60	495,251	5%	6%
3	Retail	38	338,224	3%	4%
4	Wholesale	38	312,095	3%	4%
5	Mining	41	281,504	3%	3%
6	Spirits & Wines	63	231,353	2%	3%
7	Agriculture	69	194,969	2%	2%
8	Food & Beverage	44	170,874	2%	2%
9	Water and Sewerage	134	165,646	2%	2%
10	Education	14	119,030	1%	1%
11	Fabricated Metal	44	117,423	1%	1%
12	Health	9	110,793	1%	1%
Totals		**873**	**8,588,602**	**81%**	**100%**

The 'Electricity' sector is the second largest contributor to total industry waste generation. This industry generates 485,250 tonnes of waste, which is just 4% of total industrial waste generation and 6% of the total industrial waste generation by the top twelve waste intensive sectors. There are plausible reasons for the lower contribution of the 'Electricity' sector to total industry waste generation. We know that electricity is one of the major sources of energy in Scotland. However, in accounting year of the underlying dataset employed in this Chapter (i.e. 2011), Scotland underwent a period of decarbonisation of the electricity industry and increased generation of electricity from renewable sources which are less waste intensive than electricity generation through fossil fuels.

In fact, in 2011, the Scottish Government set an ambitious target aiming for an output equivalent to 100% of Scotland's demand for electricity to be met from renewables (Scottish Government, 2011)[21]. Moreover, given that electricity in Scotland can be generated by burning waste i.e. energy from waste (EfW), the 'Electricity' sector may be considered a sector that cleans other sector's waste. A study by Sustainable Development Commission Scotland shows that EfW in Scotland could contribute approximately 2.0 Terawatt hour (TWh) of useful heat and 0.90 TWh of electricity per year. This is equivalent to approximately 3% of Scotland's total heat demand and total electricity demand (Sustainable Development Commission, 2010)[22].The remaining ten sectors in the top twelve waste intensive group in Table 2.1, individually contribute a modest share to waste generation in Scotland. This ranges from about 338,224 to 110,793, tonnes (i.e. 1% to 3%) of total waste generation. Note that these ten are mostly service sectors.

A shown in Table 2.1, many of the industries that generate the largest amount of waste are also the industries with the highest waste intensities. However, some cases are different. Let us consider the 'Water &

[21] Scottish Government (2011), 2020 routemap for renewable energy in Scotland available at http://www.gov.scot/Resource/Doc/917/0120033.pdf
[22] Sustainable Development Commission Scotland (2010) report to the Scottish Government in energy from waste potential in Scotland is available at http://www.gov.scot/resource/doc/311011/0098129.pdf

Sewerage', 'Agriculture', 'Spirit & Wine' and 'Mining' industries. These industries, in descending order are the 9th, 7th, 6th, and 5th largest waste generation sectors respectively in terms of direct physical tonnes of total industry waste generation. These same sectors have waste intensity in ascending order of 134 (2nd) for 'Water & Sewerage', 69 (3rd) for 'Agriculture', 63 (4th) for 'Spirit & Wine' and 41 (7th) for 'Mining' tonnes per £million of industry output. These figures are considerably higher than that of the top three waste intensive sectors after the 'Construction' sector.

As I explained in the data section of this chapter (Section 2.4), a number of sectors in the same IO group share the same waste coefficient or direct waste intensity. In Table 2.1, 'Retail' and 'Wholesale' sectors are examples in this regard. These service sectors have the same direct waste intensity per million of output, but their direct waste generation is quite different. 'Retail' accounts for about 338,224 tonnes (3.2%) of total industrial waste generation and 'Wholesale's is slightly lower at 312,094 tonnes (3. 0%).In effect, the 'Retail' sector contributes about 26,130 tonnes more to total industry-level waste generation than the 'Wholesale' sector.

'Education' and 'Heath' sectors share of total waste generation is only a small fraction of 1.11% and 1.05% respectively. The 'Health' sector has the lowest waste intensity across the top twelve waste intensive sectors followed by the 'Education' sector. Overall, in this section, the implications of the results and findings are that if industry level waste generation is examined based on total waste generation or intensity, it is clear that only a few industries (in particular 'Construction' sector) are accountable for most of the waste generation in Scotland.

2.6.2 Type I industry-by-industry output-waste multipliers

What I show in the previous result section is how IO methods can be used to consider industrial-level waste analysis that provides insight into not only how much waste is produced in the Scotland, but also into producer, or industry responsibility. Let us now turn our focus on to how we can use IO multiplier analysis, to consider direct and indirect responsibilities for waste generation. Table 2.2 below displays the breakdown of the Type I industry-by-industry multipliers for the top twelve waste intensive sectors in terms of direct and indirect responsibility of waste generation. See Appendix 2b, for the direct, indirect and Type I output-waste multiplier for all ninety-seven sectors. The Type I output-waste multipliers capture (a) direct effects that is the tonnes of waste directly generated by industry in its production process. The direct effects are reported in column 3 of the results in Table 2.2. Note that the direct effect figures are the same or directly comparable with the results showed in the previous section in Table 2.1. However, here the focus is to show the differences between the component of the multiplier and added information to derive not only direct, but also indirect waste generation information. The indirect effects column (column 4) on the other hand, is the amount of waste generated by the production processes of all other industries to support direct production (Court, 2012; Miller & Blair, 2009).

An underlying rationale of IO attribution analysis is that in order to produce output to meet final demand, each production sector requires inputs from other sectors of the economy (as well as primary inputs capital and labour and imports) (Miller and Blair, 2009). What we are doing in moving from direct to multiplier attribution analysis is reallocating waste from where it is directly generated in the production of output to the demand source ultimately driving that output. This is why multipliers are stated in terms of tonnes per £1million of final demand for output rather than output itself. Moreover, we can calculate and report attribution results in terms of (a) what is consumed – final demand for what outputs is driving waste generation in the system? – and/or (b) who is consuming – what source(s) of final demand is driving waste generation in the system. This is what we move onto in the next section.

In terms of the direct and indirect effects, let us discuss some examples. The 'Construction' sector has a direct waste intensity of (319.3) tonnes and an indirect effect of (104.3). These results tell us that the 'Construction' sector is directly waste intensive in that it generates higher amount of waste in its direct production process. However, the indirect effects of the sector, tells us that it purchases it goods and services (i.e. intermediate inputs) from sectors that are not large waste generating sectors (e.g. Electricity, Iron and Steel). The 'Real Estate' sector (see Sector 26 in Appendix 2b) embodies opposite results to 'Construction', with very low direct waste intensity (5.2) but relatively high indirect waste intensity (67.8). This industry does not directly generate large amounts of waste in its direct production process but, buys goods and services from more intense waste generating sectors (e.g. 'Construction' and 'Water & Sewerage'). Other sectors that exhibit relatively high indirect effects to direct effects can been seen in Appendix 2a, these include 'Furniture' (52nd), 'Telecommunications' (79th) and 'Insurance & Pension' (89th), 'Inorganic Chemical' (94th), 'Rubber & Plastic' (96th) sectors.

Table 2.2 Top 12 (out of 97) Type I output-waste multipliers tonnes per 1 million

Sector number	Sector name	$\mathbf{w}^{\mathbf{x}}$ Direct	$\boldsymbol{\Omega}[\mathbf{I}-\mathbf{A}]^{-1} - \mathbf{w}^{\mathbf{x}}$ Indirect	$\boldsymbol{\Omega}[\mathbf{I}-\mathbf{A}]^{-1}$ Total (Type I output waste multiplier
1	Construction	319.3	104.3	423.6
2	Water & Sewerage	133.9	23.5	157.4
3	Wood & Wood Products	108.2	45.3	153.5
4	Textiles	106.7	32.8	139.5
5	Leather Goods	106.7	27.2	133.9
6	Wearing Apparel	106.7	27.1	133.8
7	Forestry Harvesting	68.7	61.4	130.2
8	Electricity	60.4	55	115.3
9	Dairy, Oils & Fats	63.2	51.3	114.5
10	Meat Processing	63.2	49.9	113.1
11	Forestry Planting	68.7	35.2	103.9
12	Grain Milling & Starch	63.2	39.4	102.6
	Total	**1268.9**	**552.4**	**1821.3**

In terms of the output-waste multipliers, again, the 'Construction' sector is ranked 1st and the sector with the highest Type I output-waste multiplier. Thus, in order to directly and indirectly produce output, the 'Construction' sector will generate 423.6 tonnes of waste per £million of output. There are a number of differences across other sectors. The ranking of most of the sectors have changed when we compare Table 2.1 and Table 2.2. For instance, the 'Waste & Sewerage' industry, which was ranked 9th in the previous table (Table 2.1), is now second in terms of its Type I output-multipliers, while the 'Electricity' sector drops from 2nd in Table 2.1 to 8th in Table 2.2. Interestingly, all but these three ('Construction', 'Water & Sewerage', and 'Electricity') waste generation sectors in Table 2.1 dropout of the top twelve waste intensive group when we consider them in terms of Type I output-waste multipliers. Whereas sectors that were within the 50th to 70th rank in Appendix 2a have now moved up the charts to the top twelve in Table 2.2. For example, the 'Leather Goods', 'Forestry Planting', and 'Forestry Harvesting' sectors which were ranked 70th, 68th and 51st respectively in Appendix 2a are now ranked 5th, 11th and 7th in Table 2.2.

Overall, this type of analysis above helps us answers how waste is generated within Scotland and how we can begin to attribute responsibility across industries (or producers). Furthermore, the IO framework constitutes the recognition that output is used as intermediate inputs and that this intermediate activity can be attributed to final demands through multiplier analysis (Miller and Blair, 2009). Thus, in the next section, I go on to determine what consumer demand is driving production of output and in turn waste. To answer this question, the partial consumption attribution approach is employed.

2.6.3 Partial consumption accounts

A key feature of the demand driven IO model in Section 2.5, is that it imposes and allows us to consider a particular causal sequence. This is that production (and associated waste/pollution generation) is driven by a combination of intermediate and final demands, but with the later the ultimate and exogenous driver of all activities. Therefore, waste generated in any one sector is attributed as being driven by a combination of final demand for that sector's output and for the final demands of other sectors that are directly or indirectly within its downstream supply chain. For example, for the 'Construction' sector to produce output (e.g. buildings or office suites) to meet its final demand, the waste associated with these output will depend on the quantities/types of inputs (e.g. Paper, metal, wire etc.) used to produce the output of the 'Construction' sector which come from other sectors in the economy that are within the construction's sector upstream supply chain. Thus, when the building (i.e. the Construction sector's output) is completed it will be demanded by other intermediate sectors such as 'Real estate' sector. Where 'Real estate' sells to final demand, the waste generated in the 'Construction' element of its upstream supply chain (and in other sectors producing inputs to support the ‘Construction’ sectors’ output) will be attributable to final demand for Real estate. Therefore, waste directly attributable to industrial production can be considered in terms sources of final demand driving what is consumed, i.e. in terms of final demand for different sector output and who consumes it i.e. the different types of final demand. This is the sequence that I apply the partial consumption accounts approach to consider.

It is important to note that within the literature, there is an ongoing debate over appropriate accounting methodologies in terms of responsibility for environmental pressures, i.e., production versus consumption-based accounting (Lenzen and Dey, 2002; Minx et al., 2009; Munksgaard and Pedersen, 2001; Peters and Hertwich, 2004; Wiedmann et al., 2007). However, there is a less common debate in terms of appropriate accounting approaches in terms of type of pollutant and the jurisdictions of its impacts (e.g. local or global pollutant). Similar, argument has been drawn in Jensen (2010) and Turner et.al (2014). These authors find that when the partial consumption accounts are applied the value is that we can then clearly identify the environmental impact of waste generation either through the direct and indirect polluter. Moreover, it is can be argued that local people are likely to incur most if not all of the cost for consumption decisions elsewhere.

Following from the above discussion Let us now move from the production based analysis (using equation (2.2)) and direct waste generation in each Scottish production sector reported in Table 2.2 above to the partial consumption based account and results (based on equation (2.3)). Essentially, I use the Type I output multipliers to examine the waste that is supported by final demand for each sector's output, rather than the direct waste generation associated with the production of that output as in Table 2.2. Again, I calculate and have the results for all ninety-seven sectors (See Appendix 2c). However, for uniformity in the presentation of the results in this chapter and to kept table within space or margin, I present the result of the top twelve sectors in terms of the share of industrial waste generation attributable to total final demand.

Table 2.3 presents the results from the attribution analysis for five categories of final demand determined using equation (2.3): household consumption, government expenditures, gross fixed capital investment, non-resident households (tourists), and exports. There are some interesting results we should discuss. First, let us consider the ranking in Table 2.3 relative to the direct waste generation in Table 2.1. In Table 2.3, eight out of the twelve sectors that dominated in the direct ranking still dominate when we take into account the share attributable to final demand for industry output. Secondly, we can also note that the share of total waste generation attributable to the top twelve falls from just over 81% to 77%. This is because from previous point, most of the top twelve direct waste generation sector still dominate the charts, because there is a lot of waste generation to service own-sector output demands. However, note that for sectors like 'Construction' and 'Electricity', the share attributable falls because of the importance of downstream linkages. That is, these sectors are producing output (and waste) to service the demands of other sectors. For example, 'Construction' is servicing the intermediate demands of IOC 70, the 'Real Estate' sector, which now appears in Table 2.3 and is ranked 7th, jumping up the waste chart from no.40 (Appendix 2a) in the direct case where it didn't make the top twelve waste intensive group.

Table 2.3 Type I waste attribution to final demand for industry output (tonnes)

Sector number	Sector name	$\Omega[\mathbf{I}-\mathbf{A}]^{-1}y$ Attributable to total final demand	Share attributable to total final demand	Breakdown by type of final consumption in tonnes				
				Household	Government	Gross fixed capital formation	Non-resident household	Export
1	Construction	4752981	44.90%	130,411	21	4,022,764	3,938	595,847
2	Retail	555939	5.20%	504,503	1,403	5,345	18,220	26,469
3	Mining	521075	4.90%	12,191	0	6,157	655	502,072
4	Electricity	374038	3.50%	211,861	0	6,657	618	154,903
5	Wholesale	335264	3.20%	142,243	1	15,274	4,236	173,509
6	Public Administration	318206	3.00%	10,246	300,564	7,030	19	347
7	Real Estate	257771	2.40%	227,868	0	86	1,443	28,374
8	Spirits & Wines	244715	2.30%	22,436	0	947	710	220,623
9	Food &Beverage	214503	2.00%	182,698	0	880	30,232	693
10	Imputed Rent	207656	2.00%	207,656	0	0	0	0
11	Health	201123	1.90%	15,104	185,884	3	111	21
12	Agriculture	154280	1.50%	78,129	0	11,247	1,091	63,814
	Total	**8,137,551**	**77%**	**1,745,346**	**487,873**	**4,076,390**	**61,273**	**1,766,672**

Thirdly, apart from letting us see what type of commodity output demands are really driving waste generation in the system, the Type I attribution results in Table 2.3 also reflect the importance of different types of final consumers. For example, in the case of 'Construction' sector, the final three columns in Table 2.3 show that capital formation is the main driver of the waste ultimately attributable this sector. Household and export demand[23] causes the share of waste attributable to the 'Retail' sector to increase as we move from the direct to final demand attribution, such that this sector moves up the chart from 3rd in Table 2.1 to 2nd place in Table 2.3. Final demand in the form of household consumption demand 56.6% (211,861) and export demand 41.4% (154,903) is important in the case of the 'Electricity' sector. Similarly, Scottish household consumption and export demand together drive 94% (315,752) of waste associated with 'Wholesale' and move it up from 13th in Table 2.1 to 5th in Table 2.3. Government's final demand consumption activities drives waste generation in the 'Public Administration' sector of about 94.5% (300,564). This demand causes the 'Public Administration' sector to move up the chart from 17th in Table 2.1 to 6th place in Table 2.3.

In the case of 'Real Estate' and 'Food & Beverage', domestic demand mainly households drive 88.4% (227,868) and 85.2% (182,698) respectively of output and in turn waste in both sectors. For 'Spirits & Wines', exports demand 71.1% (220,623) is the main source of sectoral commodity outputs driving waste generation in this sector as seen in Table 2.3. 'Imputed Rent' jumps up the chart from 25th to 6th under the Type I attribution, because domestic household consumption drives

[23] Note that in this chapter, where references are made to export demand, these are RUK and ROW export demand combined.

100% (207,650) of sectoral output. Likewise, Scottish households are the main driver for 'Health sector output and in turn waste generation. While, the main demand drivers for 'Agriculture are domestic household consumption and exports.

More generally, looking at the final row in Appendix 2c, it shows that from attributing ndustrial waste generation to final demand categories, overall waste generation in Scotland is largely attributable to gross fixed capital investment at 39% (4,203,177). Another 27% (2,904,182) is attributable to export demand for Scottish output. 25% (2,672,092), is attributable to Scottish household consumption demand. While government expenditure is 7% (680,267) and non-residential household (i.e. tourist) drive only 1% (131,219). On a concluding remark, in this section shows that if policy makers were to employ a partial consumption-based account, one advantage is that they may easily identify the final demand type or types that are accountable for waste generation within a certain industry.

What I have shown in this chapter, can begin to help us think about what is coming in the next chapter (Chapter 3). Another issue to investigate is whether waste generation across the different sectors is commensurate to the payment for waste cleaning and disposal. In addition, what are the likely economy-wide impacts that arise if the polluter pays partly or fully for the resource costs of waste management services implied by their waste generation? For example, if we find that any one of the top twelve waste intensive sectors in Table 2.1 is not paying the actual resource cost of their waste generation, what will be the potential implication. The expected implication is that the output price of that sector will increase and the final demand sectors that demand the sector output will suffer the burden. So suppose the 'Construction' sector is underpaying the resource costs for the waste management implied by its waste generation in the unadjusted accounts (standard IO accounts). This means that with adjusted accounts (that incorporate resource costs actually implied by physical waste generation) the price for 'Construction' sector output is expected to increase and put upward pressure on the upstream and downstream supply chain and the payment will be passed on to the final demand sector for 'Construction' sector output. From the 'Construction' sector row in Table 2.3, it is evident that gross fixed capital formation is the final demand sector that will ultimately bear the full burden, due to its high demand for 'Construction' sector output and in turn contribution to waste generation of the sector.

Alternatively, if we find that any one of the top twelve direct waste generation sectors in Table 2.1 is paying or overpaying for their waste management services, we expect that the output price of such sectors will decrease (lower prices) with the adjusted account. For example, let us look at the 'Public Administration' row in Table 2.3, if this sector overpays for the resource cost of its waste management, its output price decreases in its adjusted accounts and the burden for waste payment are borne by the government. In Section 3.6.3, Chapter 3, I consider in greater detail the type of final consumers that my ultimately be impacted by the resource costs of their demand choices

So, what is the implication of the findings in this chapter? Generally, we learn or gain knowledge on the distribution of waste generation across industries not only in terms of direct waste generation, but in terms of also capturing the distribution of indirect waste intensities. As I explained in the introduction to this chapter, if policy focus is to consider production and in turn, waste generation in order to meet final demand, then a production based and partial consumption based accounts approach should be considered in understanding waste problems in the economy. So that, in addition to imposing regulations and restrictions on producers, policymakers may also direct waste reduction strategies at the final consumption of goods that are directly or indirectly produced by waste intensive sectors.

2.7 Reflections/rumination and some practical issues: do we require further consideration of partial consumption account for waste attribution analysis in future research

From reflective point of view, the main consensus of this chapter has been to provide information that may help or assist regional policy makers to match empirical approaches to environmental protection objectives. I argue that for substantial progress in achieving/meeting various economic-environmental objectives, the framing of policy action should link to environmental outcomes and vice versa through the use of appropriate tools. If an appropriate economic-environmental model can be built around the IO accounting framework it may permit impact analysis of alternative policy options, this will add to the analytical support available to policymakers. Moreover, such a framework would facilitate the construction of a wide range of environmental indicators.

In terms of the lesson learnt and wider applicability of footprint type framework, it is imperative to consider things from the perspective of what do we do footprint type analysis for? So far, footprint analysis has worked best for carbon and ecological footprints (for land use). More generally, environmental IO methods has provided a framework for global footprint type analysis. This may perhaps reflect the fact that mitigating climate change and moving towards a low-carbon economy remains a key focus of international and national policy. However, if/when, a global footprint analysis or target is not the policy objective or concern, but domestic or regional targets on economic-environmental issues such as physical waste and other local pollutant there is a need to consider the application of footprint type IO accounting approaches that are suitable in this regard. Moreover, although localised policy and national targets may have global orientation, there remains national and regional focus or impact to policy. It is in such cases, that I argue that the production based accounts and partial consumption accounts may be useful for regional/local policy makers.

As I have argued throughout this chapter, partial consumption accounts are less commonly applied footprint type framework, however, I propose that policy makers and future researchers should consider the application of partial consumption analysis when local/domestic impacts and implications are the concern or policy objective. The approach permits a greater focus on regional final consumption as the main exogenous driver of domestic waste creation. I argue that the latter system provides a useful tool for the domestic waste attribution problem and an additional perspective for regional policymakers.

2.8 Conclusion

In this chapter, I consider how IO multiplier methods (using IO accounting principles) may be used to develop an understanding of demand drivers of a local pollutant (taking physical waste as an example) and the final consumption demand for industry output that contributes to waste generation. Essentially, this chapters looks at top-line sectoral results in terms of how much a sector directly generates vs. how much is attributable to final demand for its output (and different sources of that final demand). There are a number of conclusions drawn from this chapter. First, by combining waste generation data with IO tables, we are able to consider the tonnes of waste required in each sector i per £1million of final demand for the output of sector j amount of waste generated per £million of output in the different Scottish industries. Such information may allow policy makers and even local authorities and councils to determine appropriate waste minimization or reduction options.

Secondly, I provided insights of industry interconnections between the waste generation in one industry and the indirect demands driving waste generation. This approach permits the identification of industries that while not large waste generation sectors in their own right, purchase goods and services from other industries within the regional economy that are more intense producers of waste. This type of insight may assist policy makers in communicating to firms how specific types of their purchase of goods and services indirectly determine waste generation through supply chain dependence, and alert low direct waste generating sectors to their total waste footprint.

Thirdly, I employ an approach to attribute all industrial waste generation to final demand in order to identify sources of consumption and final demand types that drive production of industry output and in turn waste generation. This approach could assist policy makers in identification of (a) what is consumed – final demand for what outputs is driving waste generation in the system? – and/or (b) who is consuming – what source(s) of final demand is driving waste generation in the system. Thus, policy makers can use this information to determine which categories of final demand should adjust their demand consumption behaviour.

Lastly, type of analysis carried out in this chapter, does not consider the resource cost and implications of actually cleaning or disposing of waste. On this basis, in the next chapter, I apply the environmental model IO to internalise the negative externalities and consider the economy-wide implication when externalities are accounted for in the economic process. Specifically, I consider the economy-wide implications if the polluter is forced to pay the resource cost for waste management based on their implied demand and/or according to alternative responsibility for waste cleaning.

Chapter 3: Examining the implications of incorporating the resource cost of waste management in Scottish IO accounts

3.1 Introduction

In Chapter 2, I use traditional environmental IO attribution method to examine the nature and structure of externalities via pollutants by identifying the production and final consumption activities that may ultimately drive waste generation in Scotland. However, waste generated by production and consumption activities pose an additional economic problem. This is the need to determine social and/or resource costs of supplying common resources, such as a 'clean environment', here in the form of waste cleaning/management/disposal. A key question that arises is who should and who does pay and bear the resource costs for that waste management and the provision of a clean environment. For example, are the industries shown to be directly generating the largest tonnage of waste paying the full resource cost to dispose/manage the waste they generate or, if they are not, what would be the economy-wide implication and the knock on impact to the end users if they were?

Allan et al. (2007) build on Leontief (1970) environmental IO model and attempt to begin addressing a similar set of issues using a Scottish IO table and UK average direct waste intensities of production and final consumption activities applied to Scotland for the accounting year of 1999. However, the authors highlight conceptual and practical issues with developing a full environmental IO model for Scotland that impact the extent and reliability of conclusions that could be drawn. First, there was the uncertainly that the original Leontief (1970) environmental IO model is the appropriate method for considering the resource costs implications of waste cleaning and disposal. Secondly, Allan et al. (2007) acknowledge that poor data (compatible industry-environment data for Scotland, forcing the use of UK average waste intensities) hindered complete testing of the usefulness of Leontief (1970) environmental IO model in providing better understanding of pollution cleaning and/or disposal as a key environment service activity and, thus, to potentially support policy.

In this chapter, using improved region-specific data on waste generated by industries and household in Scotland provided by SEPA and ZWS, I revisit the Allan et al. (2007) study to re-examine and re-evaluate three main issues. First, I investigate what economic activities seem to pay or not (fully) pay the resource costs of waste management services from their physical waste generation. Second, from this basis (and building on the attribution analysis of Chapter 2), I attempt to identify the types of final consumers and final consumption that may ultimately bear the full resource costs of waste management in Scotland. Third, I use output and price multipliers derived from what I refer to as the unadjusted (standard published IO data/account) and adjusted (to incorporate resource costs actually implied by physical waste generation) IO accounts - to consider how capturing and attributing the full resource cost implications of waste management to the 'Polluters' impacts both up and down-stream regional supply chains.

The remainder of chapter is structured as follows. In Section 3.2, I discuss the issues for policy in addressing the costs of environmental impacts as well as the literature around the application of the environmental IO model to 'internalise externalities' through consideration of the cost implications of environmental cleaning and protection. In Section 3.3, I discuss two main problems of introducing pollution cleaning in the IO framework as the reason for limited empirical applications of the Leontief (1970) model. The data employed in this study is described and discussed in Section 3.4. In Section 3.5, I describe the Leontief (1970) methodological development of extending conventional IO tables to environmental IO tables and the methodological framework of Allan et al. (2007). I also discuss how my research would build on both developments and contributions. All empirical results are presented and discussed in Section 3.6. In Section 3.7, I discuss the possible issues for future research and policy if/when considering different waste payment regimes. Finally, Section 3.8 gives some conclusions and policy recommendations based on the results and findings.

3.2 Issues for policy

The traditional economic approach to address environmental issues is to consider them as problems of externalities and to develop alternative mechanism that allows the economy to correct, partly or fully, for the damage caused by externalities. For example, governments may use economic measures of the price mechanism (such as taxes, marketable permits and subsidies) to internalise externalities and ensure environmental protection. In early economic literature, Pigou, (1920) proposes a tax (Pigouvain tax) imposed to capture the total value of damage caused by an extra unit of pollution, which should equal the tax levied per unit of pollution generated. Such taxes are used to signal the true social cost of pollution to the emitter, who then has the financial incentive to reduce pollution to the point where the financial implication of one unit of reduction to the emitter is equal to the social damage incurred (Pigou, 1920).

Another type of price mechanism are marketable permits. It is allocated by the government or regulatory authorities and typical set to an 'output' level that it is equal to the aggregate quantity of environmental impact. This allocation can be made through negotiations based on clear delineation of environment property rights (Coase, 1960). A contemporary example of price mechanism is the landfill tax used across various countries (e.g. UK and EU) for waste management. It is an environmental tax paid on top of normal landfill rates by any industry, local authority, or other organisation that dispose of waste via landfill (Davies and Doble, 2004; Ham et al., 2013; Martin and Scott, 2003; Schreck and Wagner, 2017). A global example of a marketable permit system is the EU Emissions Trading Scheme (ETS). The EU ETS is a 'cap and trade' approach for reducing greenhouse gas emissions by placing a limit on overall emissions by business and creating a market and price for carbon allowances[24]. However, this system has struggled to achieve an output-price equilibrium that reflects the social cost of carbon (Greenstone et al., 2013; Pindyck, 2016).

More generally, the various forms of price mechanisms (taxes and marketable permits) are policy measures that are often primarily designed to redirect behaviour from activities that are detrimental to the economy and environment. In addition, price mechanism may be employed in order that a clean or unpolluted environment is priced and treated as if it were similar to other costs (such labour or capital) (Whitten et al., 2003). This is in-line with environmental principles, such as the 'polluter pays' principle, which requires that the cost of pollution inflicted on the environment, be borne by one who causes it (De Guzman, 2016; Regebro, 2010).

[24] Full report of EU ETS is available at https://ec.europa.eu/clima/sites/clima/files/factsheet_ets_en.pdf

Typically, however, most economies do not operate a "polluter pays" scenario and the polluter externalises the costs of waste generation when it comes to waste management (Delahaye et al. 2011, Zaman 2014, Schreck and Wagner 2017). More generally, waste management and the provision of a clean environment (waste and pollution free) has generally remained directly or indirectly subsidized by local governments. In the UK, overall collection, transport, and some treatment of physical waste is mainly operated by public companies, whereas waste incinerators and landfills are commonly run by private companies (e.g. Biffa). For instance, in Scotland, across the 32 different local councils, a given number of bins and associated tonnage of waste are collected on a weekly or less frequent basis (increasingly involving households to separate landfill waste from food waste and other materials that can be recycled).

Several studies argue that an issue that is contributing to government covering most of the payment for waste is illegal disposals (e.g. fly-tipping and littering), which worsens environmental impact, making even the most ambitious waste policies less effective (Broome et al., 2000; Carlsson Reich, 2005; Pires et al., 2011). For example, a Scottish Government (2013) report[25] shows that £53 million of public money is spent tackling illegal waste disposal annually and that at least £46 million of public money is spent removing litter and fly tipping from the environment each

[25]Scottish Government (2014) Towards a litter free Scotland: A strategic approach to higher quality local environments is available at http://www.zerowastescotland.org.uk/sites/default/files/Scotland%27s%20Litter%20Problem%20-%20Full%20Final%20Report.pdf

year. Moreover, the wider negative impacts of littering impose at least a further £25 million in costs on the society and economy.

However, what if we were to consider alternative responsibility for waste management, where the polluter is actually forced to pay and is solely responsible for the payment of the resource cost for their waste generation? In addition, if government subsidises only a small amount for waste management and the polluter pays the remaining, what are the potential economy-wide implications? These are some of issues, I attempt to consider in this chapter using the 'full' Leontief environmental IO model that allows us to develop an adjusted IO account that incorporate the resource cost of waste management across the different sectors in the economy. This type of information may be important for policy and may change governments' perspective and objective on how both private and public sectors contribute to the reduction of waste and sustaining a waste free or clean environment. In the following section, I discuss some of the problems of introducing pollution/waste cleaning in the IO framework and possible insights that the full Leontief environmental IO model can provide when focus is on considering the resource cost of implied by economic-environmental interactions.

3.3 The problem of introducing pollution cleaning in IO

Leontief (1970) extends the standard IO accounting and modelling framework in two ways. First, to incorporate pollution as an additional commodity ('bads') that accompanies production and consumption activities. Second, to separately identify sectors that clean up or prevent these unwanted outputs. The first of these in particular has led the Leontief environmental IO analysis to be regarded as an important and insightful tool with widespread applications to study various environmental impacts. Such as calculating and analysing; greenhouse emissions, carbon and water footprints, pollution and embedded energy (Barrett et al., 2013; Brizga et al., 2017; Chen et al., 2016; Jones, 2013; Peters et al., 2011; White et al., 2015). However, a number of problems have limited the application of the full Leontief (1970) model, I dwell on and discuss two key issues:

The first is a practical one, with attempts to apply the framework hampered by the fact that spend on cleaning may be difficult to identify and, indeed, may already be included in the IO account. That is, the creation of a new sector in the Leontief approach may not be necessary. In the design of the model, Leontief proceeded as though the cleaning sector were newly created; this is, as though a cleaning sector were introduced into a system that previously generated untreated pollution. However, cleaning activity will already occur in the economy, whether these cleaning industries are separately identified as IO industries or not (Allan et al., 2007). A related problem then arises in that, where expenditure in cleaning is already recorded within the IO accounts, it may not be straightforward to separate out the inputs used in the cleaning from other inputs used in production in different industries (Leontief and

Ford, 1972). For example, in the case of air pollution, a number of different industries may spend on several inputs to allow them to engage in 'end of pipe' or other cleaning processes.

The second issue has more of an analytical basis. Leontief (1970) focused on physical IO relationships and the subsequent literature – with key contributions by Arrous (1994); Flick, (1974); Luptacik and Böhm (1999); Qayum (1991); Steenge (1978) and Allan et al., (2007) – focusing on considering the system in value terms. For example, Flick (1974) points out that there are unnoticed and too often disregarded by-products (as well as valuable, but unpaid-for natural inputs) that is linked directly to the physical relationships that govern the day-to-day operations an economic system. On this basis, Flick (1974) argues that it is imperative to put corresponding monetary values rather than physical quantities on all the physical transaction within the economy. In terms of considering the link between price behaviour and policy implications, Steenge (1978) proposes that to determine the price for cleaning, a set of rules (e.g. polluter pays system and full waste cleaning) need to be implemented that allocate and determine the cost of environmental protection. Other studies show that the problem can be dealt with in a straightforward manner by introducing a sector of clean air instead of a delivering sector of air pollution with negative entries and a receiving sector of anti-pollution (for example see Arrous (1994); Luptacik and Böhm, (1999); Qayum (1991)) .

The practical issue outlined above has been an important one and, to my knowledge, prior to Allan et al. (2007), Schäfer and Stahmer (1989) is the only IO study where a distinct 'sector' that carries out pollution cleaning services is separately identified. However, their analysis focuses entirely on successful completion of this stage, to identify total spending on environmental protection activities within each industry (and where their IO framework then informed Nestor and Pasurka (1995), computable general equilibrium, CGE, model). They do not proceed to an application of the full Leontief (1970) model with consideration of how, and the extent to which, spending on 'cleaning' relates to physical pollution or waste generation.

Allan et al. (2007), begins in a similar position to Schäfer and Stahmer (1989), with the identification of a single type of pollution generation and cleaning, focusing on physical waste generation and disposal and management, but extend to consider issues around whether the direct generator pays for cleaning in-line with their generation. They start by focusing on waste, where this is a distinct, SIC classified activity, already monetised and valued in IO accounts. To be specific, existing data for waste generation means that the practical issue of identifying sectoral expenditure on cleaning services is less problematic. However, Allan et al. (2007) did still face issue, in that, in the Scottish IO accounts used: (a) waste disposal was reported within a wider sector that also incorporated sewage and sanitation; (b) region-specific data on physical waste generation by sector were not available so the UK average waste intensities. These data were only reported at a relatively high level of sectoral aggregation. As a result, Allan et al. (2007) report difficulties in applying the Leontief (1970) and qualifying conclusions drawn.

As I explained in the introduction to this chapter, with improved data on waste generated by industries and households in Scotland provided by SEPA and ZWS, I revisit and build on Allan et al. (2007) study. Specifically, I investigate what economic activities seem to pay or do not pay the resource cost for waste management services implied by their waste generation. From this (and building on the attribution analysis of Chapter 2), I will attempt to identify the types of final consumers and final consumption that may ultimately bear the full resource costs of waste management in Scotland. I use output and price multipliers derived from what I refer to as the unadjusted (standard) and adjusted (to incorporate resource costs implied by waste generation) IO accounts to consider how capturing the full resource implications of waste management impacts both up and down-stream regional supply chains. My contribution to the literature is that, this approach may be very useful to policy if, for example, a 'polluter pays' scenerio is considered relative to one where government retains some commitment to pay for waste management.

3.4 Data and derivation of adjusted IO rows for waste cleaning and disposal

In what follows in adjusting the IO accounts for use in operationalising the Leontief (1970) model, I use the example of physical waste in Scotland. As already explained, I use the same dataset as in Chapter 2, but here in a different way. The dataset from Chapter 2 forms a basis and lens through which to examine the connections between local pollution and the full resource costs of waste management. A series of IO tables have been produced for Scotland since 1998. I use 2011 tables here, which describe the purchasing and sales patterns of 97 separately defined industrial sectors, including a 'Waste Management' sector. Here the 97 sectors are aggregated to map directly onto the 29 industry groups for which direct waste generation data are available (along with households). This is more appropriate given the focus on whether sectors actually pay for the waste they generate (see Chapter 2, Section 2.4). Appendix 3a shows the industrial aggregation used in this chapter and how the 97 sectors in the Scottish IO framework are mapped onto the 29 industries for which waste generation data are available.

Crucially, the dataset I use in this chapter are Scottish-specific data and have sectoral breakdown that is consistent with the SIC used in developing the economic accounts. As found by Allan et al. (2007), the lack of region-specificity in the data does have implications for the results and conclusions drawn. A common problem for environmental IO analysis is that, there is an absence of regional data that report either environmental 'goods' and 'bads' at the sectoral level and relate them to demand patterns implied by the IO accounts. This is a specific case of the more general problem that has hindered widespread application of the full Leontief environmental model to address economic-environmental issues (Allan et al., 2007). For analytical precision in identifying the relationship between economic activity and the environment, data need to be collected and reported in a manner consistent with the economic accounts and ideally for the studied region, without need for proxies (Turner, 2006).

3.5 Extending from economic conventional IO accounts to consider demand for waste management impacts in the adjusted accounts

In this section, I provide details of the process of augmenting the conventional IO framework. Essentially, this section describes how we move from the unadjusted (standard) to adjusted (to incorporate resource costs implied by waste generation) IO accounts for the case of waste management. In Chapter 2, the concern has been how much physical waste economic activity generates. This is the same question as how much demand for waste management is implied. However, this is based on the assumption of a common price for all users of a given output even though this may not be the case. So, let us rebuild the IO system starting with the economic system, where for Scotland a 'Waste management' sector is separately identified in the SIC.

Recall from Chapter 2 (Section 2.5), the basic Leontief IO framework is set up so that for an economy with N sectors, the (N x 1) output vector, $\mathbf{x}$, can be represented with conventional notations as (Miller and Blair, 2009):

$$\mathbf{x} = [\mathbf{I} - \mathbf{A}]^{-1}\mathbf{y} \qquad (3.1a)$$

In equation 3.1a, $\mathbf{A}$ is the (N x N) matrix of technical coefficients, a_{ij}'s, where a_{ij} is the input sector *i* needed to generate one unit of output in sector *j*, and $\mathbf{y}$ is the (N x 1) final demand vector. The $[\mathbf{I} - \mathbf{A}]^{-1}$matrix is the Leontief inverse, where each element, l_{ij}, gives the output in sector i directly or indirectly required to produce one unit of final demand in sector *j*.

Let us think a bit more about equation 3.1a. The general solution of equation 3.1a determines how much output each sector of the economy must produce in order to satisfy a given level of final demand for its own output and the output of all other sectors. However, what if we wanted to know how the demand for waste management would be impacted by a given level of final demand? If the 'Waste Management' sector is separately defined or identified in the SIC, this can be done by first calculating the conventional Type I or II (household endogenous) IO multiplier impact of a given vector of changes in the final demand of other sectors (Miller & Blair, 2009). This done by reading down the columns of the Leontief inverse $[\mathbf{I}-\mathbf{A}]^{-1}$ or multiplier matrix, for any one producing sector j (in this case, 'Waste' sector), each cell tells us how much output is required in each sector i per £1million of final demand for the output of sector j. Thus, the multiplication of the direct waste intensity, $\mathbf{W}^{\mathbf{X}}$ (equation 2.2, Chapter 2) and the Leontief inverse multiplier matrix allow for the identification of Type I and Type II waste multipliers: tonnes of waste required in each sector i per £1million of final demand for the output of sector j. This is a standard approach adopted to account for present waste generation and to identify the impact of changes in final demand for future waste management.

However, a question that arises is whether the demand reflected by the multiplier calculation can be mapped to the resource cost implied by waste generation and in turn waste management of each sector. We know that this is not the case, because externalities via pollutants such as waste cannot be fully dealt with through the market mechanism. For instance, if the production sector (e.g. 'Construction' sector), generated waste that would require X resources of the 'Waste Management' sector to treat or clean, it does not necessarily mean that the treatment and cleaning takes place and that the cost is borne by the sector. Unless, we make some adjustments to the standard IO accounts such that, actual physical waste generation by each sector valued per average cost of the demand for waste management services are captured in the multiplier in equation 3.1.a To do this, we need to estimate an average price for waste.

Let us determine the average price of waste, P_w. The average price is calculated by taking the sum of the expenditure (£millions) on the output of the waste sector across all intermediate and household final demand sectors divided by the total amount of waste generated by these sector (i.e. intermediate and household final demand sectors). It is important to note that, I include only household final demand (h) in the calculation of the average price of waste here. This is because there is limited data of non-household final demand sectors physical waste generation (hence the zero values in 'Waste Payment' row in Table 3.1). If/when better data becomes available the calculation of the average price of waste or other pollutants and/or resource uses should include all intermediate and final demand sectors.

$$p_w = \frac{\sum_{i=1..n,h} x_{w,i}}{\sum_{i=1..n,h} q_{w,i}} = \frac{x_{w,T}}{q_{w,T}} \tag{3.1b}$$

Equation 3.1b is developed by Allan et al.(2007) to consider the treatment of Scottish waste in an IO context. Allan et al. (2007) points out that this step is essential to determine the average cost of disposing of a physical unit of waste to identify the demand for waste disposal services implied by the physical waste generated by a sector. If the resulting value of implied demand differs from the actual demand reflected in published IO entries for the output row of the waste sector, this implies that payment for waste management services is not proportional to the implied waste generation in the economy. To address the aforementioned issue, we need to adjust the coefficients of the $\mathbf{A}$ matrix in the standard IO accounts along the waste sector row. Once, we locate the waste sector row (the w^{th} row) in the $\mathbf{A}$ matrix of the standard IO account, we change or replace those entries to reflect actual resource cost of waste management and disposal. Essentially, the standard IO account waste row is replaced with an implied waste row vector. The implied waste row entries are calculated by multiplication of the average cost of waste and physical amount of waste generated by each intermediate and final demand. Using the aforementioned process, we adjust the IO account and restate equation 3.1a as:

$$\mathbf{x} = [\mathbf{I} - \mathbf{A}^{*}]^{-1}\mathbf{y} \tag{3.1c}$$

In equation 3.1c, the definition of the notation remains the same as in equation 3.1a. However, with $\mathbf{A}^{*}$ as the (N x N) matrix (that incorporate resource costs implied by waste generation along the waste row (the w^{th} row). Once we have adjusted the IO system to capture the actual resource cost for waste management from sectoral waste generation, then we can consider alternative responsibilities for waste management in terms of 'polluter pays' scenarios or impacts of various levels of waste payment regimes. Following Allan et al. (2007) and Leontief (1970), I consider in this chapter illustrative scenario of 100% or 90% waste cleaned. Under the 100% waste cleaned we are assuming that all waste generated is cleaned and the polluter pays. Whereas, under a 90% waste cleaned we are assuming that all waste is not cleaned and the polluter pays partly. Suppose,$\beta = 1$ (100%) and $\alpha = 0.9$ (90%) representing the different levels of waste cleaned and/or managed as specified above then the j^{th} element in the waste row (w^{th}row) in the unadjusted and adjusted IO accounts are reconfigured so that 100% and 90% waste cleaned is calculated as

$$\beta = \left[\frac{X_{w,j}}{X_j} - 1\right] \tag{3.1d}$$

$$\alpha = \left[\frac{X_{w,j}}{X_j} - 0.9\right] \tag{3.1e}$$

Where $\frac{X_{w,j}}{X_j}$, is the IO coefficient of the waste sector, that is the amount of output of the waste sector that is needed to make one unit of output in any sector j. In this chapter, I employ the adjusted IO accounts with 100% and 90% as determined in equation (3.1d) and (3.1e) to test illustrative scenarios and to simulate impacts on outputs and prices under various assumptions of waste management.

In order to consider who ultimately bears the cost and burden for waste cleaning and management, the price IO system is necessary. The system of price equations can be extended to capture the cost implication of pollution elimination (Leontief 1970). This is on the assumption that each industry and pollution elimination activities bears the full cost of eliminating all pollution generated by the industry (Leontief 1970). This may help in addressing the price impacts of producing sectors when each one of them pays fully or partly the cost of reducing or eliminating pollution. In the conventional IO system, prices are calibrated to take unit values and have the following form:

$$\boldsymbol{i} = [\mathbf{I} - \mathbf{A}^{\mathbf{T}}]^{-\mathbf{1}}\ \mathbf{v} \tag{3.2}$$

In equation 3.2, $\boldsymbol{i}$ is an (N x1) vector of ones, $\mathbf{v}$ is an N x 1 column vector representing final cost per unit of output/valued added and $[\mathbf{I} - \mathbf{A}^{\mathbf{T}}]^{-\mathbf{1}}$ is the Leontief price inverse. If each all industries and the 'Waste Management' sector itself were to pay and include in the price of its output the costs of eliminating waste generation then the environmental IO price model based on the adjusted accounts can be described in matrix form as:

$$\boldsymbol{p_i} = [\mathbf{I} - \mathbf{A}^{*\mathbf{T}}]^{-\mathbf{1}}\ \mathbf{v} \tag{3.3}$$

In equation 3.3, $\boldsymbol{p_i}$, determines the price multipliers that give the overall price to final demand for any sector *j's* output per £1 spent on primary input. Adopting the price model also allows us to also estimate the percentage changes in relative prices across sectors that demand higher waste management services as inputs for production. These changes can be calculated as the vector of percentage price changes given as:

$$\Delta p_i = [p_i - i] \times 100 \tag{3.4}$$

3.6 Empirical result and discussions

Recall that in this chapter, I focus on using the environmental IO model in addressing a key policy issue regarding identifying the implications if the direct polluter pays or does not pay the resource cost for their waste management and, in either case, who ultimately bears the cost for the provision of waste management services within the economy. In this section, I present and discuss the results of adjusting the environmental IO to incorporate the resource cost of waste management implied by the waste generation of industry and household. In what follows, I begin by considering what economic activities seem to pay or do not pay the resource cost for waste management services. I then use output and price multipliers derived from unadjusted (standard) and adjusted (to incorporate resource costs implied by waste generation) IO accounts to consider how capturing the full resource implications of waste management impacts both up- and down-stream regional supply chains.

3.6.1 Does the 'Polluter' pay the resource cost for waste cleaning and disposal services?

Let use consider Table 3.1. Table 3.1 is a reduced form of the unadjusted (standard) and adjusted (to incorporate resource costs implied by waste generation) IO accounts. By reduced form, I mean the table only has some of the main information in both accounts. Mainly, the results are in an aggregated form and it does not show the whole IO table. However, if we examine Table 3.1 in detail, we see that it is a systematic approach showing the difference between the unadjusted and adjusted IO accounts and how we move from one account to the other.

In Table 3.1, the 'Non-Waste' sector in row 1 is the value of intermediate sales of non-waste sectors. For example, the intermediate demand sales of the 'Construction' sector to all other non-waste (i.e. 1-14, 16-29, see Appendix 3a for sectoral breakdown) or the intermediate demand by all non-waste sectors for the 'Construction' sector output is valued at £8208 million in the unadjusted account. The demand for 'Construction' sector output is the highest intermediate demand across the non-waste sectors. This is followed, by intermediate demand for 'Wholesale & Retail', 'Finance', 'Health', 'Electricity' sectors respectively.

The figures in row 2, 'Waste' sector show total payment to the 'Waste Management' sector for supplying its services to other sectors including its own sector demand (i.e. payment made by the 'Waste Management' to itself). Examining Row 2, we see that there are number of differences across the individual sectors that become clearer when we look at row 2 and 3 together.

In row 3, 'Waste Generation' (value) is the implied demand row. These figures are the new entries based on the actual physical amount/quantity that each sector demands from the 'Waste Management' sector valued at the average cost of waste generation (using equation 3.1b). Examining row 2 & 3 in detail, we see that the total demand column of 'Waste' sector (row 2) and 'Waste Generation' (value) (row 3) are similar. However, there are a number of noticeable differences across the industry and household sectors. On the other hand, note that for non-household final demands, the figures are the same between row 2 and row 3, a result that I will explain in the discussion of row 4.

In terms of the production sectors, the noticeable differences are more evident in 'Construction', 'Waste Management', 'Public Administration', 'Health', 'Electricity' and 'Food & Drink' respectively. Let us consider the value of the 'Construction' sector in both rows in more detail. Interestingly, in row 2, the 'Construction' sector's payment to the 'Waste Management' sector is valued at £12.3 million in the unadjusted accounts, but the adjusted accounts reveal a higher payment of £194 million. While, 'Waste Management' own sector payment is valued at £166 million in the unadjusted accounts, the adjusted account shows that the payment is £0.3 million. Row 4 shows clearer differences between row 3 and 2.

In row 4, 'Waste Payment Adjustment' reports the additional payment entry, which is the difference between row 2 and 3 (i.e. the unadjusted and adjusted accounts). Note that the row total of the 'Waste Payment Adjustment' is zero, which shows that overpayments balance out the underpayments. Within the individual sectors in row 4, the negative entries mean that for example, the 'Construction' sector (-182.4) is not directly paying the full amount for the environmental resources that it is using. If the entries are positive like in the 'Waste Management' sector (165.9), then the sector is purchasing more waste management resources than are need to treat and clean the waste it generates. This sector is government-owned. Thus, some implicit subsidy for waste management by the government seems to be what is coming through in the results. More generally, however, in the 'Waste Payment Adjustment', there are 12 sectors that are underpaying for waste management service and 17 that are overpaying. If underpayment represents an implicit subsidy, overpayment would seem to imply an implicit tax.

In the final demand part of Table 3.1, the 'Waste Payment Adjustment', is zero for all non-household final demand sectors. This result occurs because physical waste data for these final demand types are not reported. This led to the inclusion of zero values being applied in these cases such that the unadjusted and adjusted accounts coincide. As a result, a 'polluter pays' scenario is imposed overall. However, I acknowledge that in reality we do not expect waste to be fully dealt with through market mechanism. Essentially, I impose this assumption in order to show how the full Leontief environmental approach may be operationalised and to illustrate the type of insight that may be gained. Overall, we find that the production side of the economy is subsidised in terms of direct payment for waste management services by mostly 'Waste Management', 'Public Administration', and 'Health' sectors in particular. Again, these may reflect heavy government subsidies of waste management.

Table 3.1 The condensed conventional and full Leontief environmental Scottish IO table 2011

	Agriculture Forestry & Fishing	Mining & Quarry	Food & Drink	Textile	Manufacturing of Wood	Paper &Printing	Coke, petroleum	Chemical Manufacture	Non Metallic Mineral	Metals	Machinery & Equipment	Misc. Manufacture	Electricity	Water Industry
1. Non-waste sectors	1452.3	2548.5	2927.6	390.2	396.7	483.1	813.4	856.0	295.0	936.8	2671.5	620.4	4455.2	193.4
2. Waste sector	1.4	1.8	6.2	4.2	0.7	2.1	1.4	1.4	1.0	5.7	2.7	1.0	1.2	15.8
3. Waste generation (value)	8.4	10.1	17.7	4.0	3.2	1.3	1.5	0.0	0.9	4.3	3.0	1.0	18.8	5.3
4. Waste payment adjustment	-6.9	-8.4	-11.5	0.2	-2.5	0.8	-0.1	1.4	0.1	1.3	-0.3	-0.1	-17.7	10.5
5. Other primary inputs	2344.7	5144.1	5746.8	782.3	522.3	793.2	6368.0	2458.8	442.6	2129.2	5250.4	1592.1	5243.4	1027.6
6. Total inputs	3798.5	7694.4	8680.5	1176.7	919.7	1278.4	7182.9	3316.2	738.6	3071.6	7924.6	2213.4	9699.8	1236.8
7. Physical waste (tonnes)	261050.6	314786.3	548921.8	125542.9	99482.7	41574.1	47586.8	38.0	27070.0	134147.3	91839.5	32260.4	585436.1	165646.4

Table 3.1 Continued

	Waste, Management	Construction	Wholesale & Retail	Transport	Hotels & Restaurants	Communication	Finance	Real Estate	Professional & Scientific	Administration Support	Public Administration	Education	Health & Social Work	Art & Recreation	Other Services Activities
1. Non-Waste sectors	303.1	8208.4	5552.9	3617.5	1521.0	1474.1	5285.6	2377.6	3154.7	1483.7	3482.0	1114.4	4886.5	623.1	409.4
2. Waste sector	166.2	12.3	15.1	7.0	7.0	4.0	5.7	1.8	7.8	7.4	92.4	5.0	41.7	1.9	3.0
3. Waste Generation (value)	0.3	194.7	24.2	3.6	8.5	1.3	0.8	2.5	2.5	5.8	2.8	3.8	5.4	3.6	1.4
4. Waste Payment Adjustment	165.9	-182.4	-9.1	3.4	-1.5	2.7	4.8	-0.7	5.3	1.7	89.6	1.2	36.3	-1.7	1.6
5. Other primary inputs	1113.8	10729.5	14291.3	7199.3	4527.1	4534.1	10926.8	12247.8	8379.2	5437.9	10456.8	7289.3	13296.7	2479.1	1431.3
6. Total inputs	1583.1	18950.1	19859.3	10823.9	6055.1	6012.3	16218.1	14627.2	11541.8	6929.1	14031.2	8408.6	18224.9	3104.1	1843.8
7. Physical waste (tonnes)	8586.4	6051440.0	753162.0	111929.0	264820.0	40413.0	26146.0	76677.0	77653.0	179549.0	87776.0	119030.0	168494.0	111992.0	43110.0

Table 3.1 Continued

	Total Intermediate Demand	Household	Government	Gross fixed Capital Formation	Stocks	Non-resident households	Rest of UK exports	Rest of world exports	Total Final Demand	Total Demand Products
1. Non-Waste sectors	62534.1	51306.8	30587.6	14331.2	282.6	2182.3	34282.7	20054.6	153028.0	215562.1
2. Waste sector	424.8	23.1	543.8	4.4	0.0	0.4	288.6	297.9	1158.2	1583.1
3. Waste Generation (value)	340.9	83.9	543.8	4.4	0.0	0.4	288.6	297.9	1219.0	1583.1
4. Waste Payment Adjustment	83.9	-60.7	0.0	0.0	0.0	0.0	0.0	0.0	-60.7	0.0
5. Other primary inputs	154185.8	25828.1	0.0	6977.8	351.8	1367.9	6952.6	3174.0	44652.3	198838.1
6. Total inputs	217144.7	77158.1	31131.4	21313.4	634.5	3550.6	41524.0	23526.5	198838.1	415983.2
7. Physical waste (tonnes)	10596160.1	2606759.0	0.0	0.0	0.0	0.0	0.0	0.0	2606759.0	13202919.1

3.6.2 Output multiplier impacts with the unadjusted and adjusted IO accounts

The approach discussed above in reference to the results in Table 3.1 allows us to move beyond considering issues of direct waste generation and payments. The next stage is to consider the nature and magnitude of impacts on the component of each sector's output multiplier located in the waste management sector, i.e. to examine how much the demand for waste management services increase and/or decrease as the demand for sectors output changes when we move from the unadjusted to the adjusted case. What is of interest here is to show the magnitude of effects on the waste management sector that are hidden or unidentifiable in the conventional account. That is, I use the adjusted system, to identify those sectors that put most pressure of the waste management sectors in order to meet increased demand for their output. I consider the Type I and II cases to see how the effect changes when household is endogenised.

Recall that output multipliers account for output generated by all sectors in the economy per £million of final demand for sector *j*'s output. We saw in Table 3.1 that, in the unadjusted accounts, the output multiplier is understated in terms of the impacts on the 'Waste Management' sector output/services in sectors that underpay for their waste management. Table 3.2 gives the output multiplier in terms of the demand of waste management services per £million of final demand for sectoral output for Type I and II. Essentially, as an illustrative case on the applicability of the full Leontief environmental IO model, we are comparing the unadjusted output multiplier against the adjusted output multipliers with 100% and 90% alternative polluter pay scenarios. In the 100% case, we are considering the full impact of the output waste multiplier for the demand of all waste cleaned. While, 90% waste cleaned, we consider the resulting partial impact of the multiplier if government were to change waste management commitment such that not all waste is cleaned. This may come to be if for instance government impose a cap on waste management such that proportions of all waste stream might potentially be used to recover useful energy or in a circular economy context where waste is considered as a resource input rather than a material/pollutant to be cleaned or treated.

Let us begin with Type I effects in column 1, 2, and 3 in Table 3.2. Here, we see that the output multiplier impacts in waste management per monetary unit of final demand change markedly in moving from the unadjusted to the adjusted system for a number of sectors. In 15 sectors, the output multiplier effect in the 'Waste Management' sector is greater with the adjusted system relative to the unadjusted IO accounts. In particular, 'Construction', 'Manufacturing of Wood', 'Electricity', and 'Agriculture' sectors. Note that these are the sectors that directly pay less (see Table 3.1) for waste disposal and cleaning than their implied demand, hence their multipliers increase when the full implied demand is taken into account (and vice versa). For example, consider the 'Construction' sector, in the unadjusted accounts it generated very low direct and indirect demand for waste management services such that a £million increase in final demand in this sector produced only £1,337million increase in demand for waste management services. With the adjusted accounts, the impacts increased to £13,642 and £12,946 with 100% and 90% waste cleaned respectively. This reflects that the amount of direct waste generated in the sector as shown in Table 3.2 is not captured in IO entries in the unadjusted accounts. This is important, given that around 57% of all waste management in Scotland in the base year (2011) is directly generated in 'Construction' sector activities. However, this compares to less than 2% of payment of waste disposal coming from the 'Construction' sector as with the adjusted table in Table 3.1.

On the other hand, there are 14 sector, where the output multiplier impacts in 'Waste Management' are larger in the unadjusted account relative to the adjusted one. The largest differences are in 'Waste Management', 'Water Industry', 'Textile' 'Public Administration' and 'Health', where the Type I output multiplier effects are reduced in moving to the 'adjusted' system. The unadjusted account shows that these sectors are the production sectors paying most for waste management services, but with lower levels of physical waste generation. Thus, when the actual resource cost implied by waste generation are captured in the adjusted account their multiplier impact on 'Waste Management' decreases. For example, 'Public administration' sector has implied direct and indirect demand from waste disposal service is £4,753 less than the amount produced using the conventional calculation.

Table 3.2 Output multiplier effects in the waste management sector of a £million final demand for sector output

		Type I effects (household exogenous)			Type II effects (household endogenous)		
			Adjusted			Adjusted	
Sector number	Sector/Activity	Unadjusted	100 % waste cleaned	90% Waste Cleaned	Unadjusted	100 % waste cleaned	90% Waste Cleaned
1	Agriculture Forestry & Fishing	897	3099	2940	1431	4034	3828
2	Mining& Quarrying	652	2600	2467	1230	3611	3427
3	Food & Drink	1226	2842	2697	1961	4126	3915
4	Textiles	4968	4410	4185	5864	5975	5670
5	Manufacturing of Wood	1331	4853	4606	2170	6323	6000
6	Paper & Printing	2456	1930	1832	3285	3377	3205
7	Coke & Petroleum	366	395	374	509	645	612
8	Chemical Manufacture	808	373	354	1674	1886	1789
9	Non Metallic Minerals	1875	2073	1967	2806	3698	3509
10	Metals	2594	2010	1908	3516	3618	3433
11	Machinery & Equipment	830	926	879	1709	2461	2335
12	Misc. Manufacture	872	981	931	1843	2677	2541
13	Electricity	449	3482	3305	808	4114	3904
14	Water Industry	15427	5056	4798	16022	6080	5769
15	Waste Management	1117865	1000684	1000649	1118730	1002036	1001932
16	Construction	1337	13642	12946	2313	15363	14578
17	Wholesale & Retail	1193	1873	1778	2156	3555	3374
18	Transport	1191	764	725	2162	2458	2333
19	Hotel & Restaurant	1619	2004	1902	2517	3573	3390
20	Communication	1063	685	650	2103	2500	2373
21	Finance	781	496	471	1548	1834	1741
22	Real Estate	465	1258	1194	701	1672	1587
23	Professional & Scientific	1514	532	505	2666	2543	2413
24	Administrative Support	1510	1136	1078	2548	2948	2797
25	Public Administration	7701	789	749	8773	2653	2518
26	Education	833	652	619	2489	3544	3363
27	Health & Social Work	3156	600	569	4426	2814	2670
28	Art & Recreation	1003	1539	1461	1867	3049	2893
29	Other Services Activities	2200	1114	1057	3204	2866	2720

Turning our attention to the Type II results, I now compare the Type II output multipliers derived using the adjusted IO accounts relative to the unadjusted calculation by comparing the results in columns 4, 5 and 6 with the results in columns 1, 2 and 3. We find that in the Type II case, there are 23 sectors where the output multipliers are greater in the adjusted accounts relative to the unadjusted accounts. The bigger differences are in 'Construction', 'Textile', 'Manufacturing of Wood', 'Food & Drink' and 'Agriculture'. For the remaining 6 sectors, their output multiplier is larger in the unadjusted accounts relative to the adjusted model. In particular, the bigger differences are in 'Waste Management', 'Water Industry', 'Public Administration', and 'Health' with the unadjusted accounts compared to the adjusted IO accounts with 100% or 90% waste cleaned. This result may be because in Table 3.1, the household payments for waste disposal services in the unadjusted IO table are very low relative to the implied demand used in the adjusted system. This results show that Scottish household contribution to waste generation is understated by the unadjusted accounts. In other words, any induced increase in waste management services resulting from additional consumption expenditure funded by increased income from employment is not captured in the unadjusted accounts. In the following result section, I go on to consider where the price pressures for capturing the resource cost of waste management lie in the economic system and who ultimately bears the resource cost for waste management.

3.6.3 Implications for the resource costs for provision of a clean environment (waste free) on output prices

In this section, I address a number of issue. First, what would be the impact on output prices if the polluter were forced to pay fully or partly the actual resource cost for waste management services implied by their waste generation? In particular, I consider the similarities or differences of the price multiplier results based on the unadjusted and adjusted accounts. Secondly, I relate back to Section 2.6.3, Chapter 2 and those results to determine what final demand sectors ultimately bear the resource cost for waste management shown in Table 3.3

Recall, that the price multiplier determines the overall price to final demand for sector *j* output per £1 spent on primary input i.e. the direct and/or knock on impacts on the price of output. However, in this chapter, I focus on the percentage changes in the vector of output prices when we replace the unadjusted price inverse with the price inverses derived from the adjusted IO account as calculated in equation 3.3.

Let us consider Table 3.3, which reports the percentage change in the impact on output prices based on Type I and II analysis of 100% and 90% waste managed or cleaned relative to the unadjusted account. The first column of the results, 'Adjusted' (100% waste cleaned), assumes all waste is managed or cleaned and that the polluter pays. The second column 'Adjusted' (90% waste cleaned), assumes that the polluter partly pays, such that all waste is not cleaned or disposed. As a result, the percentage change in output prices is expected to fall relative to the 100% case. Let us begin our examination of the results in Table 3.3, from the 100% waste cleaned column in the Type I case. First, there are 15 sectors where the percentage change in output price are lower than in the unadjusted accounts, if the polluter is forced to pay the full resource cost for waste management implied by their waste generation. The bigger negative differences are seen in the 'Waste Management' 'Water Industry', 'Public Administration' and 'Health' sectors. Three of the aforementioned sectors ('Waste Management', 'Public Administration' and 'Health') are government owned and the channels government for their expenditure of waste management. The impact of the percentage change on output prices of these sectors are 10.4%, 0.9%, 0.6%, and 0.2% lower than with the unadjusted accounts estimations.

In the remaining 14 sectors, the impacts of a percentage change in output prices are higher in the adjusted accounts relative to unadjusted accounts. We observe the bigger differences in 'Construction', 'Manufacture of Wood', 'Electricity' 'Agriculture', 'Mining' and Food & Drink'. These sector percentages changes in output prices are 1.10%, 0.31%, 0.27%, 0.20%, 0.17%, and 0.14% higher than in the unadjusted model. More generally, the price results of the 14 sectors, indicate that the output price in the unadjusted accounts do not fully incorporate the resource costs of the provision of a waste free/clean environment. Instead, in the unadjusted IO accounts the resource cost for waste management and the provision of a clean environment are incorporated in the output prices of the other 15 sectors. The implication is that; the cost will be borne by the final consumers of the outputs of these sectors. From Appendix 2c, the main final demand sectors for 'Waste Management' sector output and in turn waste generation are export and government demand. For the 'Water Industry', household and gross fixed capital formation demands are the highest for this sector 's output. The demand for 'Public Administration' and the 'Health' sectors output are dominated by government and household. In all, for sectors where government is the main consumer, the resource cost for the provision of a waste free/clean environment are transferred to the local taxpayers. However, in other sectors domestic household or foreign consumption bears the additional cleaning cost. The pattern of results in terms of positive and negative percentage output price changes are the same under the 90% waste cleaned. The only difference with the 100% cleaned, is that in the 90% case, the size of the negative price in the 15 sectors grows and the positive percentage price effects in the other 14 sectors become smaller. Consequently, the resource cost burden for the provision of a waste free or clean environment still fall on the taxpayer and consumers, but a higher cost is borne by the environment.

Table 3.3 Percentage change in output prices with the adjusted account relative to unadjusted account

Sector number	Sector/Activity	Type I effects (household exogenous) Adjusted 100% waste cleaned	Type I effects (household exogenous) Adjusted 90% waste cleaned	Type II effects (household endogenous) Adjusted 100% waste cleaned	Type II effects (household endogenous) Adjusted 90% waste cleaned
1	Agriculture Forestry & Fishing	0.197%	0.183%	0.225%	0.211%
2	Mining & Quarrying	0.174%	0.162%	0.205%	0.193%
3	Food & Drink	0.145%	0.132%	0.184%	0.171%
4	Textiles	-0.050%	-0.070%	-0.002%	-0.022%
5	Manufacturing of Wood	0.315%	0.293%	0.360%	0.338%
6	Paper & Printing	-0.047%	-0.056%	-0.003%	-0.012%
7	Coke & Petroleum	0.003%	0.001%	0.010%	0.008%
8	Chemical Manufacture	-0.039%	-0.041%	0.007%	0.006%
9	Non Metallic Minerals	0.018%	0.008%	0.067%	0.058%
10	Metals	-0.052%	-0.061%	-0.003%	-0.012%
11	Machinery & Equipment	0.009%	0.004%	0.055%	0.051%
12	Misc. Manufacture	0.010%	0.005%	0.061%	0.057%
13	Electricity	0.271%	0.255%	0.291%	0.275%
14	Water Industry	-0.928%	-0.951%	-0.897%	-0.920%
15	Waste Management	-10.483%	-10.486%	-10.441%	-10.444%
16	Construction	1.101%	1.039%	1.153%	1.091%
17	Wholesale & Retail	0.061%	0.052%	0.112%	0.104%
18	Transport	-0.038%	-0.042%	0.013%	0.010%
19	Hotel & Restaurant	0.034%	0.025%	0.082%	0.073%
20	Communication	-0.034%	-0.037%	0.022%	0.019%
21	Finance	-0.026%	-0.028%	0.015%	0.013%
22	Real Estate	0.071%	0.065%	0.084%	0.078%
23	Professional & Scientific	-0.088%	-0.090%	-0.027%	-0.029%
24	Administrative Support	-0.033%	-0.039%	0.022%	0.017%
25	Public Administration	-0.618%	-0.622%	-0.561%	-0.565%
26	Education	-0.016%	-0.019%	0.072%	0.069%
27	Health & Social Work	-0.229%	-0.231%	-0.161%	-0.164%
28	Art & Recreation	0.048%	0.041%	0.094%	0.087%
29	Other Services Activities	-0.097%	-0.102%	-0.044%	-0.049%

In the Type II case, I recalculate the price multiplier matrix with the adjusted account. There are a number of differences in the Type II impact of the percentage changes in the output price results relative to Type I. In the Type II case, induced (income and consumption) effects have spread throughout the system. Moreover, recall from Table 3.1, that household implied demand for waste management service is actually lower than their implied waste generation. Therefore, in the adjusted accounts the negative and positive Type II percentage change in output prices are higher than in Type I case. There are 9 sectors were the percentage changes in output prices are lower than with the adjusted accounts. Again, the biggest negative differences are in 'Waste Management', 'Water Industry' 'Public Administration'. For the other 20 sectors, the percentage change in output are higher than in the unadjusted account. The biggest positive differences are again in Construction', 'Manufacture of wood', 'Electricity' 'Agriculture', 'Mining' and Food & Drink'. Overall, the results and discussion in this section provide us with information and knowledge that may help us to identify sources of cost pressures and sector that put upward pressure on the supply chain that is eventually passed forward to the different final consumers that demand that sector output.

3.7 Reflections/rumination and some practical issues: do we require further consideration of payments for waste management in future research?

After carrying out the analysis in this chapter and discussing the findings and results-there are a number of areas to reflect on. First, have we gained any additional value from redoing things and picking up from the challenges of previous studies? In particular, by revisiting the Allan et.al (2007) study. The results and findings in this chapter promote that there is value in redoing analysis. Most especially, there is sensitivity in terms of data. Making solid analytical arguments is sensitive to the quality of data employed. Moreover, if /when data improves it provides the opportunity to check or test if the findings and results research still holds or change. The main points are data is always a priority to the accuracy of findings and results. If uncertainties arise with the results, there is a need to redo analysis.

Second, in terms of the lessons learnt in this chapter, a key finding is that waste generation is not commensurate to payment for waste cleaning and disposal. Crucially, government owned sectors (Public Administration and Waste Management) are bearing most of the payment for waste management. This then prompts the question, how can we take the information and insights from this chapter to begin a critical consideration of the implication of waste payment regimes. In the first instance, how do we currently pay for waste cleaning and management? In Scotland payments for waste disposal and cleaning is on a case by case basis. For households, waste payments are included implicitly in council tax[26]. This suggest that, waste management and cleaning is absorbed in council tax and payment for waste management and cleaning is not based on amount of waste generated per tonne or per household but by general residential property (i.e. council tax band) and certain number of collection of waste by the council.

[26] Full council tax collection statistics in Scotland for various years is available at https://beta.gov.scot/search/?q=council%20tax%20collection%20statistics

On the other hand, companies and business pay a non-domestic rate (NDR) or business rate collected by local authorities as a way to contribute towards the cost of local services (such as education, social care, waste management, local roads management and cultural services)[27]. However, local authorises do not usually collect and disposal every company and business waste. Most times companies and business usually pay per rate to private companies to pick their waste and dispose of it. This suggest that the payment for waste are in the SIC sector (i.e. within the companies or sectors supply chain). Some companies' also pay a landfill tax charged on the disposal of waste to landfill.

The crucial issue then is, given different systems of waste collection, disposal and payment are not easily identifiable in national account system and may be difficult to say where they go. Moreover, how do we build on IO system to consider implied subsidy vs. generation? It will be beneficial to breakout the waste sector into private and public sectors: user of the one sector paying same price-but no data. In principle this can be done in IO but in practice may be better to this is a more advance economy-wide framework. A future research method recommended is a CGE analysis, as an extension of the work in this chapter to consider what if scenarios that is on the range of different payment regimes and policy actions to help us isolate and understand the role of each player in explaining the

[27] Further discussion on business rates can be seen in the Report of the Barclay Review of Non-Domestic Rates (2017). Available at http://www.gov.scot/Topics/Government/localgovernment/17999/11199/BarclayReview16-17

economy-wide implication of different waste regimes. Another, core recommendation of this chapter, is that statistic authorities may see the need for the breakdown of expenditures for waste in IO databases to permit clearer identification of the implication of different payment regimes and identifying with sectors are underpaying or overpaying for waste to support policy action on public, private and household sectors.

3.8 Conclusion

In this chapter, I revisit and further develop a previous Scottish study conducted by Allan et al. (2007) which made a key methodological contribution by operationalizing the Leontief (1970) environmental IO model to consider the need to determine social and/or resource costs of supplying common pool resource such as a 'clean environment', at a local or regional level. Thus, from applying environmental IO model to 2011 accounting year, important findings arise. First, I find that with the unadjusted system the resource cost of waste management implied by each sectors' waste generation is hidden or identifiable in the unadjusted accounts. Once I adjust the accounts, I find that the production side and household final demand of the economy is subsidised in terms of direct payment for waste management services by mostly 'Waste Management', 'Public Administration' and 'Health' sectors in particular. These may reflect heavy government subsidies of waste management, given that the above-mentioned sectors are mostly government-owned and these sectors are purchasing more resources for waste management than they generate.

Secondly, I find that with the unadjusted accounts, the output multipliers are understated in terms of the impacts on the 'Waste Management' sector. Specifically, the demand reflected by the unadjusted multiplier calculation cannot be mapped to the resource cost implied by waste generation of each sector. Such that the sectors that directly pay less for waste disposal and cleaning than their implied demand, have their multipliers increase when the full implied demand is taken into account. Whereas, sectors that directly pay or overpay have their multiplier decrease with the adjusted accounts

Thirdly, with the unadjusted accounts the average cost of waste management/disposal vary across different types of waste and also maybe across different types of public and private waste disposal organisations. However, once I impose or force each polluter to pay the actual cost for waste management implied by their waste generation, there are then positive and negative effects on the output prices with the unadjusted and adjusted IO accounts. Overall, this chapter provide information that may be very useful to policy if, for example, a 'polluter pays' scenerio is considered relative to one where government retains some commitment to pay for waste management.

Fourth, there are a number of contributions in this chapter that adds to our knowledge from applying an adjusted Leontief environmental IO model to consider/incorporate the resource cost of waste manage into the economic system in relation to the previous and/or incomplete study by Allan et al. (2007). In terms of the who pays the resource cost for waste management services implied by their waste generation, I find in this chapter that 12 sectors are underpaying and 16 sectors are overpaying for waste management services. Whilst, Allan et al. (2007) found 11 sectors underpaying and 9 sectors to be overpaying. The difference in findings may be attributable to differences in level of aggregation applied[28]. It is also very likely that these differences reflect problems of inadequate data, Allan et al. (2007) faced. Such that the improve data of industrial and household waste generated I use in this chapter, help to better identify sectors within the Scottish economy that pay below the resource cost for waste management.

Another point for consideration is based on the implied direct and indirect demand for waste disposal services per £1 million of final demand expenditure across sectors. Allan et al. (2007) identified only 8 sectors, whereas I identified 15 sectors where the multiplier is greater with unadjusted IO accounts. Moreover, they have 12 sectors relative to 14 sectors here, where the impacts on the demand for waste management or disposal is greater with the adjusted accounts relative to the conventional

[28] Allan et al. (2007) use Scottish IO table (20x20) IO table with 7 final demand sectors for the accounting year 1999 compared to (29x29) IO table with 7 final demand sectors for the base year 2011 in the current study

system. Thirdly, Allan et al. (2007) do not go as far I do to consider the type of final cosnumer that bear the burden and ultimately pays the full resource cost for waste disposal and cleaning. Therefore, I provide additional information on the usefulness of the Leontief environmental IO model and arrive at new conclusions. I find that, final demand consumers in 'Waste management', 'Public Administration' and 'Health' sectors which is mainly the Government, bears the full resource cost and ultimately pays the resource costs for waste management in Scotland.

Finally, Allan et al.(2007) provide key contributions that reflect further usefulness of the Leontief (1970) model as an appropriate method for endogenising other common pool resources such as road capacity and irrigation systems. This is in so far as services provided in the form of common pool resource are often considered are free goods and are often limited by property rights and its usage is not entirely allocated through the market mechanism. Therefore, the 'User' does not pay the actual cost of provision or use of common pool resources. In Chapter 4, I test this proposition by augmenting the Leontief (1970) environmental IO framework in a similar way as I have in this chapter. However, in Chapter 4, I shift the focus from the original case of considering local pollution output (environmental 'bad') as examined in this chapter to considering resource inputs, such as the supply and provision of water (environmental 'good'). The motivation for doing so is that there may be significant gains in applying the model to consider resource issues particularly for resolving market failure on the deviation between actual water use and payment for water services.

Chapter 4: Augmenting the environmental IO model to consider the economy-wide implications of water supply and use

4.1 Introduction

In Chapter 3, I apply the full environmental IO model to consider what economic activity pays or does not pay for the true resource cost of cleaning or disposing of waste ('environmental bad'). Furthermore, I consider what the Scottish industries and/or final consumers ultimately bear the resource cost for cleaning. However, the issue of considering the resource cost of using the environment to meet economic needs is not limited to looking at the 'environmental bads' (e.g., waste, air pollution and carbon emissions) as I have shown in Chapter 3. It is also as relevant in the case of the provision of environmental 'goods' i.e., natural resources (e.g., water, minerals) (Allan et al., 2007).

In this chapter, I extend the environmental IO model to contemplate sectors that use a natural resource and the sector(s) that supply it. This is in the applications of the Leontief (1970) environmental IO model to consider the treatment and supply of a natural resources (water) rather than the provision of a clean environment, a development not considered in previous IO literature. I review the Leontief (1970) model and the further methodological developments of several authors, which culminated with the Allan et al. (2007) study (that resulted in the greatest advances in operationalising the Leontief framework). Then I explore how the aforementioned developments may be applied to consider the specific set of potential issues in the case of supplying a physical resource like water, focusing on issues around price assumptions of various users of a given sector in the IO model.

More generally, I begin the analysis by considering whether the direct 'User' pays or do not pay the resource cost for water usage. I also explore alternative IO approaches to generate physical multiplier values using Welsh water data to consider the impacts on different types of final demand. In particular, I compare the results from the conventional physical environmental IO model with the results from an earlier generalised Leontief (1970) method, both with and without adjustments to the core IO coefficients matrix (known as the **A**-matrix). I argue that policy makers and regulators may make valuable use of this type of framework in understanding the demands and supply of UK regional water resources, their roles in supporting economic expansion, and the function of potential government intervention where there are issues preventing efficient market provision of resource treatment and supply.

The chapter proceeds as follows. In Section 4.2, some issues for policy in considering the resource cost of supplying a physical resource like water are discussed. Section 4.3 reviews some examples of studies that consider various water issues (e.g., Daly (1968); Dietzenbacher and Velázquez (2007); Duarte and Yang (2011); Isard (1969); Okadera et al. (2015)). Section 4.4 describes the data used in this application and the derivation of the adjusted IO rows that reflect the differences between actual payments made to the water sector and payments implied by actual water use. In Section 4.5, a step by step account of how the Leontief (1970) model can be applied to the demand for and the supply of a physical resource is demonstrated. The findings of the analysis are discussed in Section 4.6. In Section 4.7, I take reflective review of the analysis in the chapter and consider issues that may arise going forward. Finally, Section 4.8 highlights and restates the key findings and concludes.

4.2 Issues for policy

There is competing demand for water resources because water supply and consumption are associated with different activities, such as irrigation, bathing, washing, cleaning, cooling, and food processing etc. (Fisher et al., 2010; Gu et al., 2014; Lenzen et al., 2013; Madani & Dinar, 2013; Sarker et al., 2014). However, a crucial issue is that there has been little to no attention paid to the fact that there are resource costs and implications for the economy regarding the supply and use of water. Water resource is a service provided by the environment which can be regarded as a common pool resource (Sarker et al., 2008). Its consumption is rival such that using the resource will impose costs on other users. Moreover, the use of the resource is not fully excludable due to ineffective or incomplete property rights. As a result, the 'User' does not have to pay the full cost and use is not optimally determined through the market mechanism.

As with the case of preventing impacts of the environmental 'bads' (e.g., waste) discussed in Chapter 3, policies for sustaining environmental 'goods' like water resources need to focus on capturing and considering the resource cost implications associated with the provision of water. It can be argued that policies to date seem to only focus in more general terms on the direct link or linear relationship between economic and environmental issues, without going beyond to actually consider the resource cost implications of water use and supply. Currently, the UK seems to be more advanced in addressing economic-environmental issues in terms of waste and/or pollution as shown in Chapter 3.

In fact, there is at least region specific waste data available and the base year data is relatively recent. (e.g. 2011 dataset used in Chapter 3). This compares with the data used in this current chapter, which are mix of regional data (England and Wales) that are not region-specific and the base year data not as recent (i.e. year 2007 data). Moreover, it seems that UK policy makers may not be asking the right questions or tackling the right issues in valuing and protecting natural resources and developing natural resource accounts.

Currently, water policies and regulations across the EU (including the Water Framework Directive WFD) (EU, 2000)[29] provide legislation for planning and supplying improved water management (European Commission, 2011)[30]. Prior to the trigger of Article (50) and Brexit negotiations, DEFRA (2011)[31] outlines the UK's obligations to deliver under the WFD and also widens the context to cover the uneven geographical distribution of water resources and different levels of stress on water resources. The UK's water-stressed regions tend to be more densely populated. This means that future water demands might require unsustainable water abstraction levels and associated water stress in resource abundant regions in order to meet increased demand from more heavily populated areas. It can be argued then that policy makers, water companies, and regulators therefore face the challenge of comprehending the complex economic interactions that determine water usage and the sustainability of water supply. In particular, there is a need to appreciate the economy-wide implications of future industry development and the connection between water use in one industry and the embedded water use in supply chains.

29 EU Water Framework Directive (2000). See http://ec.europa.eu/environment/water/water-framework/index_en.html

30 European Union (2011) Blueprint to safeguard Europe's water resources (See http://www.eea.europa.eu/policy-documents/a-blueprint-to-safeguard-europes

31 Defra (2011) 'Water for Life' (See https://www.gov.uk/government/publications/water-for-life

In this chapter, I use Welsh IO tables, together with data from the UK Environmental Accounts[32] to construct three alternative water multiplier measures for Wales based around both physical and resource-use methods. These produce quantitative results that differ, sometimes quite radically. The investigation of these differences is important for both policy and analytical reasons.

4.3 Examples of studies using environmental IO methods to various water issues

The application of IO methods to investigate issues in the supply and demand of water at different geographical scales has a long history (see for example Daly (1968) and Isard (1969)). In their early contributions, Daly (1968) and Isard (1969) proposed incorporating water use information in an IO framework. These studies attempted to model both the environmental and economic system in a manner that is consistent with the Material Balance Principle (MBP). Proceeding from this approach, flows (e.g., water) within and between the economy and the environment operate along the same lines as inter-regional trade in an inter-regional IO model. However, these all-encompassing economy-environment models were difficult to operationalise.

[32] UK Environmental Accounts for industrial water use in England and Wales were derived from sources including DEFRA, Environment Agency, WRAP and WRC and include household use, water company own use and system losses. See www.ons.gov.uk/ons/dcp171778_267211.pdf

The more recent IO literature focuses on water issues. It adopts an environmental IO approach that is influenced by both the Leontief generalised and limited economic-ecologic models (see Victor (1972)). This approach focuses more on linear relationships for physical resource inputs to and outputs from economic sectors per monetary unit of total input or output. This focus has provided the basis for most mixed physical-monetary environmental IO studies (Hubacek and Giljum, 2003; Suh, 2004; Xu and Zhang, 2009). However, this approach does not explicitly incorporate endogenous cleaning sectors and the ecological inputs from the environment. In this chapter, I will refer to this approach as the conventional environmental IO model.

Consequently, there is an extensive body of literature relating to the conventional environmental IO approach and it discusses extending the context and concepts of IO analysis and employing them in addressing different aspects of water use and issues of scarcity. Let us consider the exiting literature in more detail. First, I review studies that consider water allocation problems within and between regions facing acute water scarcity. These studies focus on how water resources might be shared between regions. In particular, such studies identify the direct and indirect consumption of scarce water resources and facilitates economic and environmental policy initiatives oriented towards saving water (for example see Carter and Ireri (1968); Seung et al. (1997); Duarte et al. (2002); Velázquez (2006); Feng et al. (2007); Guan and Hubacek (2008)).

In the context of water allocation problems, Velázquez (2006) employs the conventional environmental IO method to determine what relationship exists between the production and consumption of water in the Andalusia region. In addition, the author identifies the production sectors that consume greater amount of water and the extent to which water may become a limiting factor to the growth of other producing sectors. The use of conventional environmental IO model in water reosurce allocation and planning was also applied by Wang et al. (2009) to examine the relationship between production activities and related water consumption in Zhangye city northwest of China. Their results confirms that the region suffers from high water shortages and recommend that policy markers should include both direct and indirect water consumption in their resource allocation planning.

Secondly, Allan (1993) introduces the concept of 'virtual water' to this study area. 'Virtual water' is the water use embedded directly or indirectly in the production of goods or services. The introduction of this concept allows for consideration of how water scarce regions may effectively import water via purchasing water-intensive goods (e.g. agricultural products) from water abundant regions to address water shortages. Subsequently, there has been several studies that consider embedded water flows and water transfers in interregional and multiregional IO frameworks (for example see Dietzenbacher & Velázquez, 2007; Duarte & Yang, 2011; Feng et al., 2012; Guan & Hubacek, 2007; Huang et al., 2016; Mubako et al., 2013).

In analysing virtual water issues in the IO framework, Dietzenbacher and Velázquez (2007) consider whether water scarce and abundant regions are likely to be net importers/exporters of water. They find huge amounts of water consumption in Andalusia, embodied in exports and conclude that Andalusia is a net exporter of water. A key recommendation of their study, suggest that policy makers should restrict the exportation of agricultural products from the Andalusia regions to other parts of the world. Duarte and Yang (2011) provide a comprehensive review or survey on water problems and considered the role the IO framework can play in addressing different water issues (e.g water scarcity, virtual water and water footprint analysis) and the connection to economic activity.

Lastly, in extension of the 'virtual water' concept, the conventional environmental IO method has also provided a framework for consumption accounting methods (e.g., water footprints, (Cazcarro et al., 2010; Chapagain and Hoekstra, 2011; Feng et al., 2012; Wang et al., 2013) which were analogously developed according to ecological footprints (Hoekstra & Hung, 2002). Water footprints measure the physical amount of water use outside the territorial boundaries of a region or nation required to meet the domestic public or private consumer demand of the its inhabitants (Chapagain, 2017; Dong et al., 2014; Zhao et al., 2010).

Using an illustrative approach, Zhang et al. (2010) show that Chinese water scarcity issues relate to a disconnect between the geographical distributions of water resources, economic development and other primary factors of production. These authors use a multi-regional input-output (MRIO) framework to estimate the nature of virtual water trade and consumption-based water footprints (see also Okadera et al., 2015). Similarly, White et al. (2015) employed an integrated MRIO hydro-economic model to examine a consumption-based water footprint and the embedded water flows in inter-regional trade in China. They show that whilst there might be value in increasing imports of virtual water from water rich regions, care is needed because this could result in greater water stress in other water-scarce regions.

The identification of virtual water flows and water footprints is commonly addressed using interregional or multiregional IO models. However, a number of studies take a global approach so as to include other water issues (such as waste-water, water quality, water pollution) that are caused by climate change and pose significant threats to global water sustainability (for example see Liu et al., 2009; Yu et al., 2010; Yang et al., 2012; Feng & Hubacek, 2015; Arto et al., 2016; Cazcarro et al., 2016; Duchin, 2016).

However, there is a fundamental problem with the concept of and consideration of trade in virtual water. Unlike the generation of greenhouse gas emissions in the context of concerns about global climate change (which is the focus of carbon footprint estimates), the social opportunity cost of water use differs spatially. For example, a cubic meter of water extracted from Africa may have higher social opportunity costs than in more water abundant region (e.g. Europe). This has implications for footprint-type analyses based on simply adding across different water uses in different regions/countries.

More generally, previous contributions neglect crucial aspects of the Leontief model approach that can be productively applied to water use. The Leontief model identifies the economic resources employed in the collection, preparation, and movement of water. Two specific insights from the operation of the full environmental model prove to be particularly relevant in this case. First, the resources used in the water supply sector can act as an alternative index of water use. Second, differences between the water use multiplier values generated by the conventional environmental and the full Leontief generalised approach identify important issues for environmental IO analyses in particular, and also for IO analysis as a whole. In this chapter, I use the Welsh IO tables and the data from the UK Environmental Accounts[33] in Leontief's approach to consider the full nature of its insights into the full social and resource implications of managing these impacts has not been widely used to this day in the applied policy context, or fully explored in the academic literature. To the best of my knowledge, there is at present no attempt to

[33] UK Environmental Accounts for industrial water use in England and Wales were derived from sources including DEFRA, Environment Agency, WRAP and WRC and include household use, water company own use and system losses. See www.ons.gov.uk/ons/dcp171778_267211.pdf

apply, discuss, and explore the full Leontief (1970) environmental IO model in this way.

4.4 Data and derivation of adjusted IO row entries for actual and implied water use

This chapter uses Welsh IO accounts and data relating to the public water supply sector in Wales, a devolved region of the United Kingdom. The accounts are for 2007, the latest date for which the Welsh IO table are available (Jones et al., 2010). These accounts identify the purchases and sales of 88 separately defined industrial sectors, one of which is water supply. Some aggregation of these sectors is required to make them consistent with the information available on the industrial use of water resources. Appendix 4a reveals the industrial aggregation used in this chapter and how the 88 sectors in the Welsh IO framework are mapped on to the 27 industries for which physical water consumption data are available.

Note three important points concerning the physical water data used. First, I use public water supplied. Second, UK water data are incomplete. That is to say; there are several sources of water use and supply data, including the Department for Environment, Food and Rural Affairs (DEFRA), the Environment Agency (EA) and the Waste and Resources Action Programme (WRAP), and WRc plc. However, none provides the complete picture. In Wales, this partly reflects the challenge of reporting and collecting water data where catchments span political boundaries and sometimes water company 'boundaries'. Secondly, there is an absence of regional natural resource data that report water use at sectoral level and relate these to demand patterns implied by the IO accounts. As I explained in Section 3.4, Chapter 3, this is a specific case of the more general problem that has hindered the widespread application of the Leontief (1970) environmental model to address natural resources and/or pollution concerns (Allan et al., 2007). For analytical precision in identifying the relationship between economic activity and natural resources, water accounting data need to be collected and reported in a manner consistent with the economic accounts.

This study brings together available evidence relating to industrial and household public water use, which requires a number of study-specific assumptions to be made. I believe that this data is useful for the experimental application of the theoretical model presented in Leontief (1970) to Welsh water problems. Therefore, while the IO data are Welsh specific, information about physical water use has to be estimated by spatially disaggregating the combined English and Welsh environmental accounts. These provide information on industrial and household water use (public water supply) and water companies' leakages in England and Wales for 2006-07.[34] From the outset, it is important to clarify that this disaggregation is made primarily on the assumption that the intensity of

[34] Data in the UK Environmental Accounts for industrial water use in England and Wales were derived from sources including DEFRA, Environment Agency, WRAP and WRC and include household use, water company own use and system losses. See www.ons.gov.uk/ons/dcp171778_267211.pdf

water use across industries and for households do not differ between England and Wales. If this is not true, the Welsh physical water use figures will contain inaccuracies.

The vector of Welsh industrial water use is calculated in the following way. Each element is determined by dividing the England and Wales water use figure in each industry in proportion to the corresponding industry's employment levels in the two regions. This is given as:

$$x_{k,i}^{W} = x_{k,i}^{E+W} \left[\frac{e_i^W}{e_i^{E+W}} \right] \tag{4.1}$$

In equation (4.1), $x_{k,I}$ is the use of water in physical terms in industry *i*, (industry k is the water industry), e_i is employment in industry *i*, and the W and E superscripts apply to Wales and England respectively. The Welsh household physical water use, $x_{k,h}^{W}$, is estimated based on the Welsh share of the England and Wales's population (Pop^W/Pop^{E+W}). This is given as:

$$x_{k,h}^{W} = x_{k,h}^{E+W} \left[\frac{Pop^W}{Pop^{E+W}} \right] \tag{4.2}$$

However, there is limited information on physical water supplied to all non-household final demand uses, $x_{k,nh}^{W}$. This is essentially export demand from England for Welsh water. The assumption is that the physical share of non-household water final demand to the physical total water output is equal to the corresponding value share, as given in the Welsh IO tables. This corresponds to the assumption that all non-household final demand users pay the average industry price for the water that they purchase, and so:[35]

$$x_{k,nh}^{W} = \left[\frac{q_{k,nh}^{W}}{q_{k,T}^{W} - q_{k,nh}^{W}} \right] \left[x_{k,h}^{W} + \sum_{i} x_{k,i}^{W} \right] = \frac{q_{k,nh}^{W}}{p_k} \tag{4.3}$$

Total physical Welsh water generation, $x_{k,T}^{W}$, is the sum of the values calculated using equations (4.1), (4.2), and (4.3):

$$x_{k,T}^{W} = \sum_{i} x_{k,i}^{W} + x_{k,h}^{W} + x_{k,nh}^{W} \tag{4.4}$$

Using these procedures, total Welsh water production in 2007 (public water supply) is estimated at 253 million cubic metres. Households accounted for 158 million (63%).69 million cubic metres (27%) were supplied to Welsh industries as intermediate inputs.

4.5 Application and augmentation of the environmental IO model to consider water supply and use

In chapter 3 (Section 3.5), I focus on understanding waste payment and comparing the unadjusted IO accounts to an adjusted IO account that incorporates the resource cost of waste management service from the

[35] The average price is determined in equation (4.13).

polluter's waste generation. In this chapter, I apply the same methodology in a slightly different way as we ask different questions while using the same concepts for the case of water. The focus will be on comparing the unadjusted IO accounts with corresponding adjusted accounts that capture the resource cost of water supply from the actual water use by the 'User'. We assume in both cases that there is some level of price discrimination. However, the focus of the current chapter is on displaying/representing the usefulness of the augmented Leontief environmental to other commonly used and/or not so common environment models in the literature (i.e., conventional environmental model and the Leontief generalised model).

So, for a fuller and more complete method, let us begin by considering how water use may be tracked through the conventional environmental IO approach. Again, the sectorally disaggregated output of an economy with N sectors can be represented as (Miller & Blair, 2009):

$$\mathbf{x} = [\mathbf{I} - \mathbf{A}]^{-1}\boldsymbol{y} \tag{4.5}$$

In equation (4.5), $\mathbf{x}$ and $\mathbf{y}$ are respectively the (N x 1) output and the final demand vectors, where the i^{th} element in each is respectively the output and final demand for the product or service generated by sector *i*. $\mathbf{A}$ is the (N x N) matrix of technical coefficients, where an element, a_{ij}, is the value input of sector *i* directly necessary to produce one unit of the value output of sector *j*. The $[\mathbf{I} - \mathbf{A}]^{-1}$ matrix is the Leontief inverse. Each element, l_{ij} , gives the output in sector *i* directly or indirectly necessary to produce one unit of final demand in sector *j*. The sum of the elements of column *j* therefore gives the total value of output required, directly and indirectly, to meet one unit of final demand for the output of sector *j*. In the application of the conventional environmental IO approach to water use, these value multipliers are transformed into physical water multipliers which measure the physical water needed, directly or indirectly, to produce a unit of final demand expenditure in each sector. These are derived as the sum of the conventional column entries in the Leontief inverse. Each is weighted by the corresponding industry *i's* direct physical water coefficient. This generates a measure, which is the direct and indirect use of physical water per unit value of final demand. This procedure is represented formally in equation (4.6).

$$m_1^p = \mathrm{w}_1[\mathbf{I} - \mathbf{A}]^{-1} \tag{4.6}$$

In equation (4.6), m_1^p is a (1x N) row vector, where the i^{th} element is the i^{th} industry's physical water multiplier value and w_1 is a (1xN) vector where the i^{th} term is the direct physical water use in sector *i,* $\mathrm{x}_{k,i}$ divided by the total output of sector *i*, $\mathrm{q}_{i,T}$, so that:

$$w_{1,i} = \frac{x_{k,i}}{q_{i,T}} \qquad \forall_i \tag{4.7}$$

Note that here, as elsewhere, the water sector is denoted as sector k.

Alternatively, the physical water multiplier, m_2^p , can be calculated using the Leontief generalised approach. In this case, rather than directly tracking the physical water use, the expenditure made in the water supply sector is used to indicate the resources used in cleaning and delivering water. To identify the direct and indirect water used in meeting a unit of final demand in sector *j*, I locate the j^{th} element on the water supply row (the k^{th} row) of the Leontief inverse and convert this value to physical units by dividing by the average price of water.

More formally, this is determined by pre-multiplying the Leontief inverse by a (1 x N) row vector, w_2, where all elements are zero apart from the j^{th}, which is the inverse of the average price of water, p_k^{-1} This generates a (1 x N) row vector of physical water multiplier values, m_2^p , as:

$$m_2^p = w_2[\mathbf{I} - \mathbf{A}]^{-1} \tag{4.8}$$

The price of water is found by summing up the total expenditure on the output of the water sector, across all intermediate and final demands taken from the IO accounts, and dividing it by the total water extracted for these uses.[36] Therefore:

[36] The way in which these physical figures are calculated is given in Section 4.4 and formalised in equations (4.1) to (4.4).

$$p_k = \frac{\sum_{i=1...n,f} q_{k,i}}{\sum_{i=1...n,f} x_{k,i}} = \frac{q_{k,T}}{x_{k,T}} \tag{4.9}$$

Where the f and T subscripts stand for final demand and total respectively.[37]

The multiplier values calculated using the standard environmental IO approach (equation 4.6) and the Leontief generalised approach (equation 4.8) are the same if one central assumption of the value-denominated IO analysis holds. The assumption is that all uses of the output of a particular sector should face the same price for that good or service. In this specific case, this means that the two multiplier values will be equal if all users of water face the same price. If $m_1^p \neq m_2^p$, this is because the pattern of physical water use across sectors does not match the corresponding distribution of expenditure on the output of the water sector, as captured in the IO accounts.

Discounting data and reporting errors, there are two possible reasons why this might be the case. First, the technology for abstracting, treating, and distributing water might differ between uses. As Duchin (2009) argues, water itself is a common pool resource that is not necessarily directly paid

[37] An alternative way of calculating m_2^p is $m_2^p = w_3[\mathbf{I} - \mathbf{A}]^{-1}$ where w_3 is a (1 x N) row vector where the ith element is $a_{k,i}/p_k$.

for. In the context of IO accounts, the water sector only pays for the resources needed to collect/abstract, treat, and distribute water but not for the water itself. The differences in price per unit of physical water delivered could, therefore, reflect variations in the value of inputs needed to deliver that water to different uses.

An alternative explanation is that there is some form of price discrimination in supplying water to different industries and in elements of final demand. This perspective has been previously used by Weisz and Duchin (2006) to consider the factors surrounding the general differences between physical and monetary IO analysis. It has also been adopted by Allan et al. (2007) in the application to the treatment of Scottish waste.

In the previous chapter on the analysis of Scottish waste, the production sectors appear to pay only partially, and unsystematically, for waste management. Therefore, in effect, some sectors are charged more for waste management services than others. For the Welsh water use analysed in the present chapter, all the transactions involve public water supply and therefore all go through the market mechanism in principle. Therefore, all the market resource costs are covered by firms paying for water as an intermediate input and consumers paying for it as domestic supply. However, if there is no difference in the resources needed to supply water to different users, then any difference between the two physical water multiplier values (m_1^p and m_2^p) comes down to some form of price discrimination.

Whichever explanation applies in the end, if these multiplier values differ, there are prima facie problems for IO analysis. If the resources needed to deliver water vary across uses, and if the differences are large enough to cause significant variation in the multiplier values, then there should be a greater disaggregation of the IO table, particularly in the water sector in this case. For example, a disaggregation between the provision of industrial and domestic water might be appropriate.[38] Only if the resources needed to deliver water are constant in composition across uses but vary in their ability to deliver the same quantity of water will the conventional environmental IO multiplier, m_1^p , give the correct value (and the m_2^p value would give an inaccurate measure).

Alternatively, if price differences solely reflect price discrimination, an appropriate adjustment can be made to correct the water multiplier calculations. This involves changing the entries in the water row of the A matrix of the initial IO accounts to reflect the true/actual water use. The initial water row vector is therefore replaced by an implied water row vector derived from multiplying the physical water use per unit of value output divided by the average price of water. The row total is then balanced by an appropriate positive or negative subsidy entry.

[38] In a similar situation, Allan, G., McGregor, P.G., Swales, J.K., and Turner, K., 2007. Impact of alternative electricity generation technologies on the Scottish economy: an illustrative input-output analysis. *Proceedings of the Institution of Mechanical Engineers, Part A: Journal of Power and Energy*, 221 (2), 243–254 disaggregates the electricity supply sector in the Scottish IO table into generation and distribution and then consider different renewable technologies in the application of IO analysis to energy issues.

Again, identifying the water input as the k[th] row, the resulting vector of multiplier values, m_3^p , is given as the following:

$$\mathrm{m}_3^{\mathrm{p}} = \mathrm{w}_2[\mathbf{I} - \mathbf{A}^*]^{-1} \tag{4.10}$$

In equation (4.10), elements of the matrix $\mathbf{A}^*$ are given as the following:

$$\begin{aligned} &If\ i \neq k, \quad a_{i,j}^* = a_{i,j} \\ &If\ i = k, \quad a_{k,j}^* = \frac{x_{k,i}\, p_k}{q_{i,T}} = w_{1,i}\, p_k \end{aligned} \tag{4.11}$$

Under price discrimination, m_3^p is the correct water multiplier value.[39]

This procedure corrects the water multiplier value where price differences are as a result of price discrimination. It is perhaps important to emphasise that this occurs through revising the entries in the conventional Leontief inverse. Imagine that there are price variations across the uses, in this case, a given expenditure is associated with a different physical output of the product, depending on the use for which that expenditure was made. This also applies to elements of final demand for water. For example, if exports receive a lower price than output sold

[39] An alternative way of dealing with the problem of pure price discrimination would be to construct the IO table as a mixed table with the water sector specified in physical units (Duchin, 2009; Weiz and Duchin, 2006). However, our approach mantains the accounting identities embedded in the value-denominated IO accounts and facilitates the subsequent price adjustment calculation.

to home consumers, then an increase in household consumption will be associated with a lower physical output and a lower actual multiplier impact, as opposed to what is associated with an increase in export expenditure.

These problems occur whenever price discrimination is present. Studying a relatively homogeneous sector and focusing on the physical output of that sector more easily reveals any price differences that exist. Whilst these challenges almost certainly apply in other sectors, and could be more prevalent with greater product differentiation; they will likely be more difficult to detect.

Where the divergence between the relative value and quantity of water used is attributed to price discrimination, the IO price model can determine the subsequent deviation in the prices of all commodities, and therefore the implicit price subsidies or penalties. The price model is the dual of the quantity model represented by equation (4.5). In the original set of IO accounts, the sector prices are calibrated to take unit values. They have the following form:

$$i = [\mathbf{I} - \mathbf{A}^{\mathbf{T}}]^{-1}\,\mathbf{v} \tag{4.12}$$

Where i is an (N x1) vector of ones, $[\mathbf{I} - \mathbf{A}^{\mathbf{T}}]$ is the Leontief price multiplier and $\mathbf{v}$ is the vector of unit value added figures in the initial period. Equation (4.16) gives the corresponding set of prices, p_3^p, where the original **A** matrix is replaced by the augmented $\mathbf{A}^*$ matrix.

$$p_3^p = [\mathbf{I} - \mathbf{A}^{*\mathbf{T}}]^{-1}\,\mathbf{v} \tag{4.13}$$

This is the vector of prices that would hold if all sectors and final demand uses of water were charged at the same price. Adopting the price model allows the estimation of changes in relative prices across sectors that demand water services as inputs for production. Equation (4.14) calculates these changes, Δp_3^p, as the vector of percentage price variations:

$$\Delta p_3^p = \left[\, p_3^p - i \,\right] \times 100 \tag{4.14}$$

If the payment for the water sector services were always proportional to the physical amount of water purchased, then the multiplier values generated using equations (4.6), (4.8) and (4.10) would be the same, i.e., $m_1^p = m_2^p = m_3^p$, and each element of the Δp_3^p vector would be 0. However, this is not the case using the Welsh data. These results are discussed in some detail in Section 4.6.

4.6 Empirical results and discussions

4.6.1 Does the 'User' pay the resource cost for the provision of water services?

Let us recall that in this chapter, the analysis is set in the context of the provision of common pool resources where the 'Users' typically do not pay the full social cost for their resource use (and it is not possible to fully exclude use). I begin the analysis by considering if the direct 'User' pays or do not pay the resource cost for water use. I, then explore alternative IO approaches to generating physical multiplier values using Welsh water data to consider the impacts on different types of final demand. In particular, I compare the results from using the conventional physical environmental IO model with an approach based upon the earlier generalised Leontief (1970) method, both with and without adjustments to the core IO coefficients matrix (known as the **A**-matrix).Finally, I consider the impacts on output prices of adjusting the water payments for the actual direct water use.

Table 4.1 is a condensed version of the 2007 IO Tables for Wales with a number of additions. It shows the pattern of sales of the water sector, the physical use of water and the accounting adjustments required if expenditure on water is to match water use. Rows 1 to 6 give accounting data for 2007 prices in £ million. Row 7 gives the physical water use in millions of cubic metres. Physical water use calculated as discussed in equations (4.5) to (4.14).

Rows 1 and 2 disaggregate the expenditures on domestic output made by industrial sectors and final demand. Row 1, labelled "Non-water sectors", is the payments made to the combined non-water sectors. Non-water sectors are sectors 1-17 and 19-28 (see Appendix 4a). The entries in row 2, 'Water sector', give the payment entry for water services in the original IO accounts. The total output of the water sector at £697.82 million, is just less than 0.5% of the total Welsh output at £140,916 million. Note that actual payments for water are dominated by final demand and particularly, by household demand, which at £512.42 million, makes up for over 73% of the total. The expenditure on water as an intermediate input is highest for the 'Chemicals & pharmaceuticals', 'Public administration', 'Basic metals' and 'Accommodation' sectors. Each of these Welsh sectors spent more than £10 million on the water in 2007. The highest is 'Chemicals & pharmaceuticals' at £13.29 million.

Row 3 reports the actual water use, measured in value terms. To be specific, it takes the physical water use figure from row 7 of Table 4.1 and multiplies it by the average price of water (equation 4.9). The figure in row 3 is, therefore, the potential expenditure for water in its different uses if water had the same price in all uses. Note that rows 2 and 3 have the same row totals, but that the entries for individual uses sometimes differ drastically. To begin, the actual use of water as an intermediate input is

£190.01 million, over 66% higher than the actual payment for water as an intermediate. The household use indicates an equal position, the opposite result to the actual payment for water as an intermediate: household water payments are greater than the value of water use. For the adjusted water use by individual sectors, six sectors now have values greater than £10 million. These are, in descending order, 'Agriculture, forestry & fishing', 'Food & drink', 'Accommodation', 'Health', 'Other Business Services', and 'Chemicals & Pharmaceuticals'.

The figures in row 4, 'Additional payment for water' are the differences between the unadjusted (row 2) and adjusted (row 3) water payment entries. The row total is zero so that overpayments are balanced by underpayments. The positive entries in this row indicate an overpayment for water. This occurs for the household consumption but also for some industrial sectors, such as 'Coke & Refined Petroleum', 'Chemicals & pharmaceuticals', 'Basic metals', 'Construction' and 'Public administration'. These include some sectors ('Chemicals' and 'Basic metals') which are identified in previous analysis as high users of water per £ of Welsh GVA (Jones et al. 2010).[40] A negative row 4 entry shows that in the unadjusted system these sectors are net under payers. Of the 28 industrial sectors, 19 sectors are net under payers. 'Agriculture, forestry & fishing', 'Food & drink', and 'Education' and 'Health' are responsible for over three quarters of this underpayment.

[40] This previous analysis also employed Welsh IO tables for 2007, but a different set of water consumption data.

Rows 5 and 6 give the other primary inputs and total (unadjusted) value of inputs figures for each sector from the original Welsh Table. The other primary inputs include payments for labour and other value added as well as imports (from both the rest of the UK and the rest of the world) taxes and subsidies. For each sector, the unadjusted value of inputs figure is also the value of output figure.

Table 4.1 The condensed conventional and full environmental Welsh industry-by-industry IO table for 2007

	Agriculture, Forestry & Fishing	Mining & Quarry	Food & Drink	Clothing & Textiles	Wood	Paper & Paper Products	Printing	Coke & Refined Petroleum	Chemicals & Pharmaceutical	Rubber & Plastic	Non-Metallic Minerals	Basic Metals	Electronics & Electrical Engineering	Motor Vehicles
1. Non-Water sectors	438.1	104.5	1019.2	46.9	100.6	186.3	102.3	547.0	574.9	291.0	166.1	1691.6	932.7	706.7
2. Water sector	5.5	0.7	6.3	0.5	0.3	1.0	0.4	4.9	13.3	1.1	1.6	10.5	3.9	1.3
3. Water Use (Value)	34.1	3.1	19.5	0.5	1.6	1.1	0.3	0.8	10.8	0.7	1.7	6.3	3.3	6.3
4. Water Payment Adjustment	-28.6	-2.5	-13.1	0.0	-1.2	-0.1	0.1	4.2	2.4	0.4	-0.1	4.3	0.4	-5.0
5. Other Primary Inputs	961.5	225.0	2014.2	226.8	391.1	689.9	449.3	4583.1	2192.6	913.7	495.8	4847.3	3440.3	1746.8
6. Total Inputs	1405.1	330.3	3039.7	274.2	492.1	877.2	551.9	5135.1	2780.8	1205.8	663.5	6549.5	4376.6	2454.7
7. Physical Water Use (millM3)	12.4	1.1	7.1	0.2	0.6	0.4	0.1	0.3	3.9	0.3	0.6	2.3	1.2	2.3

Table 4.1 Continued

	Other Transport	Furniture	Electricity Gas, Waste & Sewage	Water	Construction	Wholesale & Retail	Transportation	Accommodation.	Finance & Insurance	Other Business Services	Public Administration	Education	Health	Other Services
1. Non-Water sectors	535.8	192.1	2543.5	480.8	1690.9	1986.4	933.1	575.5	1154.4	1771.4	1434.4	538.1	2957.3	720.4
2. Water sector	2.7	0.2	2.9	0.3	6.4	4.5	1.54	10.2	1.09	4.2	12.9	6.5	6.5	3.2
3. Water use (value)	4.8	2.6	5.2	0.6	1.8	9.2	4.4	15.0	2.7	12.6	9.4	9.9	14.6	6.1
4. Water Payment Adjustment	-2.1	-2.4	-2.3	-0.3	4.6	-4.8	-2.9	-5.8	-1.6	-8.4	3.5	-3.3	-8.2	-2.9
5. Other Primary Inputs	1723.8	728.8	2734.1	216.6	3401.8	6590.3	2720.0	2039.4	2744.3	10776.2	4899.4	3107.5	5198.5	2908.3
6. Total Inputs	2262.2	921.0	5280.5	697.8	5099.2	8581.3	3654.6	2625.1	3899.8	12551.8	6346.7	3652.1	8162.2	3631.9
7. Physical Water Use (millM3)	1.75	0.95	1.89	0.21	0.67	3.34	1.60	5.79	0.96	4.57	3.40	3.57	5.31	2.2

Table 4.1 Continued

	Total Intermediate Demand	Households	Tour 1-3	Tour 4+	Tour Intl	Tour Bus	Government	Gross fixed capital formation	Stock2007	Exports RUK	Exports ROW	Total Final Demand	Total Demand Products
1. Non-water sectors	24055.1	18731.3	217.3	964.2	296.3	217.0	13785.9	3003.9	498.6	25840.2	8828.4	72382.9	140219.1
2. Water sector	114.2	512.4	0.1	0.6	0.2	0.2	0.0	15.4	38.6	15.2	0.8	583.6	697.8
3. Water use (value)	190.0	436.7	0.1	0.6	0.2	0.2	0.0	15.4	38.6	15.2	0.8	507.8	697.8
4. Water payment adjustment	-75.8	75.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	75.8	0.0
5. Other primary inputs	273.4	17639.6	26.2	159.5	41.9	28.2	481.7	2413.1	189.3	5448.1	1382.2	27809.8	100776.2
6. Total l inputs	-33.9	36883.4	243.7	1124.4	338.4	245.4	14267.6	5432.4	726.5	31303.5	10211.1	100776.2	198278.9
7. Physical water use (millM3)	68.87	158.27	0.05	0.23	0.06	0.05	0.00	5.59	13.98	5.52	0.31	184.05	252.92

If the differences in the cost of water for different uses solely reflect price discrimination, the negative or positive row 4 entries indicate whether any given sector is directly subsidising or is being subsidised for water use in other parts of the economy. In addition to looking at the relative expenditure by individual production sectors, it is also important to identify the position relative to final demand uses. There are limitations here because for all non-household final demand sectors, the assumption is that in the face of insufficient physical water use data, these sectors fully pay for their water use, hence their zero value in row 4. However, the household sector's additional payment entry, which is based on actual data, has a high positive value of £75.76 million. This suggests that households pay much more for water than their physical water use implies. As a result, households are subsidising industrial water use.

4.6.2 Physical water multipliers

In this section, I use the Welsh data outlined in Section 4.4 to calculate the water multiplier values m_1^p, m_2^p, and m_3^p given in Section 4.3 by equations (4.6), (4.8), and (4.10). Table 4.2 presents the Type I and II values for the three physical water multipliers (m_1^p, m_2^p, and m_3^p) outlined in Section 4.5. The required direct water coefficients in order to calculate these multipliers are also reported. The first data column gives the physical water use coefficient, ($x_{k,i}/q_{i,T}$), which is measured in thousands of cubic meters per £million of output. These figures comprise the elements of the vector w_1. On this measure, the four most water intensive sectors, in descending order, are 'Agriculture, forestry & fishing', 'Mining & quarrying', 'Food & drink', and 'Accommodation'. All of these sectors have a water intensity value of over 2 thousand cubic meters of water per £million of output. The measurement for the 'Agriculture, forestry & fishing' sector, the water intensity value of which is valued at 8,790 cubic meters, is particularly high.

The second data column reports the corresponding original direct water coefficient in the **A** matrix. These figures give the proportion of total costs in that sector going directly to the water sector. Using this metric, the top four most water intensive sectors are: 'Chemicals & pharmaceuticals', 'Agriculture, forestry & fishing', 'Accommodation', and 'Non-metallic mineral'. It is clear that ordering the sectors by the share of costs which go to intermediate water expenditure differ from ordering by the physical water-use intensity.

The third column gives the 'adjusted' expenditure coefficients calculated by multiplying the physical coefficients in column 1 by the price of water and dividing it by a thousand. These are the water row coefficients used in the $\mathbf{A}^*$ matrix which are incorporated in the Leontief inverse employed in the calculation of m_3^p. The ordering of water intensities is exactly the same as in column 1. However, a comparison of columns 2 and 3 indicates the extent to which the two water intensity measures differ.

Table 4.2 Water use in Wales in 2007 in thousand cubic meters (1000m^3)

	Sector/Activity	$X_{ki}/q_{i,T}$	a_{ki}	$X_{ki}p/q_{i,T}$	$m_1^p = w_1[I-A]^{-1}$		$m_2^p = w_1[I-A]^{-1}$		$m_3^p = w_1[I-A^*]^{-1}$	
					Type I	Type II	Type I	Type II	Type I	Type II
1	Agriculture, Forestry & Fish	0.00879	0.00392	0.02426	0.00979	0.01346	0.00168	0.00573	0.00981	0.01353
2	Mining & Quarrying	0.00346	0.00206	0.00954	0.00379	0.00631	0.00090	0.00368	0.00379	0.00633
3	Food and Drink	0.00232	0.00209	0.00641	0.00375	0.00629	0.00107	0.00388	0.00375	0.00631
4	Clothing & Textile	0.00063	0.00179	0.00174	0.00075	0.00383	0.00072	0.00411	0.00075	0.00382
5	Wood	0.00115	0.00066	0.00316	0.00168	0.00398	0.00037	0.00291	0.00168	0.00399
6	Paper and Paper products	0.00045	0.00112	0.00123	0.00062	0.00254	0.00050	0.00261	0.00062	0.00254
7	Printing	0.00019	0.00067	0.00052	0.00030	0.00349	0.00031	0.00383	0.00030	0.00349
8	Coke and Refined Petroleum	0.00006	0.00097	0.00016	0.00013	0.00108	0.00039	0.00145	0.00013	0.00108
9	Chemicals and Pharmaceuticals	0.00141	0.00478	0.00390	0.00157	0.00377	0.00183	0.00425	0.00157	0.00376
10	Rubber& plastic	0.00021	0.00087	0.00058	0.00036	0.00346	0.00042	0.00385	0.00036	0.00346
11	Non-Metallic Mineral	0.00090	0.00241	0.00249	0.00112	0.00401	0.00100	0.00419	0.00112	0.00401
12	Basic Metals	0.00035	0.00161	0.00096	0.00051	0.00297	0.00070	0.00342	0.00051	0.00297
13	Electronics & Electrical Engineering	0.00028	0.00084	0.00076	0.00040	0.00300	0.00039	0.00326	0.00040	0.00300
14	Motor Vehicles	0.00093	0.00051	0.00257	0.00111	0.00322	0.00032	0.00265	0.00112	0.00323
15	Other Transport	0.00077	0.00119	0.00213	0.00092	0.00341	0.00053	0.00327	0.00093	0.00341
16	Furniture	0.00104	0.00023	0.00286	0.00124	0.00378	0.00015	0.00296	0.00124	0.00379
17	Electricity, Gas, Waste & Sewage	0.00036	0.00054	0.00099	0.00075	0.00302	0.00039	0.00290	0.00075	0.00302
18	Water	0.00030	0.00046	0.00084	0.00065	0.00307	0.36282	0.36550	0.36310	0.36552
19	Construction	0.00013	0.00126	0.00036	0.00032	0.00367	0.00064	0.00433	0.00032	0.00366
20	Wholesale & Retail	0.00039	0.00053	0.00107	0.00057	0.00444	0.00028	0.00454	0.00057	0.00444
21	Transportation & storage	0.00044	0.00042	0.00121	0.00058	0.00467	0.00023	0.00474	0.00059	0.00467
22	Accommodation & food	0.00221	0.00389	0.00608	0.00266	0.00674	0.00155	0.00605	0.00266	0.00674
23	Finance Insurance	0.00025	0.00028	0.00068	0.00042	0.00374	0.00019	0.00386	0.00042	0.00374
24	Other Business Service	0.00036	0.00033	0.00100	0.00044	0.00290	0.00017	0.00289	0.00044	0.00290
25	Public Administration	0.00054	0.00203	0.00148	0.00068	0.00568	0.00083	0.00635	0.00068	0.00567
26	Education	0.00098	0.00178	0.00270	0.00111	0.00823	0.00072	0.00858	0.00111	0.00823
27	Health	0.00065	0.00079	0.00179	0.00100	0.00530	0.00046	0.00521	0.00100	0.00530
28	Other Services	0.00061	0.00089	0.00168	0.00075	0.00504	0.00040	0.00514	0.00075	0.00504

The figures in columns 4 and 5 give the physical water Type I and II multiplier values using the conventional environmental IO approach, m_1^p , as given in equation (4.6). They are measured in thousand cubic meters for each £million of final demand expenditure. The Type I multipliers include only direct and indirect effects. That is to say, in measuring Type I multipliers, household consumption is held constant and only endogenous intermediate water demands are included as elements of the supply chain. Type I multipliers are typically used for footprint analysis. Type II multipliers also incorporate the induced water consumption of direct workers, and workers attributed to the sectors extended supply chain. This would be the most appropriate multiplier value for increases in activity which were expected to be accompanied by increases in population.

The conventional Type I physical water multiplier value presented in column 4 must be higher than the corresponding direct water coefficient shown in column 1 because it incorporates both the direct water input and the embedded water in the other intermediate inputs. For example, in 'Agriculture, forestry & fishing', the direct water use is 8,790 cubic meters per £1 million of final demand whereas the conventional Type I value is 9,790 cubic meters. Typically, the difference is relatively small. However, in some cases, the proportionate differences can be large. The 'Food & drink' sector has a direct water coefficient of 2,320 cubic meters, but a Type I multiplier value of 60% higher at 3,790 cubic meters per £million of final demand.

The conventional physical Type II water multiplier values are higher still, since they incorporate additional induced household water use. The Type II measure used endogenises all the household water use, which is more than double intermediate water use. So, for most sectors, the Type II physical water multiplier is significantly higher than the Type I value. Although the 'Agriculture, Forestry & Fishing' sector maintains its position as the most water intensive on this measure, other more labour intensive sectors begin to play a more prominent role. 'Education' moves from 1,110 cubic meters of the Type I multiplier to 8,230 cubic meters for the Type II and takes second place on that measure. 'Accommodation' shows a similarly large gain. At 6,740 cubic meters per £1 million final demand of the Type II multiplier, it is the third most water-intensive sector.

The Type I and Type II physical water multiplier values that are calculated on the basis of water sector payments are shown in columns 6 and 7. Note the low value for the Type I multiplier values. For 20 industries, the Type I m_2^p multiplier value is lower than the corresponding m_1^p figure. The Type I m_2^p multiplier value is never greater than 2,000 cubic meters per £1million and is only greater than 1,000 cubic meters per £1 million in 5 sectors. 'Chemicals & Pharmaceuticals' has the largest value, at 1,830 cubic meters, which is followed by 'Agriculture, forestry & fishing', 'Accommodation', and 'Food & drink'. The relative low measure stems from the lower expenditure on water as an intermediate input than would be expected from the physical water use.

The Type II values incorporate household water use, which is overvalued in the expenditure (as against physical) figures. This means that there is no overall bias in the Type II m_2^p value. However, there are big differences for some individual sectors in the Type II m_1^p and m_2^p values. Some examples are 'Agriculture Forestry & Fishing', 'Mining & Quarrying', 'Food & Drink', and 'Wood'.

The m_3^p multiplier adjusts the Leontief inverse so that the technical water expenditure coefficients match the physical intermediate and final demand water use values. If the 'adjusted' **A** matrix is used, the conventional and the extended Leontief multiplier values into line, such that that $w_1\left[1-A^*\right]^{-1}=w_2\left[1-A^*\right]^{-1}$. This is the appropriate procedure if the mismatch between the physical and expenditure water use data is solely due to price discrimination amongst water uses. In this case, it is clear that the m_3^p values are much closer to the m_1^p values than the m_2^p values. This suggests that calculating the physical water multipliers by merely tracking the value of the output of water sector will potentially give very inaccurate multiplier values for some individual sectors. On the other hand, the conventional environmental approach, which augments the value Leontief inverse with direct physical water/output ratios, generates multiplier estimates that, while theoretically incorrect, are extremely close to the m_3^p values. However, this almost certainly reflects the small scale of the water sector in the Welsh economy. Adjusting the coefficients for a large sector should have bigger impacts on the calculated inverse values.

4.6.3 Implications of the resource costs for provision of water on output prices

If there is variation across uses in that the price paid per unit of delivered physical water and if that variation is the result of pure price discrimination, then the impact on commodity prices of adjusting the water payments for the actual direct water use can be calculated using equations (4.12), (4.13), and (4.14). The deviations from the original prices are given in Table 4.3. These figures show whether sectors presently bear the full resource cost of water use through direct and/or knock-on impacts on the price of their output. Column 1 reports the impacts on the prices of sectoral output using the Type I price multiplier values and the 'adjusted' system. In this case, wage payments are taken as an element of the value-added vector, **v**, and do not adjust to variations in the sector prices; the nominal wage is held constant. The percentage change in prices in column 2 identify the corresponding results using Type II multipliers. Essentially, this holds the real wage constant and adjusts the nominal wage to changes in sector prices. An important issue here is that the price consumers pay for water are above the average price, such that an adjustment to uniform pricing will have a direct impact on the nominal wage.

In the Type I case, there are 7 sectors where the price of output would be lower if a uniform price is charged for water across all uses. The largest negative adjustments are for the 'Construction', 'Coke & refined petroleum', and 'Chemicals & Pharmaceuticals' sectors. However, these impacts are small. These sectors all suffer a cost disadvantage of less than 0.1%, which stems from the existing water price differentials. In 21 sectors, the adjustment increases the Type I price multiplier values. In some cases, the impact is particularly high. For instance, the 'Agriculture, Forestry & Fishing' price increased by 2.24% and prices in the 'Mining & Quarrying' and 'Food & Drink' sectors rose by 0.80% and 0.74% respectively.

In calculating the Type II 'adjusted' prices, two changes to the Type I method are made. First, wage income is removed from the vector of sectoral value-added, so that all elements in the value-added vector are reduced. Second, the **A** matrix is augmented to incorporate the wage and household expenditure. The net impact is to reduce the 'adjusted' price in all sectors as against the Type I value. That is to say, if the price adjustment was negative for Type I multiplier, it is even more so with the Type II calculation. On the other hand, if the Type I price change is positive, the Type II value will be smaller, or even negative.

Table 4.3 Impact on output prices of the adjusted to full Leontief environmental IO accounts

	Sector name	Percentage change in price multiplier relative to 'unadjusted' price IO Type I effects (household exogenous) 'adjusted'	Type II effects (household endogenous)' 'adjusted'
1	Agriculture, Forestry & Fishing	2.239%	2.177%
2	Mining & Quarrying	0.799%	0.756%
3	Food & Drink	0.739%	0.696%
4	Clothing & Textiles	0.009%	-0.042%
5	Wood	0.363%	0.325%
6	Paper & Paper Products	0.035%	0.003%
7	Printing	-0.003%	-0.056%
8	Coke & Refined Petroleum	-0.074%	-0.090%
9	Chemicals & Pharmaceuticals	-0.071%	-0.108%
10	Rubber & Plastic	-0.018%	-0.070%
11	Non-Metallic Mineral	0.034%	-0.015%
12	Basic Metals	-0.053%	-0.094%
13	Electronics and Electrical Engineering	0.003%	-0.041%
14	Motor Vehicles	0.219%	0.183%
15	Other Transport	0.109%	0.067%
16	Furniture	0.300%	0.257%
17	Electricity, Gas., Waste & Sewage	0.098%	0.060%
18	Water	0.076%	0.035%
19	Construction	-0.086%	-0.142%
20	Wholesale & Retail	0.082%	0.017%
21	Transportation	0.097%	0.029%
22	Accommodation	0.306%	0.238%
23	Finance & insurance	0.063%	0.007%
24	Other business services	0.074%	0.033%
25	Public administration	-0.042%	-0.125%
26	Education	0.108%	-0.011%
27	Health	0.148%	0.076%
28	Other services	0.097%	0.025%

The biggest difference occurs for 'Education'. Row 4 in Table 4.1 shows that 'Education' is a net under payer for water. This is reflected in the higher Type I price multiplier in the first column of Table 4.3. However, 'Education' is a labour/wage intensive sector. This means that it is impacted by the effect of households overpaying for water as an "input" to the provision of labour services in the Type II case. In the 'adjusted' system, on the other hand, where households only pay the unit cost for the water they actually use, downward pressure is exerted on the cost of labour and on the price multipliers of labour-using sectors.

4.7 Reflections/rumination and some practical issues: do we require further consideration of payments for water use in future research?

An overarching consensus of this chapter is that there is price discrimination in water payments. In particular, household consumption demand is paying more for water than intermediate demand. Thus, under what circumstances do we want price discrimination vs. average cost or common price of water across the society? In order words, why should policy focus on same/common price for water across different uses? Water use, supply and payment has been a very sensitive matter and in terms of if/when price discrimination or common price system should be considered is highly dependent on the objective of the water policy or strategy at hand. For instance, an objective of water policy (e.g. Water Strategy for Wales[41]) in Wales has been sustainable management of water. Another water redistribution from water abundant areas to water scarce areas to support continued availability and accessibility to water for all (DEFRA (2011)[42]

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[41] Full report on Water Strategy for Wales is available at http://gov.wales/docs/desh/publications/150521-water-strategy-for-wales-en.pdf

[42] DEFRA (2011) Water for Life' report. https://www.gov.uk/government/publications/water-for-life

From an economic perspective price discrimination may come to be, if government charged higher prices to water users that are less responsive to price changes (those that will not significantly change the amount of water they use as price changes (e.g. production industries (Agriculture) and lower prices to the most price responsive water consumers (e.g. household). On the other hand, government may want to introduce a common price system to encourage a pay as you use system, such that water is affordable for all 'Users'. This may be a relevant approach when policy objective is to safe guide health and human well-being. If water were charged at different rates, it may become too expensive for consumers on lower income bands. Therefore, making the use and accessibility to water for basic human hygiene and daily activities difficult for such users and eventually affect their health.

From non-governmental perspective, there is recent evidence that suggest big companies (e.g. Colgate and Nestle) are looking to set an internal price for water (CDP 2017)[43] report. These companies suggest that an internal price may facilitate water savings and reduce cost in particular to help companies against risk and supply chain disruption in the price of water. More generally, there are a number of avenue to purse when considering price discrimination or common price for water. However, an essential and core message is that given that water supply in Wales in privately

[43] CDP report by Head of Water Security, Cate Lamb is available at https://www.greenbiz.com/article/why-colgate-and-nestle-are-setting-internal-price-water

owned, but regulated by government, there may be the need to implement both price discrimination and common price system to meet policy objectives. Moreover, I have only considered public water supply in this research-the situation may be quite different if/when, data is available to consider other types of water (e.g. tidal water and water from renewable sources).

4.8 Conclusion

This chapter explores alternative IO approaches to generating physical multiplier values using Welsh water data. In particular, it compares the results from using the conventional physical environmental IO model with an approach based upon an earlier generalised Leontief (1970) method, both with and without adjustments to the **A** matrix. Essentially the generalised Leontief (1970) method uses the demand for the industry output involved in the collection, preparation, and movement of water as an index of physical water use. The motivation for using this alternative approach came from the importance emphasized for cleaning sectors in the Leontief (1970) method. However, in many other cases, the physical use of environmental goods, such as rare metals, could be tracked by the expenditures on the industries supplying such goods.

In the case of Welsh water, I find that the price paid per physical amount of water appears to vary greatly amongst different users. In general, the data suggest water used for household consumption is charged at a higher price than intermediate industrial demand. Prices also vary widely across different industries. Only if physical water-use data are employed to adjust the IO **A** matrix does the generalised Leontief model work satisfactorily. In principle, this is problematic for IO analysis in general. However, the small scale of the Welsh water sector means that the conventional environmental IO multipliers appear to be quite accurate.

In terms of implications for policy, it is key that accurate physical water multiplier values be provided to calculate the impact of industrial development strategies on demand for water and the sustainability of growth. For Wales, the major policy implication of this work is that water expenditure information reported in the core economic IO accounts is inadequate for producing accurate physical water multiplier values. This implies that the tables must be augmented with direct physical water coefficients. However, physical data on the resource (often referred to as environmental satellite accounts) are commonly not collected and published at a regional level. In particular, as Section 4 has explained, the unavailability of Welsh specific physical water coefficients meant that averages across a wider 'England and Wales' region have had to be applied.

In terms of progression in the application the Leontief environmental IO model, from Chapter 3 and the current chapter, I have shown how the Leontief (1970) environmental IO model can be used in diverse ways to capture the respective resource costs of pollution output and resource input. As I ready explained, Chapter 3 and 4 use same model but in slightly different ways to address different economic-environmental issues. I find very different and opposite results and in some case similar results, when I compare the findings in Chapter 4 to Chapter 3. I discuss three main major findings. First, I find that the production side of the economy is heavy subsidised by household in the water case (Chapter 4). Whereas in the waste case (Chapter 3), the production side of the economy is subsidised mostly by 'Waste Management', 'Public Administration' and 'Health' which are mostly government owned. Second, I find that there are issues of price discrimination in water across different uses as shown in Chapter 4. While, in Chapter 3, in a slightly different context, the unit cost of waste disposal might vary across different types of waste, and also maybe across different types of public and private waste disposal organisations.

More generally, reflecting on the results in Chapter 3 and 4, I have made further contributions through demonstrating the added value of the environmental IO model initially developed by Leontief (1970) and augmented by Allan. et al (2007) in addressing priority economic-environmental issues. In Chapter 3 and particularly in Chapter 4, I show how Leontief's approach is important to consider the full nature of its insights into the full social and resource implications of managing environmental impact. The findings clearly show that if the appropriate data is available and used with the full Leontief model, there are a number of insights to be gained on the economy-wide impacts of using the environmental to meet different economic needs in terms of incorporating the resource costs implied by waste generation or water use. The next chapter (Chapter 5) consolidates the core chapters (chapters 2-4), gives an overall summary of the contribution of the core chapter of this thesis, and provides direction for future research.

Chapter 5: Summary, contribution of the research and direction for future research initiatives

5.1 Introduction

In this thesis, I focus on determining the connection between economic activity and the environment. I do so by demonstrating how IO methods and particularity how the environmental IO model (Leontief, 1970) is a useful and suitable tools to study the connections between the economy and the environment. I have argued that the IO methods may help to support already existing economic and environmental policies and or inform new policy decisions. However, the relevant application and value of the IO approach has not been properly and fully assessed in informing policy decisions or in considering market failure issues.

In this final chapter, I provide a conclusion to this study. This chapter serves as a consolidation of the previous chapters, merging the issues discussed and pointing out potential areas for future research. The chapter is structured as follows. In Section 5.2, I provide a summary of the work undertaken in each chapter and I discuss the major insights generated by this study. In Section 5.3, I discuss the contributions made as well as the resulting implications and recommendations of the research findings. Some of the main limitation of the study are discussed in terms of follow up and continuation of this research in Section 5.4 Finally, in Section 5.5, I propose some directions for future research.

5.2 Summary of the thesis

In this thesis, I aim to address some particular types of impacts of economic activity on the environment, focusing in on some economy-wide implications of using the environment to meet different economic needs. I employed environmental IO methods to achieve theses aims. Specifically, I refine environmental IO approaches to provide key information where it may be argued that policy action (whether or not it is acknowledged) may ultimately require reconsideration of how best to attribute responsibility for environmental issues, particularly where the resource costs of providing common pool resources is a concern. The core of this thesis comprises of three independent but related chapters (Chapter 2, 3 & 4). These involves analyses that are introduced and considered in a progressive way to enumerate the importance of multi-sectoral environmental IO models.

In Chapter 2, I consider how IO multiplier methods may be used to develop our understanding of demand drivers of a local pollutant (taking physical waste as an example). Specifically, I demonstrate how environmental IO Type I multipliers (incorporating direct and indirect or inter-industry effects) may be used to describe and communicate key elements of the impact of local pollution. I find that only a few industries are accountable for most of the waste generation in Scotland. I also find that, if we consider the production side of the economy and waste generation, which occurs in order to meet final demand, then gross fixed capital formation, household, and government final demand types occupy greater roles and generates more significant impacts in waste generation in Scotland than previous studies depict. For this reason, I conclude that in addition to regulating producers, some focus might be directed towards curbing final consumption goods that are directly or indirectly produced by waste intensive industries.

In the second core chapter (Chapter 3), I revisit a previous but incomplete study conducted by Allan et al. (2007). The Allan et al. (2007) study made key contributions in method and application in operationalizing the Leontief (1970) environmental IO model to explore the need to determine social and/or resource costs of supplying common pool resources such as a 'clean environment' at a regional level. However, Allan et al.(2007) acknowledge that poor data hindered complete testing of the usefulness and the potential to support policy of Leontief (1970) environmental IO model in providing a better understanding of pollution cleaning and/or disposal as a key environment service activity. From here, I reconstructed the environmental IO account for Scotland (2011) to reexamine and revaluate a number of issues with the help of improved data on waste generated by industries and household in Scotland (developed by the Scottish Government in collaboration with Zero Waste Scotland). I find that production sectors appear to only pay for the waste treatment on a partial and unsystematic basis. In effect, some sectors seem to be charged more for waste disposal services than others. I also find that the demand reflected by the multiplier calculation cannot be mapped onto the resource cost implied by each sector's waste generation. However, when I impose an average cost of waste management, I find that the production side of the economy is subsidised in terms of direct payment for waste management services by the 'Waste management', 'Public administration' and 'Health' sectors in particular. These sectors are purchasing more resources than they need to manage their own waste generation. Given that these are government-owned sectors, this reflects heavy government subsidies of waste management, which are being channelled through the above-mentioned sectors. These findings are very similar to conclusions drawn by Allan et al. (2007).

In the third core chapter (Chapter 4), my thesis makes its most novel contribution to the IO field and the wider environmental economics literature. I apply the Leontief (1970) environmental IO model to consider the treatment and supply of a natural resources (water) rather than waste cleaning to provide a clean environment. I explore how the Leontief (1970) model and a number of further methodological developments, culminating in the Allan et al. (2007) study (which made the greatest advances in actually operationalising the Leontief framework) may be applied to consider the specific set of issues that may be relevant in the case of supplying a physical resource like water. I focussed on issues around the assumptions of prices faced by different users of a given sector in the IO model. I find that the price paid per physical amount of water appears to vary greatly amongst different uses. In addition, I find that the production side of the economy is heavily subsidised by household. As a result, households are paying far too much for water than implied by their demand. I argue that policy makers and regulators may make valuable use of this type of framework and approach in understanding the demands on and supply of UK regional water resources, their role in supporting economic expansion, and the role of potential government intervention where there are issues preventing efficient market provision of resource treatment and supply.

5.3 Contributions to IO literature and policy debate

In addition to the proposed directions and plan for future research I discuss in Section 5.4, my thesis makes a number of contributions adding to the literature on applications of environmental IO framework and to policy debates centred on economic-environmental issues and economy-wide implications of using the environment to meet some type of economic needs.

In Chapter 2, I conduct a comparative regional analysis of the structure of direct and indirect waste generation and I discuss how this is driven by different types (domestic or export demand) of final demand for the output of regional production sectors. This presents an original contribution to the development and application of regional-specific waste IO framework for Scotland. Chapter 2 has addressed a policy issue of which economic sectors may be considered responsible for waste generation. It also provided an understanding of the consumption patterns which ultimately drive production and its related waste pressures. Unlike previous studies that apply IO accounting measures to identify and track CO_2 embedded in complex economic interactions, supply chains, and international trade flows, I shift focus away from a global pollutant (CO_2) and toward a local pollutant (waste). I attempt to address a fundamental issue of what IO measures are appropriate when we consider local pollutants. There are at least three main practical and empirical contributions in this chapter to the IO literature. First, following Turner et al. (2014), I show that the production based and partial consumption based accounting measures are more appropriate for local pollutants. Second, traditional 'attribution' approaches of applying the environmental IO analysis mostly employ aggregated data. However, in Chapter 2, I conduct a relatively highly disaggregated IO analysis (identifying 97 IO sectors) with the help of improved data on the amount of waste generated by each production sector, mapping onto the Scottish IO sectoral breakdown that is consistent with 2007 SIC. I argue that this approach may be more appropriate for informing local policy makers given its level of detail and hence its ability to support local policy concerns. Overly aggregated IO data may undermine and marginalise the actual contribution to waste generation of each individual sectors, especially if the focus is on monitoring and understanding the nature and structure of pollution or waste problem at the regional level.

Recall that I mentioned that Chapter 2 is based on previous work done with policy analysts within the Scottish Government and ZWS. Both organisations were interested in a possible way to understand the interaction between the waste generated and the economy. In this chapter. I have shown how IO accounting methods is an excellent means for analysing priority environmental problems and has multiple potential uses that may add to the existing analytical capacity available to policymakers. In this context, given the awareness and interest of policy analysts and decision-makers in the UK, as well as that of the wider regional and environmental IO research communities, my thesis contributes by demonstrating ability of the IO methods to appropriately and transparently address some economic-environmental issues. Overall, the information from Chapter 2 may prove useful if regional policy makers attempt to consider waste reduction through consumption-focused polices as well as production-based ones.

In Chapter 3, by revisiting,reevaluting and extending a previous Scottish study by Allan et al. (2007) to operationalise the Leontief (1970) environmental IO model in considering the resource costs implications of cleaning and disposing of physical waste in Scotland, I make a unique contribution to the IO literature, by demonstrating the value of redoing analysis. Moreover, I go further than Allan et al. (2007) and I consider the type of final consumers that bear the burden and ultimately pays the full resource cost for waste disposal and cleaning in the economy. In this way, I provide additional information, set out the level of usefulness of the full

Leontief (1997) model and arrive at new conclusions, that the final demand consumers in 'Waste management', 'Public Administration', and 'Health' sectors which is mainly the Government bearing more of the burden for waste cleaning than other final demand types. As a result, the resource cost of waste management may be pushed to local tax payers so that they bear the burden of the resource cost for waste disposal and cleaning.

In Chapter 4, I develop and apply an innovative method around regional IO tables that facilitates a better understanding of connections between scarce domestic water resources, complex industry supply chains, and regional economic growth. Specifically, I extend the conventional demand-driven IO model to develop a framework where the full resource costs of water use and the impacts of regulatory constraints may be examined.

Chapter 4 contributes to the IO literature in two ways. First, while there is a significant body of research using IO methods to consider water problems, it has largely focused on cases where water is acutely scarce and consideration of how water resources may be shared between regions. Chapter 4 focuses on economic development in regions that are relatively water abundant at least at the UK level, but are subject to regulatory constraint. Secondly, it builds on a solid theoretical framework developed explicitly to deal with the true resource costs of market failure due to environmental problems. This framework has rarely been applied empirically due to data problems in identifying the economic transactions involved. I consider water a common resource (rather than the pollution for which this framework was initially used) where interaction between the sectors that supply and use water can be identified from regional accounts. This represents an original contribution to the development and application of a region-specific water IO framework for Wales.

I chose the above research areas explored in my thesis because I wish to develop the potential of IO methods to support already existing economic and environmental policies and/or inform new policy decision. However, the relevant application and value of the IO approach for this purpose has not been properly and fully assessed in informing policy decisions These types of economic-environmental issues become even more relevant with the ongoing Brexit negotiations. There are varying degrees of uncertainty on what the impacts of Brexit will have on every aspect of political life in the UK. From an economic-environmental policy perspective, an important layer and aspect of Brexit uncertainty is its impacts on economic and environmental policy. This raises an overarching question: will Brexit introduce additional issues to the economic and environmental system or will it be a source of new opportunities? The answer is clearly one that remains uncertain. However, in this present study, I provide evidence and results that may help regional devolved governments of Scotland and Wales to play a leading role in the UK in developing stringent economic and environmental policies and framework based on IO method in the event that powers return to the UK after on-going negotiations.

5.4 Limitation of the IO framework and the need for other and more advanced economy-wide models

Whilst, the primary focus of this study is to demonstrate the usefulness and added value of environmental IO method in addressing economic-environmental issue, I acknowledge that there a number of issues that in principle can be considered in an IO framework, but in practical sense will require other and advanced macro-economic models. As such in this Section, I discuss some limitations of IO method and possible solutions through consideration on the extension and continuation of this current research.

From an empirical perspective, the study may be critiqued in terms of (1) how sufficient is the IO framework as an analytical tool given the focus on the internalisation of externalities and consideration of the economy wide implications of economic-environmental interaction. (2) Does the current study pay enough attention to relative price changes? (3) Would more advanced macroeconomic models be required or more appropriate and sufficient to address the research aims and objectives in this study? These questions are all very relevant and I reflect on them in the following discussions. First, it is the singular objective of this study to demonstrate how the IO framework and methods are a useful first step in considering economy-wide or system wide implications of internalisation of externalities before considering extension to more advance macroeconomic models. IO provides the basis for simple but transparent 'multiplier' modelling methods that may provide useful preliminary insights on the potential economy-wide impacts of economic-environmental interaction.

Secondly, overall, in this study, I have focussed on considering payment regimes where the 'Polluter' or 'User' is responsible for paying the resource cost of using input from and output to the environment using IO methods. However, in the context of continuation of the research, when we begin to consider if someone else (e.g. government) other than the 'Polluter' or the 'User' pays that resource cost, the game changes and I acknowledge that for such analysis, IO may no longer be appropriate and we need to move to a SAM framework. A key feature of SAM is that it provides a more comprehensive representation of information on flows of incomes transfers and payments/receipts between sectors, institutions and factors of production within an economy (Stone, 1986). Within the SAM, we can begin to address questions like who funds the government, if government pays all waste management cost? And how do we capture the effects on domestic incomes and prices?

Moreover, other advanced macroeconomic models such as the CGE that can facilitate the continuation of this research in addressing a range of economic-environment scenarios are traditionally calibrated using SAM. Thus, indeed, this study can benefit from more flexible models with less restrictive assumptions. While there are other advance macroeconomic models relative to IO, I consider CGE as the ultimate method for continuation and extension of my research for two main reason. First, IO tables and methods constitute both a key elements of national accounts and the core structural database of CGE modelling framework to consider the economic implications of a range of potential economic, technological and policy developments. Secondly, I consider the application of CGE modelling techniques as a continuation of the current research as it allow us to endogenise both price and quantity determinations and to model alternative investment decisions across industries (Lecca et al. 2013). It also allows us to build in constraints on selected sectors and more generally, for example, in the supply of labour and/or capital across different timeframes) and to model the adjustment of the economy over time. Analyses of the potential impacts of investment decisions in e.g. water industry over time are likely to be of particular interest to regulator and industry stakeholders.

5.5 Directions and plan for future research initiatives

Based on my thesis, there are a number of potential avenues to be taken which may facilitate the direction of future research. However, I focus on three future research initiatives that I believe are feasible, immediately workable and already in progress in some respects.

An overarching question is whether this type of analysis in this study can benefit other externalities (e.g. air pollution). For future research, I propose that similar or even the same method applied in this study, may play a potential role in thinking of and considering carbon capture and storage (CCS) and CO_2 utilisation. Leontief's idea about establishing new economic activities that 'deal' with pollution problems provides the basis for introducing recycling processes more generally, and CO_2 utilisation in the context of a circular economy IO framework. Interestingly, not long after my Viva examination, I became involved in an impact accelerator project (internal funded projected) that I consider as a follow up and continuation of the analysis to this study. The project is titled 'Making the macroeconomic case for energy policy actions? Energy efficiency and CCS in the UK'. The anticipated impact is in the area of helping energy policy analysts understand how proposed policy actions may be assessed using the type of economy-wide modelling frameworks employed by policy departments that are responsible for allocating support across a range of competing policy demands. The pathways to this impact extend to helping develop communication and understanding between different policy departments and stakeholders in this regard.

As a result of my involvement in the on-going project, it has been a good learning experience for me especially in terms of going back to the Leontief (1970) model to consider the possibility for exploring its application to other pollutants order than the ones I have considered in this study. In the on-going project, we are considering carbon capture processes as a first stage of either a disposal or recycling/utilisation process so that they would share characteristics of Leontief's 'cleaning' (or disposal) sector. Where transport and storage are also required before, during or after utilisation (e.g. enhanced oil recovery using CO_2 in the North Sea would require pipeline transport before utilisation and storage after) these will become part of or form additional 'cleaning' sector(s). CCS activity does not currently exist as a sector in the economy, thus, when we focus on new activity using the IO system the game changes the analysis become complicated and a number of issues arise. For instance, how do we rebalance the IO tables when we introduce a new sector into the IO tables. How do we capture final demand for CCS? At the current stage of the project, these are the main issues we are addressing. It is worth mentioning, that once we can address these aforementioned issues we are taking a new development in IO analysis, which to the best of our knowledge has not been previous done.

Secondly, linked to the discussion in the previous paragraphs, I also have interested to test the applicability of the analysis in this study to wider/other common pool resource issues. Allan et .al (2007) have suggested that highways and irrigation system as explorable areas in this context. In Chapter 4 of this study, I have already began taking another or second step in considering other common pool resources. In this case public water supply. It will also be interesting to see what are the likely challenges when addressing other common pool resources that are not clearly identified in the IO accounts. In this regard, there may be possibility to look into rare metals This may then boil down to breaking out and disaggregating data for fuller details of activity. Moreover, it may provide some opportunities to begin to think of other ways to expand and explore other new dimensions of the IO framework. For instance, to consider hydrogen and unconventional oil and gas using the IO framework in the first instance to help policy makers and other stakeholders get transparent representation of the functioning of the economy under different policy objective and pathways.

On a concluding note, through the analysis conducted in this study and the main findings and results, I take the position that policy makes need to recognise the value of supporting policy objectives and decisions with appropriate tools that may provide a clear picture of economic-environmental interaction and the economy-wide implications of using the environmental to meet various economic needs. In addition, I propose that this research may be viewed as a practical guide in terms of the application of the Leontief (1970) economic model in the estimation of the resource cost of environmental protection and the economy-wide implications of taking input from and returning outputs to the environment to meet various economic needs. Finally, the proposed future work discussed above are reliant on a key factor, which is available of the appropriate data. Specifically, regional specific IO tables and environmental impact data. A key recommendation of this thesis is that policy makers and appropriate statistical authorities should invest in the construction of region and country specific environmental and natural resource accounts that are consistent with IO format structure. This is a fundamental part of the application of multi-sectoral modelling in order to provide useful insights into policy outcomes on the impacts of economic activity on the environment and the subsequent implications to the economic from using or polluting the environment.

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Appendices

Appendix 1a: Classification of the 97 IO industry (IOC) group in Scottish IO tables by SIC (2007) classes

SIC07 Section		Input-Output Classification		Standard Industrial Classification of Economic Activities 2007					
Agriculture, forestry and fishing	A	1	Agriculture, hunting and related services	01					
		2	Silviculture and other forestry activities and support services	02.1	02.4				
		3	Logging and gathering	02.2	02.3				
		4	Marine and freshwater fishing	03.1					
		5	Marine and freshwater aquaculture	03.2					
Mining and quarrying	B	6	Coal and lignite	05					
		7	Crude petroleum, natural gas and metal ores; other mining and quarrying	06	07	08			
		8	Mining support services	09					
Manufacturing	C	9	Preserved meat and meat products	10.1					
		10	Processed and preserved fish, crustaceans, molluscs, fruit and vegetables	10.2	10.3				
		11	Dairy products, vegetable and animal oils and fats	10.4	10.5				
		12	Grain mill products, starches and starch products	10.6					
		13	Bakery and farinaceous products	10.7					
		14	Other food products	10.8					
		15	Prepared animal feeds	10.9					
		16	Alcoholic beverages - spirits, wines and cider	11.01	11.02	11.03	11.04		
		17	Alcoholic beverages - beer and malt	11.05	11.06				
		18	Soft drinks	11.07					
		19	Tobacco products	12					
		20	Textiles	13					
		21	Wearing apparel	14					
		22	Leather and related products	15					
		23	Wood and of products of wood and cork, except furniture; articles of straw and plaiting materials	16					
		24	Paper and paper products	17					
		25	Printing and recording services	18					
		26	Coke, refined petroleum products and petrochemicals	19	20.14	20.16	20.17	20.6	
		27	Paints, varnishes and similar coatings, printing ink and mastics	20.3					
		28	Soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations	20.4					
		29	Other chemical products	20.5					
		30	Industrial gases, inorganic chemicals, fertilisers, dyestuffs and agrochemicals	20.11	20.12	20.13	20.15	20.2	
		31	Basic pharmaceutical products and pharmaceutical preparations	21					
		32	Rubber and plastic products	22					
		33	Manufacture of cement, lime, plaster and articles of concrete, cement and plaster	23.5	23.6				
		34	Glass, refractory, clay, other porcelain and ceramic, stone and abrasive products	23.1	23.2	23.3	23.4	23.7	23.9
		35	Basic iron and steel	24.1	24.2	24.3			
		36	Other basic metals and casting	24.4	24.5				
		37	Fabricated metal products, including weapons and ammunition	25					
		38	Computer, electronic and optical products	26					
		39	Electrical equipment	27					
		40	Machinery and equipment not elsewhere classified	28					
		41	Motor vehicles, trailers and semi-trailers	29					
		42	Other transport equipment	30					
		43	Furniture	31					
		44	Other manufactured goods	32					
		45	Repair and installation of machinery and equipment	33					
Electricity, Gas, Steam and Air Conditioning supply	D	46	Electricity; generation, transmission, distribution and trade	35.1					
		47	Gas; distribution of gaseous fuels through mains; steam and air conditioning supply	35.2	35.3				
Water Supply, Sewerage, Waste Management and Remediation	E	48	Natural water treatment and supply services, sewerage services	36	37				
		49	Waste collection, treatment and disposal; materials recovery; remediation and other waste management	38	39				

Appendix 1a. Continued

SIC07 Section		Input-Output Classification		Standard Industrial Classification of Economic Activities 2007		
Construction	F	50	Construction	41	42	43
Wholesale and Retail Trade; Repair of Motor Vehicles and Motorcycles	G	51	Wholesale and retail trade and repair services of motor vehicles and motorcycles	45		
		52	Wholesale trade services, except of motor vehicles and motorcycles	46		
		53	Retail trade services, except of motor vehicles and motorcycles	47		
Transportation and Storage	H	54	Rail transport services	49.1	49.2	
		55	Land transport services and transport services via pipelines, excluding rail transport	49.3	49.4	49.5
		56	Water transport services	50		
		57	Air transport services	51		
		58	Warehousing and support services for transportation	52		
		59	Postal and courier services	53		
Accommodation and Food Service activities	I	60	Accommodation services	55		
		61	Food and beverage serving services	56		
Information and Communication	J	62	Publishing services	58		
		63	Motion picture, video & tv programme production, sound recording & music publishing activities; programming and broadcasting activities	59	60	
		64	Telecommunications services	61		
		65	Computer programming, consultancy and related services	62		
		66	Information services	63		
Financial and Insurance activities	K	67	Financial services, except insurance and pension funding	64		
		68	Insurance, reinsurance and pension funding services, except compulsory social security and pension funding	65		
		69	Services auxiliary to financial services and insurance services	66		
Real Estate activities	L	70	Real estate services, excluding on a fee or contract basis and imputed rent	68.1	68.2	
		71	Imputed rent services	-		
		72	Real estate activities on a fee or contract basis	68.3		
Professional, Scientific and Technical activities	M	73	Legal services	69.1		
		74	Accounting, bookkeeping and auditing services; tax consulting services	69.2		
		75	Services of head offices; management consulting services	70		
		76	Architectural and engineering services; technical testing and analysis services	71		
		77	Scientific research and development services	72		
		78	Advertising and market research services	73		
		79	Other professional, scientific and technical services	74		
		80	Veterinary services	75		
Administrative and Support Service activities	N	81	Rental and leasing services	77		
		82	Employment services	78		
		83	Travel agency, tour operator and other reservation services and related services	79		
		84	Security and investigation services	80		
		85	Services to buildings and landscape	81		
		86	Office administrative, office support and other business support services	82		
Public Administration and Defence	O	87	Public administration and defence services; compulsory social security services	84		
Education	P	88	Education services	85		
Human Health and Social Work activities	Q	89	Human health services	86		
		90	Residential care activities and social work activities without accommodation	87	88	
Arts, Entertainment and Recreation	R	91	Creative, arts and entertainment services	90		
		92	Libraries, archives, museums and other cultural services	91		
		93	Gambling and betting services	92		
		94	Sports services and amusement and recreation services	93		
Other Service activities	S	95	Services furnished by membership organisations	94		
		96	Repair services of computers and personal and household goods	95		
		97	Other personal services	96		
Activities of Households	T	98	Services of households as employers of domestic personnel	97		

Appendix 2a: Direct, total direct waste generation and % share of total direct waste generation for all 97 sectors in Scotland 2011

Sector number	Sector name	Direct	Total Direct Waste Generated	Share of Total Direct Waste generated
1	Construction	319.33	6,051,440.01	57.14%
2	Electricity	60.36	495,250.81	4.68%
3	Retail	37.92	338,224.28	3.19%
4	Wholesale	37.92	312,094.51	2.95%
5	Mining Support	40.91	281,504.22	2.66%
6	Spirits & wines	63.24	231,352.94	2.18%
7	Agriculture	68.73	194,969.24	1.84%
8	Food & beverage services	43.74	170,873.77	1.61%
9	Water and sewerage	133.93	165,646.38	1.56%
10	Education	14.16	119,030.00	1.12%
11	Fabricated metal	43.67	117,422.50	1.11%
12	Health	9.25	110,793.23	1.05%
13	Wholesale & Retail	37.92	102,843.21	0.97%
14	Wood and wood products	108.17	99,482.71	0.94%
15	Accommodation	43.74	93,946.23	0.89%
16	Gas	60.36	90,185.25	0.85%
17	Public administration	6.26	87,776.00	0.83%
18	Textiles	106.69	81,735.38	0.77%
19	Meat processing	63.24	81,088.04	0.77%
20	Fish & fruit processing	63.24	69,727.95	0.66%
21	Bakery & farinaceous	63.24	62,494.58	0.59%
22	Residential care and social work	9.25	57,700.77	0.54%
23	Employment services	25.91	49,095.68	0.46%
24	Coke, petroleum & petrochemicals	6.63	47,586.79	0.45%
25	Imputed rent	5.24	47,424.05	0.45%
26	Sports & recreation	36.08	45,050.32	0.43%
27	Architectural services	6.73	41,413.48	0.39%
28	Gambling	36.08	41,378.29	0.39%
29	Dairy products, oils & fats	63.24	38,602.18	0.36%
30	Rental and leasing services	25.91	38,313.17	0.36%
31	Other land transport	10.34	36,400.59	0.34%
32	Wearing apparel	106.69	35,692.32	0.34%
33	Support services for transport	10.34	34,294.59	0.32%
34	Building services	25.91	31,716.21	0.30%
35	Paper & paper products	32.52	29,600.26	0.28%
36	Business support services	25.91	28,991.04	0.27%
37	Other transport equipment	11.59	28,255.18	0.27%
38	Other food	63.24	27,525.86	0.26%
39	Travel & related services	25.91	25,728.29	0.24%
40	Real estate - own	5.24	25,528.78	0.24%
41	Aquaculture	68.73	25,236.28	0.24%
42	Machinery & equipment	11.59	25,112.65	0.24%
43	Computers, electronics	11.59	24,686.20	0.23%
44	Oil & gas extraction, metal	40.91	22,300.32	0.21%
45	Repair & maintenance	14.57	21,907.01	0.21%
46	Other personal services	20.54	21,089.74	0.20%
47	Telecommunications	6.72	21,019.39	0.20%
48	Soft Drinks	63.24	18,736.59	0.18%
49	Fishing	68.73	18,100.79	0.17%

Appendix 2a Continued

Sector number	Sector name	Direct	Total Direct Waste Generated	Share of Total Direct Waste generated
50	Glass, clay & stone	36.65	16,189.38	0.15%
51	Forestry harvesting	68.73	13,900.12	0.13%
52	Creative services	36.08	13,413.89	0.13%
53	Membership organisations	20.54	13,072.81	0.12%
54	Insurance & pensions	1.61	12,603.82	0.12%
55	Computer services	6.72	12,253.25	0.12%
56	Cultural services	36.08	12,149.50	0.11%
57	Printing and recording	32.52	11,973.85	0.11%
58	Post & courier	10.34	11,578.51	0.11%
59	Financial services	1.61	11,532.27	0.11%
60	Air transport	10.34	11,093.18	0.10%
61	Coal & lignite	40.91	10,981.74	0.10%
62	Cement lime & plaster	36.65	10,880.57	0.10%
63	Head office & consulting services	6.73	10,538.10	0.10%
64	Iron & Steel	43.67	10,388.38	0.10%
65	Rail transport	10.34	9,700.11	0.09%
66	Electrical equipment	11.59	8,938.25	0.08%
67	Water transport	10.34	8,862.02	0.08%
68	Forestry planting	68.73	8,844.17	0.08%
69	Waste management	5.42	8,586.37	0.08%
70	Leather goods	106.69	8,115.18	0.08%
71	Other manufacturing	14.57	8,067.34	0.08%
72	Beer & malt	63.24	7,978.01	0.08%
73	Animal feeds	63.24	7,521.18	0.07%
74	Legal activities	6.73	7,319.03	0.07%
75	Other metals & casting	43.67	6,336.39	0.06%
76	Research & development	6.73	5,782.52	0.05%
77	Accounting & tax services	6.73	5,740.96	0.05%
78	Security & investigation	25.91	5,704.61	0.05%
79	Motor Vehicles	11.59	4,847.21	0.05%
80	Grain milling & starch	63.24	3,894.52	0.04%
81	Other professional services	6.73	3,801.53	0.04%
82	Real estate - fee or contract	5.24	3,724.17	0.04%
83	Repairs - personal and household	20.54	3,715.80	0.04%
84	Publishing services	6.72	3,185.84	0.03%
85	Film video & TV etc; broadcasting	6.72	2,854.77	0.03%
86	Furniture	14.57	2,286.06	0.02%
87	Auxiliary financial services	1.61	2,009.91	0.02%
88	Advertising & market research	6.73	1,736.01	0.02%
89	Veterinary services	6.73	1,321.37	0.01%
90	Information services	6.72	1,099.75	0.01%
91	Rubber & Plastic	0.01	15.65	0.00%
92	Pharmaceuticals	0.01	13.36	0.00%
93	Inorganic chemicals, dyestuffs	0.01	3.62	0.00%
94	Other chemicals	0.01	3.23	0.00%
95	Cleaning & toilet preparations	0.01	1.58	0.00%
96	Paints, varnishes and inks	0.01	0.53	0.00%
97	Tobacco	0.00	0	0.00%
	Total	3255.69	10,590,928.48	100%

Appendix 2b: Direct, indirect and Type I output-waste multipliers

Sector number	Sector name	Direct	Indirect	Total
1	Construction	319.33	104.25	423.58
2	Water and sewerage	133.93	23.49	157.42
3	Wood and wood products	108.17	45.34	153.51
4	Textiles	106.69	32.82	139.51
5	Wearing apparel	106.69	27.09	133.78
6	Leather goods	106.69	27.21	133.90
7	Agriculture	68.73	26.90	95.63
8	Forestry planting	68.73	35.18	103.91
9	Forestry harvesting	68.73	61.44	130.17
10	Fishing	68.73	14.26	82.98
11	Aquaculture	68.73	21.43	90.15
12	Meat processing	63.24	49.88	113.11
13	Fish & fruit processing	63.24	30.33	93.56
14	Dairy products, oils & fats processing	63.24	51.28	114.52
15	Grain milling & starch	63.24	39.38	102.61
16	Bakery & farinaceous	63.24	21.00	84.23
17	Other food	63.24	28.21	91.45
18	Animal feeds	63.24	27.41	90.65
19	Spirits & wines	63.24	12.68	75.91
20	Beer & malt	63.24	13.77	77.01
21	Soft Drinks	63.24	20.64	83.87
22	Electricity	60.36	54.96	115.31
23	Gas etc	60.36	14.24	74.59
24	Accommodation	43.74	19.07	62.81
25	Food & beverage services	43.74	17.83	61.57
26	Iron & Steel	43.67	17.52	61.19
27	Other metals & casting	43.67	21.88	65.56
28	Fabricated metal	43.67	18.67	62.34
29	Coal & lignite	40.91	32.86	73.77
30	Oil & gas extraction, metal ores & other	40.91	18.88	59.79
31	Mining Support	40.91	41.56	82.47
32	Wholesale & Retail - vehicles	37.92	11.16	49.09
33	Wholesale - excl vehicles	37.92	19.25	57.18
34	Retail - excl vehicles	37.92	25.59	63.51
35	Cement lime & plaster	36.65	28.50	65.15
36	Glass, clay & stone etc	36.65	22.70	59.35
37	Creative services	36.08	14.51	50.58
38	Cultural services	36.08	21.87	57.95
39	Gambling	36.08	5.62	41.70
40	Sports & recreation	36.08	13.77	49.85
41	Paper & paper products	32.52	31.38	63.90
42	Printing and recording	32.52	18.98	51.50
43	Rental and leasing services	25.91	8.12	34.03
44	Employment services	25.91	7.02	32.93
45	Travel & related services	25.91	19.28	45.19
46	Security & investigation	25.91	6.32	32.23
47	Building & landscape services	25.91	9.98	35.90
48	Business support services	25.91	6.98	32.89

Appendix 2b Continued

Sector number	Industry	Direct	Indirect	Total
49	Membership organisations	20.54	15.10	35.64
50	Repairs - personal and household	20.54	8.80	29.35
51	Other personal services	20.54	8.91	29.46
52	Furniture	14.57	33.72	48.29
53	Other manufacturing	14.57	17.01	31.58
54	Repair & maintenance	14.57	13.16	27.73
55	Education	14.16	6.14	20.30
56	Computers, electronics & opticals	11.59	10.84	22.43
57	Electrical equipment	11.59	14.37	25.96
58	Machinery & equipment	11.59	18.93	30.51
59	Motor Vehicles	11.59	14.75	26.34
60	Other transport equipment	11.59	22.11	33.70
61	Rail transport	10.34	16.32	26.66
62	Other land transport	10.34	11.10	21.44
63	Water transport	10.34	19.22	29.56
64	Air transport	10.34	14.59	24.93
65	Support services for transport	10.34	14.84	25.18
66	Post & courier	10.34	11.11	21.45
67	Health	9.25	8.50	17.75
68	Residential care and social work	9.25	11.70	20.94
69	Legal activities	6.73	7.04	13.77
70	Accounting & tax services	6.73	4.77	11.50
71	Head office & consulting services	6.73	10.21	16.93
72	Architectural services etc	6.73	11.18	17.90
73	Research & development	6.73	11.06	17.78
74	Advertising & market research	6.73	7.44	14.17
75	Other professional services	6.73	5.85	12.58
76	Veterinary services	6.73	10.72	17.45
77	Publishing services	6.72	10.57	17.30
78	Film video & TV etc; broadcasting	6.72	11.14	17.86
79	Telecommunications	6.72	21.41	28.13
80	Computer services	6.72	6.91	13.63
81	Information services	6.72	7.51	14.23
82	Coke, petroleum & petrochemicals	6.63	5.59	12.21
83	Public administration & defence	6.26	18.98	25.23
84	Waste, remediation & management	5.42	18.32	23.75
85	Real estate - own	5.24	67.80	73.04
86	Imputed rent	5.24	17.71	22.95
87	Real estate - fee or contract	5.24	5.96	11.20
88	Financial services	1.61	9.42	11.03
89	Insurance & pensions	1.61	21.14	22.75
90	Auxiliary financial services	1.61	6.36	7.98
91	Paints, varnishes and inks etc	0.01	9.35	9.36
92	Cleaning & toilet preparations	0.01	14.72	14.73
93	Other chemicals	0.01	5.20	5.21
94	Inorganic chemicals, dyestuffs & agrochemicals	0.01	17.31	17.32
95	Pharmaceuticals	0.01	4.86	4.88
96	Rubber & Plastic	0.01	16.80	16.81
97	Tobacco	0.00	0.00	0.00

Appendix 2c: Type I waste attribution to final demand for industry output (tonnes)

Sector number	Sector name	Attributable to total final demand	Share attributable to total final demand	Breakdown by type of final consumption: Household	Government	Gross fixed Capital Formation	Non-resident households	Exports
1	Construction	4752981	44.9%	130,411	21	4,022,764	3,938	595,847
2	Retail	555939	5.2%	504,503	1,403	5,345	18,220	26,469
3	Mining Support	521075	4.9%	12,191	0	6,157	655	502,072
4	Electricity	374038	3.5%	211,861	0	6,657	618	154,903
5	Wholesale	335264	3.2%	142,243	1	15,274	4,236	173,509
6	Public administration	318206	3.0%	10,246	300,564	7,030	19	347
7	Real estate	257771	2.4%	227,868	0	86	1,443	28,374
8	Spirits & wines	244715	2.3%	22,436	0	947	710	220,623
9	Food & beverage services	214503	2.0%	182,698	0	880	30,232	693
10	Imputed rent	207656	2.0%	207,656	0	0	0	0
11	Health	201123	1.9%	15,104	185,884	3	111	21
12	Agriculture	154280	1.5%	78,129	0	11,247	1,091	63,814
13	Education	146559	1.4%	35,661	96,579	63	282	13,973
14	Water and sewerage	133492	1.3%	130,551	0	1,642	102	1,197
15	Insurance & pensions	120855	1.1%	55,077	0	203	273	65,303
16	Meat processing	111312	1.1%	55,244	0	186	632	55,250
17	Accommodation	106124	1.0%	56,510	0	78	49,085	451
18	Residential care and social work	91870	0.9%	31,106	60,624	18	0	121
19	Fish & fruit processing	85700	0.8%	23,404	0	111	260	61,926
20	Wholesale & Retail -	77424	0.7%	43,789	0	17,755	383	15,497
21	Fabricated metal	75242	0.7%	6,441	0	19,642	231	48,928
22	Coke, petroleum & petrochemicals	70970	0.7%	9,776	0	473	726	59,995
23	Bakery & farinaceous	68041	0.6%	30,259	0	-44	896	36,931
24	Financial services	67337	0.6%	4,658	0	336	36	62,306
25	Wood and wood products	66784	0.6%	10,123	0	2,180	363	54,119
26	Architectural services etc	65867	0.6%	1,462	11	14,633	100	49,661
27	Textiles	63884	0.6%	29,159	0	1,054	1,489	32,181
28	Other transport equipment	58926	0.6%	5,242	0	11,890	34	41,760
29	Gas etc	57574	0.5%	30,145	0	337	55	27,038
30	Dairy products, oils & fats processing	56809	0.5%	28,747	0	836	383	26,842
31	Sports & recreation	50400	0.5%	29,939	12,492	1,144	1,408	5,417
32	Telecommunications	50213	0.5%	27,514	2	3,524	462	18,711
33	Machinery & equipment	46790	0.4%	4,643	0	12,444	373	29,330
34	Wearing apparel	41207	0.4%	29,701	0	290	1,674	9,542
35	Gambling	37086	0.4%	30,478	23	695	1,346	4,545
36	Computers, electronics & opticals	31493	0.3%	2,974	0	4,004	60	24,455
37	Other land transport	28803	0.3%	15,808	0	361	656	11,979
38	Waste, remediation & management	27503	0.3%	549	12,913	104	9	13,927
39	Travel & related services	26046	0.2%	2,007	0	125	379	23,535
40	Other food	25958	0.2%	11,176	0	63	230	14,489
41	Paper & paper products	24490	0.2%	1,835	0	198	50	22,407
42	Rental and leasing services	24394	0.2%	9,821	1	155	570	13,847
43	Other personal services	23809	0.2%	22,450	6	260	304	788
44	Aquaculture	23307	0.2%	785	6	134	64	22,317
45	Support services for transport	22791	0.2%	2,324	0	1,055	152	19,260
46	Soft Drinks	21952	0.2%	15,750	0	-443	292	6,352
47	Employment services	20807	0.2%	388	320	390	3	19,706
48	Air transport	20024	0.2%	9,426	0	154	92	10,352

Appendix 2c continued

Sector number	Sector name	Attributable to total final demand (y)	Share of total waste attributed)	Breakdown by type of final consumption household	Government	Gross fixed Capital Formation	Non-resident households	Exports
49	Repair & maintenance	19652	0.2%	1,492	0	3,689	19	14,451
50	Computer services	18728	0.2%	532	257	2,961	19	14,959
51	Water transport	18540	0.2%	8,426	0	781	251	9,083
52	Business support services	17917	0.2%	1,087	414	1,350	22	15,043
53	Rail transport	17376	0.2%	15,202	0	125	806	1,244
54	Fishing	17173	0.2%	1,071	3	90	52	15,957
55	Cultural services	16712	0.2%	9,452	5,784	-541	1,405	612
56	Creative services	16105	0.2%	10,868	821	31	972	3,414
57	Other manufacturing	15227	0.1%	9,177	0	923	244	4,883
58	Membership organisations	12269	0.1%	11,869	19	79	16	285
59	Forestry harvesting	11811	0.1%	5,520	0	336	938	5,017
60	Glass, clay & stone etc	11610	0.1%	3,116	0	640	196	7,657
61	Printing and recording	10925	0.1%	1,323	24	326	305	8,946
62	Electrical equipment	10795	0.1%	1,721	0	1,983	42	7,049
63	Research & development	10439	0.1%	295	15	154	2	9,974
64	Rubber & Plastic	10049	0.1%	1,859	0	603	50	7,537
65	Oil & gas extraction, metal ores	9874	0.1%	1,156	0	286	50	8,382
66	Auxiliary financial services	9104	0.1%	397	0	64	12	8,632
67	Leather goods	8757	0.1%	4,892	0	47	424	3,393
68	Head office & consulting services	8616	0.1%	184	254	428	2	7,747
69	Motor Vehicles	8192	0.1%	3,459	0	1,775	17	2,940
70	Coal & lignite	8072	0.1%	507	0	2,481	27	5,056
71	Film video & TV etc; broadcasting	6697	0.1%	3,410	1,736	270	25	1,256
72	Building & landscape services	6481	0.1%	2,058	0	985	16	3,423
73	Real estate - fee or contract	6318	0.1%	331	0	4,947	39	1,002
74	Furniture	6258	0.1%	3,833	0	1,456	42	928
75	Iron & Steel	6137	0.1%	296	0	200	27	5,614
76	Publishing services	5941	0.1%	3,399	0	130	3	2,409
77	Beer & malt	5741	0.1%	1,929	0	46	96	3,670
78	Post & courier	4952	0.0%	2,229	1	85	210	2,428
79	Legal activities	4133	0.0%	149	0	841	2	3,140
80	Animal feeds	3992	0.0%	1,833	0	136	24	2,000
81	Other professional services	3810	0.0%	476	25	92	34	3,184
82	Cement lime & plaster	3504	0.0%	232	0	243	14	3,016
83	Repairs - personal and household	3326	0.0%	1,363	0	50	2	1,911
84	Grain milling & starch	3265	0.0%	1,690	0	21	28	1,525
85	Other metals & casting	2887	0.0%	161	0	389	8	2,329
86	Forestry planting	2645	0.0%	384	36	1,896	12	317
87	Veterinary services	2632	0.0%	2,622	0	6	0	4
88	Inorganic chemicals, s& agrochemicals	2477	0.0%	259	0	123	6	2,090
89	Accounting & tax services	2394	0.0%	32	6	57	0	2,298
90	Pharmaceuticals	2290	0.0%	246	0	29	8	2,007
91	Advertising & market research	1873	0.0%	31	1	-18	3	1,857
92	Cleaning & toilet preparations	1713	0.0%	875	0	30	16	792
93	Security & investigation	1712	0.0%	48	6	23	0	1,635
94	Information services	1270	0.0%	91	14	46	5	1,114
95	Other chemicals	1021	0.0%	220	0	32	3	767
96	Paints, varnishes and inks etc	134	0.0%	23	0	11	2	98
97	Tobacco	0	0.0%	0	0	0	0	0
	Total	10,590,938	100%	2,672,092	680,267	4,203,177	131,219	2,904,182

Appendix 3a: Sectoral aggregation scheme production sector activities identified in the Scottish IO Table 2011

	Sectors	Scottish IO Categories	SIC(2007) Codes
1	Agriculture, Forestry & Fishing	1--5	1-3.2
2	Mining & Quarrying	6--8	5--9
3	Food & Drink Manufacture	9--18	10.1-12
4	Textiles	20--22	13-15
5	Manufacturing of Wood Products	23	16
6	Paper & Printing	24--25	17-18
7	Coke & Petroleum	26	19
8	Chemical Manufacture	26--32	20-22
9	Non Metallic Minerals	33-34	23
10	Metals	35--37	24-25
11	Machinery & Equipment	38--42	26-30
12	Misc Manufacture	43--45	31-33
13	Electricity	46--47	35
14	Water Industry	48	36-37
15	Waste Management	49	38-39
16	Construction	50	41-43
17	Wholesale & Retail	51--53	45-47
18	Transport	54--59	49.1-53
19	Hotels & Restaurants	60--61	55-56
20	Communication	62--66	58-63
21	Finance	67--69	64-66
22	Real Estate	70--72	68.1-68.3
23	Professional & Scientific	73--80	69.1-75
24	Admin & Support	81--86	77-82
25	Public Admin	87	84
26	Education	88	85
27	Health & Social Work	89--90	86-88
28	Arts & Recreation	91--94	90-93
29	Other Service Activities	95--98	94-96

Appendix 3b: Scotland Industry-by-Industry (29x29) conventional IO tables for 2011 (£Million)

		Agriculture Forestry and Fishing	Mining and Quarry	Food & Drink Manufacture	Textile	Manufacturing of Wood	Paper and Printing	Coke, petroleum	Chemical Manufacture	Non Metallic Mineral	Metals	Machinery & Equipment	Misc Manufacture	Electricity	Water Industry
1	Agriculture Forestry and Fishing	431.9	3.0	906.4	0.9	66.1	5.0	5.0	11.7	0.6	1.6	3.5	0.8	6.9	0.1
2	Minning and Quarry	9.5	351.5	18.6	3.1	2.1	4.7	19.0	16.7	81.2	8.1	14.5	17.1	151.9	0.7
3	Food Drink & Manufacture	82.0	5.8	562.4	9.1	1.1	2.2	14.5	5.1	1.7	5.0	11.1	2.4	4.6	0.6
4	Textiles	9.6	1.2	16.2	163.1	1.3	19.8	1.9	14.2	0.9	2.1	7.9	2.7	0.6	0.3
5	Manufacturing of Wood	2.5	3.1	8.5	4.3	137.6	3.8	4.4	3.4	2.0	9.5	29.2	14.5	0.7	0.1
6	Paper and Printing	15.3	1.4	92.3	8.3	7.2	149.7	5.0	49.3	4.6	8.0	15.8	3.7	4.1	1.6
7	Coke & Petroleum	86.0	80.6	49.7	15.8	14.3	19.0	146.4	92.1	19.5	19.0	41.5	12.7	41.6	5.0
8	Chemical Manufacture	122.4	11.4	109.9	18.2	12.1	19.5	86.6	208.9	5.3	20.9	89.9	25.1	2.9	3.0
9	Non Metallic Minerals	9.5	15.3	50.9	0.3	4.1	0.1	4.6	23.6	23.6	10.2	12.6	1.1	1.2	0.6
10	Metals	15.7	65.5	78.5	6.8	15.4	1.4	42.4	59.1	8.6	364.4	462.9	55.2	43.9	1.3
11	Machinery & equipment	58.3	88.9	58.3	8.0	16.2	12.4	44.1	34.8	6.7	72.8	783.9	98.9	84.3	5.7
12	Misc Manufacture	15.3	45.1	28.3	3.6	10.0	4.1	26.6	19.8	2.5	33.7	249.4	29.3	14.9	3.0
13	PoIr Industry	41.9	322.2	149.0	16.8	15.9	102.3	24.9	55.8	51.0	81.2	161.4	30.5	3618.8	13.3
14	Water Industry	17.7	8.2	17.4	2.2	0.8	3.6	12.3	3.8	1.5	3.5	6.3	2.5	31.1	81.6
15	Waste management	1.4	1.8	6.2	4.2	0.7	2.1	1.4	1.4	1.0	5.7	2.7	1.0	1.2	15.8
16	Construction	49.9	475.5	25.7	7.0	9.7	11.2	11.0	6.7	3.9	15.0	38.9	20.2	80.4	28.8
17	Wholesale and Retail	176.1	66.8	272.6	53.2	26.1	39.3	293.4	126.5	29.5	138.2	355.3	70.3	121.1	6.8
18	Transport	89.4	271.5	192.1	25.3	28.1	41.9	18.0	33.9	31.7	49.7	59.6	30.3	19.6	5.4
19	Hotel and Restaurant	8.5	27.2	12.4	1.3	1.5	1.1	2.7	2.0	0.7	0.7	36.3	2.3	10.7	0.7
20	Communication	14.0	19.1	25.8	4.6	2.4	6.2	2.8	8.1	2.0	7.8	24.2	11.4	18.2	3.9
21	Finance	60.1	50.5	37.7	8.4	8.5	7.3	7.1	14.4	4.9	16.9	38.5	12.8	32.5	7.8
22	Real Estate	33.5	5.4	5.3	1.7	1.9	2.4	0.5	1.9	0.5	5.8	8.4	2.7	9.7	2.1
23	Professional & Scientific	73.8	355.2	120.0	17.6	6.5	12.9	23.1	33.1	4.8	23.1	128.1	37.3	72.8	9.7
24	Admin Support	12.3	214.4	57.7	5.1	5.1	7.6	11.8	12.6	5.2	21.5	54.9	124.0	45.6	6.2
25	Public administration & defence	4.1	11.0	12.6	1.9	1.2	1.5	1.1	5.9	0.5	8.4	9.8	3.6	4.7	1.9
26	Education	1.2	7.5	5.9	1.7	0.3	1.1	2.7	3.8	0.7	4.1	10.1	3.4	8.4	1.6
27	Health and Social Work	2.4	8.0	4.1	0.5	0.3	0.9	0.5	5.9	0.1	2.9	6.0	2.4	9.5	1.1
28	Art & Recreation	3.3	29.4	6.1	0.8	0.7	1.1	0.3	1.3	0.4	0.7	6.7	1.3	4.7	0.1
29	Other Services Activities	6.0	3.9	3.1	0.4	0.1	0.8	0.6	1.5	0.3	1.8	5.1	1.9	9.7	0.3
	Total Intermediate	1453.8	2550.3	2933.8	394.4	397.4	485.2	814.8	857.4	296.0	942.4	2674.2	621.4	4456.4	209.2
	Imports from rest of UK	816.7	964.7	1412.3	239.8	150.8	238.8	3772.8	429.2	117.6	483.7	1288.3	322.8	1326.1	55.1
	Imports from rest of world	170.9	221.3	565.0	80.1	55.7	85.4	1792.0	159.4	33.9	312.7	980.7	203.1	811.9	18.1
	Taxes less subsidies on products	88.0	135.2	123.9	19.2	14.6	21.1	149.9	92.9	19.1	22.1	53.7	14.0	158.5	9.8
	Taxes less subsidies on product	-611.0	8.8	26.1	6.4	9.0	12.2	14.7	25.3	8.8	29.8	43.7	18.5	172.6	38.5
	Compensation of employees	471.0	1118.2	2037.1	345.1	222.8	337.4	196.1	1059.9	233.4	972.5	2222.5	765.9	714.9	278.8
	Gross operating surplus	1409.2	2696.0	1582.4	91.7	69.3	98.4	442.5	692.1	29.8	308.4	661.5	267.7	2059.5	627.3
	Total Primary Input	2344.7	5144.1	5746.8	782.3	522.3	793.2	6368.0	2458.8	442.6	2129.2	5250.4	1592.1	5243.4	1027.6
	Total Input	3798.5	7694.4	8680.5	1176.7	919.7	1278.4	7182.9	3316.2	738.6	3071.6	7924.6	2213.4	9699.8	1236.8

Appendix 3b continued

		Waste, management	Construction	Wholesale and Retail	Transport	Hotels and Restaurants	Communication	Finance	Real Estate	Professional & Scientific	Admin Support	Public administration & defence	Education	Health and Social Work	Art & Recreation	Other Services Activities
1	Agriculture Forestry and Fishing	0.4	18.4	20.9	6.6	90.3	1.0	2.5	0.9	2.1	1.0	3.2	2.2	9.1	0.9	0.6
2	Mining and Quarry	3.5	222.9	57.3	17.9	9.0	5.4	11.0	7.6	19.6	9.0	13.3	5.6	17.4	1.7	1.8
3	Food Drink & Manufacture	2.2	13.5	161.7	20.0	506.5	4.8	13.7	0.7	12.6	9.8	15.2	17.7	56.8	8.8	5.3
4	Textiles	0.6	18.4	25.9	5.3	4.7	2.6	5.4	0.8	3.2	1.9	16.0	2.8	13.0	1.2	1.8
5	Manufacturing of Wood	0.4	221.9	7.4	2.4	4.6	0.7	4.3	1.2	2.5	4.3	1.8	5.6	1.9	1.3	0.7
6	Paper and Printing	2.9	21.0	47.6	11.0	8.4	23.2	49.1	4.8	18.6	6.3	58.8	17.8	37.6	6.8	2.9
7	Coke & Petroleum	2.5	38.6	94.2	356.9	32.7	15.9	20.8	1.3	27.3	16.0	57.5	16.2	39.0	5.9	4.5
8	Chemical Manufacture	3.8	201.0	91.3	57.1	8.1	17.9	14.2	2.5	13.1	16.6	28.7	15.1	559.6	6.8	7.5
9	Non Metallic Minerals	2.9	270.0	20.7	5.1	1.2	0.9	0.4	0.5	0.5	1.7	10.5	10.1	3.4	3.1	0.6
10	Metals	14.8	354.4	35.3	17.8	1.9	4.8	6.1	3.0	4.1	3.4	35.6	6.9	8.1	1.7	1.6
11	Machinery & equipment	14.9	335.1	90.3	116.3	6.9	37.8	21.7	5.2	19.3	20.5	359.7	13.1	81.7	7.2	8.7
12	Misc Manufacture	3.1	170.4	24.4	61.4	3.4	13.8	10.9	2.6	10.2	6.8	57.9	8.8	27.1	4.1	2.6
13	Electricity Industry	7.1	94.9	192.4	67.0	45.5	36.3	67.4	60.3	63.0	36.1	109.8	57.4	119.8	34.0	8.0
14	Water Industry	29.3	8.0	7.7	3.9	4.3	2.4	30.4	2.2	4.3	5.7	31.5	11.8	44.8	7.0	2.9
15	Waste management	166.2	12.3	15.1	7.0	7.0	4.0	5.7	1.8	7.8	7.4	92.4	5.0	41.7	1.9	3.0
16	Construction	26.4	4214.7	522.5	102.1	59.1	108.6	220.0	1087.2	71.5	37.9	349.0	30.0	75.1	26.1	15.3
17	Wholesale and Retail	27.1	414.6	355.9	198.2	114.1	59.2	100.0	17.3	42.3	82.3	171.2	36.9	233.6	19.7	17.6
18	Transport	45.2	165.3	1782.2	1584.8	108.3	116.9	625.6	29.9	149.6	113.6	327.3	84.9	191.9	21.6	18.0
19	Hotel and Restaurant	1.4	26.8	118.9	33.9	45.6	15.2	129.4	5.5	37.5	12.8	97.1	24.5	214.7	5.0	5.1
20	Communication	5.5	88.3	207.1	107.4	57.9	433.3	376.3	51.6	122.8	59.0	230.7	27.9	80.6	30.4	15.9
21	Finance	11.8	108.9	215.4	64.9	41.3	34.9	2000.0	478.4	56.2	33.8	181.0	14.2	90.8	11.8	9.3
22	Real Estate	6.8	121.2	473.0	53.0	34.7	34.4	240.2	51.0	27.0	21.7	223.9	15.4	85.2	9.3	9.1
23	Professional & Scientific	26.0	520.7	527.7	186.9	116.8	196.5	668.7	178.9	1144.1	311.6	420.0	58.6	276.8	58.3	63.6
24	Admin Support	52.2	430.6	361.6	311.4	129.1	172.7	369.4	63.4	436.6	581.5	189.3	166.1	228.7	104.8	44.2
25	Public administration	3.4	92.4	28.8	147.4	8.9	4.5	16.1	304.1	689.3	8.5	33.8	0.4	9.6	2.4	2.2
26	Education	2.5	17.1	27.4	37.3	16.4	39.5	94.4	11.0	104.1	20.2	280.4	429.9	36.4	6.7	12.1
27	Health and Social Work	1.4	5.6	12.7	7.9	12.9	10.1	63.5	0.2	20.3	5.8	25.0	9.8	2265.0	8.2	14.0
28	Art & Recreation	3.1	7.0	26.5	12.8	22.9	49.4	89.1	3.5	26.6	22.3	50.9	11.5	16.0	145.9	52.4
29	Other Services Activities	1.8	6.6	16.3	20.8	25.6	31.2	34.9	2.3	26.4	33.8	103.1	13.1	62.9	82.5	81.3
	Total Intermediate	469.3	8220.6	5568.0	3624.5	1528.0	1478.1	5291.3	2379.4	3162.5	1491.1	3574.4	1119.4	4928.2	625.0	412.5
a	Imports from rest of UK	250.2	2098.5	2510.4	1686.4	699.5	804.5	2364.2	1936.8	1344.9	964.2	2143.9	446.6	1588.1	272.7	186.1
b	Imports from rest of world	94.5	561.5	498.8	445.0	319.1	223.1	391.5	151.6	248.7	135.7	843.6	130.0	709.6	64.0	47.3
c	Taxes less subsidies on products	97.3	55.5	110.4	420.8	377.0	24.5	627.3	29.7	43.0	25.1	848.1	152.0	656.3	48.0	43.3
d	Taxes less subsidies on product	13.2	80.4	825.9	81.3	190.3	96.7	155.4	-16.1	70.3	69.5	0.0	19.1	18.7	53.4	33.2
e	Compensation of employees	458.4	5194.4	6879.5	3528.4	2011.2	2314.2	3730.8	599.0	4802.7	2753.0	5634.8	6081.5	8641.1	1016.1	699.6
f	Gross operating surplus	200.1	2739.2	3466.3	1037.5	929.9	1071.2	3657.6	9546.8	1869.6	1490.5	986.4	460.1	1682.9	1024.9	421.8
	Total Primary Input	1113.8	10729.5	14291.3	7199.3	4527.1	4534.1	10926.8	12247.8	8379.2	5437.9	10456.8	7289.3	13296.7	2479.1	1431.3
	Total Input	1583.1	18950.1	19859.3	10823.9	6055.1	6012.3	16218.1	14627.2	11541.8	6929.1	14031.2	8408.6	18224.9	3104.1	1843.8

Appendix 3b continued

		Total intermediate demand	Household	Government	Gross fixed Capital Formation	Stocks	Non-resident households	Rest of UK exports	Rest of world exports	Total demand	Gross Output
1	Agriculture Forestry & Fishing	1603.4	884.7	0.5	95.6	45.4	20.1	739.8	409.0	2195.0	3798.5
2	Mining & Quarry	1101.8	174.0	0.0	77.2	35.9	9.1	5249.2	1047.2	6592.7	7694.5
3	Food Drink & Manufacture	1557.1	2016.1	0.0	10.7	9.1	39.5	2219.1	2829.0	7123.4	8680.6
4	Textiles	345.4	467.6	0.0	8.2	1.9	26.4	143.2	184.1	831.3	1176.7
5	Manufacturing of Wood	484.6	65.9	0.0	9.3	4.9	2.4	303.2	49.4	435.0	919.7
6	Paper & Printing	683.0	54.4	0.5	8.1	1.3	6.7	297.4	227.0	595.4	1278.4
7	Coke & Petroleum	1372.4	800.4	0.0	5.3	33.4	59.5	1819.3	3092.6	5810.5	7182.9
8	Chemical Manufacture	1779.4	280.1	0.0	30.9	27.3	6.7	464.1	727.7	1536.8	3316.2
9	Non Metallic Minerals	489.2	56.1	0.0	9.8	4.7	3.5	84.4	90.9	249.4	738.6
10	Metals	1720.4	110.6	0.0	299.6	24.6	4.3	404.9	507.1	1351.2	3071.6
11	Machinery & Equipment	2511.4	637.9	0.0	1060.6	22.4	18.2	1453.4	2220.7	5413.2	7924.6
12	Misc Manufacture	893.1	423.7	0.0	193.6	-1.2	9.3	298.0	396.9	1320.4	2213.4
13	Poir Industry	5684.3	2241.4	0.0	61.1	1.2	6.1	1580.3	125.5	4015.5	9699.8
14	Water Industry	388.8	829.3	0.0	11.9	-1.5	0.6	5.6	2.0	848.0	1236.8
15	Waste Management	424.8	23.1	543.8	4.4	0.0	0.4	288.6	297.9	1158.2	1583.1
16	Construction	7729.3	307.9	0.0	9413.9	83.1	9.3	1232.2	174.5	11221.0	18950.3
17	Wholesale & Retail	3665.3	11323.1	22.1	712.9	0.1	368.8	1964.8	1802.3	16194.0	19859.3
18	Transport	6262.0	2167.0	0.0	99.5	0.4	88.8	1338.2	868.0	4562.0	10823.9
19	Hotel & Restaurant	881.4	3867.2	0.0	15.4	0.1	1272.6	13.4	5.0	5173.7	6055.1
20	Communication	2045.3	1411.1	117.1	368.7	-0.3	19.7	1410.0	640.7	3967.0	6012.3
21	Finance	3660.4	2892.6	0.0	47.4	0.1	16.8	7477.8	2123.1	12557.7	16218.1
22	Real Estate	1487.5	12195.9	0.0	442.7	-0.1	23.2	416.5	61.4	13139.7	14627.2
23	Professional & Scientific	5673.0	313.1	19.0	930.5	-6.8	8.9	3070.3	1533.8	5868.8	11541.8
24	Admin Support	4225.7	436.6	22.5	86.3	2.1	26.4	1547.5	582.0	2703.4	6929.1
25	Public Administration	1420.0	406.1	11912.1	278.5	0.1	0.7	10.1	3.6	12611.2	14031.2
26	Education	1187.9	1757.0	4758.4	4.9	-1.8	13.9	464.0	224.5	7220.8	8408.6
27	Health & Social Work	2507.1	2336.1	13367.5	1.0	0.0	6.2	5.3	1.7	15717.9	18225.0
28	Art & Recreation	596.9	1709.4	367.2	33.3	-2.4	104.0	203.3	92.4	2507.2	3104.1
29	Other Services Activities	578.0	1141.6	0.7	14.3	-1.5	10.9	67.4	32.5	1265.8	1843.8
	Total Intermediate	62958.9	51330.0	31131.4	14335.6	282.6	2182.7	34571.4	20352.5	154185.8	217145.1
	Imports from rest of UK	30915.7	13382.7	0.0	3595.1	181.1	595.7	3970.7	3118.7	24844.0	55759.8
	Imports from rest of world	10354.1	4457.9	0.0	1314.6	170.7	294.6	2981.9	55.3	9275.1	19629.2
	Taxes less subsidies on product	4480.3	7987.4	0.0	2068.2	0.0	477.6	0.0	0.0	10533.2	15013.4
	Taxes less subsidies on product	1494.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1494.5
	Compensation of employees	65320.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	65320.5
	Gross operating surplus	41620.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	41620.7
	Total Primary Input	154185.8	25828.1	0.0	6977.8	351.8	1367.9	6952.6	3174.0	44652.3	198838.1
	Total Input	217144.7	77158.1	31131.4	21313.4	634.5	3550.6	41524.0	23526.5	198838.1	415983.2

Appendix 3c: Scotland Industry-by-Industry (29x29) environmental IO tables for 2011 (£Million)

		Agricultur e Forestry and Fishing	Mining and Quarry	Food & Drink Manufacture	Textile	Manufacturing of Wood	Paper and Printing	Coke, petroleum	Chemical Manufacture	Non Metallic Mineral	Metals	Machinery & Equipment	Misc Manufacture	PoIr Industry	Water Indust ry
1	Agriculture Forestry and Fishing	431.9	3.0	906.4	0.9	66.1	5.0	5.0	11.7	0.6	1.6	3.5	0.8	6.9	0.1
2	Mining and Quarry	9.5	351.5	18.6	3.1	2.1	4.7	19.0	16.7	81.2	8.1	14.5	17.1	151.9	0.7
3	Food and Drink	82.0	5.8	562.4	9.1	1.1	2.2	14.5	5.1	1.7	5.0	11.1	2.4	4.6	0.6
4	Textiles	9.6	1.2	16.2	163.1	1.3	19.8	1.9	14.2	0.9	2.1	7.9	2.7	0.6	0.3
5	Manufacturing of Wood	2.5	3.1	8.5	4.3	137.6	3.8	4.4	3.4	2.0	9.5	29.2	14.5	0.7	0.1
6	Paper and Printing	15.3	1.4	92.3	8.3	7.2	149.7	5.0	49.3	4.6	8.0	15.8	3.7	4.1	1.6
7	Coke & Petroleum	86.0	80.6	49.7	15.8	14.3	19.0	146.4	92.1	19.5	19.0	41.5	12.7	41.6	5.0
8	Chemical Manufacture	122.4	11.4	109.9	18.2	12.1	19.5	86.6	208.9	5.3	20.9	89.9	25.1	2.9	3.0
9	Non Metallic Minerals	9.5	15.3	50.9	0.3	4.1	0.1	4.6	23.6	23.6	10.2	12.6	1.1	1.2	0.6
10	Metals	15.7	65.5	78.5	6.8	15.4	1.4	42.4	59.1	8.6	364.4	462.9	55.2	43.9	1.3
11	Machinery & equipment	58.3	88.9	58.3	8.0	16.2	12.4	44.1	34.8	6.7	72.8	783.9	98.9	84.3	5.7
12	Misc Manufacture	15.3	45.1	28.3	3.6	10.0	4.1	26.6	19.8	2.5	33.7	249.4	29.3	14.9	3.0
13	Electricity	41.9	322.2	149.0	16.8	15.9	102.3	24.9	55.8	51.0	81.2	161.4	30.5	3618.8	13.3
14	Water Industry	17.7	8.2	17.4	2.2	0.8	3.6	12.3	3.8	1.5	3.5	6.3	2.5	31.1	81.6
15	Waste management	31.3	37.7	65.8	15.1	11.9	5.0	5.7	0.0	3.2	16.1	11.0	3.9	70.2	19.9
16	Construction	49.9	475.5	25.7	7.0	9.7	11.2	11.0	6.7	3.9	15.0	38.9	20.2	80.4	28.8
17	Wholesale and Retail	176.1	66.8	272.6	53.2	26.1	39.3	293.4	126.5	29.5	138.2	355.3	70.3	121.1	6.8
18	Transport	89.4	271.5	192.1	25.3	28.1	41.9	18.0	33.9	31.7	49.7	59.6	30.3	19.6	5.4
19	Hotel and Restaurant	8.5	27.2	12.4	1.3	1.5	1.1	2.7	2.0	0.7	0.7	36.3	2.3	10.7	0.7
20	Communication	14.0	19.1	25.8	4.6	2.4	6.2	2.8	8.1	2.0	7.8	24.2	11.4	18.2	3.9
21	Finance	60.1	50.5	37.7	8.4	8.5	7.3	7.1	14.4	4.9	16.9	38.5	12.8	32.5	7.8
22	Real Estate	33.5	5.4	5.3	1.7	1.9	2.4	0.5	1.9	0.5	5.8	8.4	2.7	9.7	2.1
23	Professional & Scientific	73.8	355.2	120.0	17.6	6.5	12.9	23.1	33.1	4.8	23.1	128.1	37.3	72.8	9.7
24	Admin Support	12.3	214.4	57.7	5.1	5.1	7.6	11.8	12.6	5.2	21.5	54.9	124.0	45.6	6.2
25	Public administration &	4.1	11.0	12.6	1.9	1.2	1.5	1.1	5.9	0.5	8.4	9.8	3.6	4.7	1.9
26	Education	1.2	7.5	5.9	1.7	0.3	1.1	2.7	3.8	0.7	4.1	10.1	3.4	8.4	1.6
27	Health and Social Work	2.4	8.0	4.1	0.5	0.3	0.9	0.5	5.9	0.1	2.9	6.0	2.4	9.5	1.1
28	Art & Recreation	3.3	29.4	6.1	0.8	0.7	1.1	0.3	1.3	0.4	0.7	6.7	1.3	4.7	0.1
29	Other Services Activities	6.0	3.9	3.1	0.4	0.1	0.8	0.6	1.5	0.3	1.8	5.1	1.9	9.7	0.3
	Total Intermediate	1483.6	2586.3	2993.4	405.2	408.7	488.1	819.1	856.0	298.2	952.9	2682.5	624.3	4525.4	213.2
	Imports from rest of UK	816.7	964.7	1412.3	239.8	150.8	238.8	3772.8	429.2	117.6	483.7	1288.3	322.8	1326.1	55.1
	Imports from rest of world	170.9	221.3	565.0	80.1	55.7	85.4	1792.0	159.4	33.9	312.7	980.7	203.1	811.9	18.1
	Taxes less subsidies on products	88.0	135.2	123.9	19.2	14.6	21.1	149.9	92.9	19.1	22.1	53.7	14.0	158.5	9.8
	Taxes less subsidies on product	-611.0	8.8	26.1	6.4	9.0	12.2	14.7	25.3	8.8	29.8	43.7	18.5	172.6	38.5
	Compensation of employees	471.0	1118.2	2037.1	345.1	222.8	337.4	196.1	1059.9	233.4	972.5	2222.5	765.9	714.9	278.8
	Gross operating surplus	1409.2	2696.0	1582.4	91.7	69.3	98.4	442.5	692.1	29.8	308.4	661.5	267.7	2059.5	627.3
	Additional payment row	-29.9	-36.0	-59.6	-10.8	-11.3	-2.9	-4.3	1.4	-2.3	-10.4	-8.3	-2.9	-69.0	-4.0
	Total Primary Input	2314.9	5108.1	5687.2	771.5	511.0	790.3	6363.8	2460.2	440.4	2118.8	5242.1	1589.2	5174.4	1023.6
	Total Input	3798.5	7694.4	8680.5	1176.7	919.7	1278.4	7182.9	3316.2	738.6	3071.6	7924.6	2213.4	9699.8	1236.8

Appendix 3c continued

		Waste, management	Construction	Wholesale & Retail	Transport	Hotels and Restaurant	Communication	Finance	Real Estate	Professional & Scientific	Admin Support	Public Administration	Education	Health and Social Work	Art & Recreation	Other Services Activities
1	Agriculture Forestry and Fishing	0.4	18.4	20.9	6.6	90.3	1.0	2.5	0.9	2.1	1.0	3.2	2.2	9.1	0.9	0.6
2	Mining a	3.5	222.9	57.3	17.9	9.0	5.4	11.0	7.6	19.6	9.0	13.3	5.6	17.4	1.7	1.8
3	Food Drink & Manufacture	2.2	13.5	161.7	20.0	506.5	4.8	13.7	0.7	12.6	9.8	15.2	17.7	56.8	8.8	5.3
4	Textiles	0.6	18.4	25.9	5.3	4.7	2.6	5.4	0.8	3.2	1.9	16.0	2.8	13.0	1.2	1.8
5	Manufacturing of Wood	0.4	221.9	7.4	2.4	4.6	0.7	4.3	1.2	2.5	4.3	1.8	5.6	1.9	1.3	0.7
6	Paper and Printing	2.9	21.0	47.6	11.0	8.4	23.2	49.1	4.8	18.6	6.3	58.8	17.8	37.6	6.8	2.9
7	Coke & Petroleum	2.5	38.6	94.2	356.9	32.7	15.9	20.8	1.3	27.3	16.0	57.5	16.2	39.0	5.9	4.5
8	Chemical Manufacture	3.8	201.0	91.3	57.1	8.1	17.9	14.2	2.5	13.1	16.6	28.7	15.1	559.6	6.8	7.5
9	Non Metallic Minerals	2.9	270.0	20.7	5.1	1.2	0.9	0.4	0.5	0.5	1.7	10.5	10.1	3.4	3.1	0.6
10	Metals	14.8	354.4	35.3	17.8	1.9	4.8	6.1	3.0	4.1	3.4	35.6	6.9	8.1	1.7	1.6
11	Machinery & equipment	14.9	335.1	90.3	116.3	6.9	37.8	21.7	5.2	19.3	20.5	359.7	13.1	81.7	7.2	8.7
12	Misc Manufacture	3.1	170.4	24.4	61.4	3.4	13.8	10.9	2.6	10.2	6.8	57.9	8.8	27.1	4.1	2.6
13	Electricity	7.1	94.9	192.4	67.0	45.5	36.3	67.4	60.3	63.0	36.1	109.8	57.4	119.8	34.0	8.0
14	Water Industry	29.3	8.0	7.7	3.9	4.3	2.4	30.4	2.2	4.3	5.7	31.5	11.8	44.8	7.0	2.9
15	Waste management	1.0	725.6	90.3	13.4	31.8	4.8	3.1	9.2	9.3	21.5	10.5	14.3	20.2	13.4	5.2
16	Construction	26.4	4214.7	522.5	102.1	59.1	108.6	220.0	1087.2	71.5	37.9	349.0	30.0	75.1	26.1	15.3
17	Wholesale and Retail	27.1	414.6	355.9	198.2	114.1	59.2	100.0	17.3	42.3	82.3	171.2	36.9	233.6	19.7	17.6
18	Transport	45.2	165.3	1782.2	1584.8	108.3	116.9	625.6	29.9	149.6	113.6	327.3	84.9	191.9	21.6	18.0
19	Hotel and Restaurant	1.4	26.8	118.9	33.9	45.6	15.2	129.4	5.5	37.5	12.8	97.1	24.5	214.7	5.0	5.1
20	Communication	5.5	88.3	207.1	107.4	57.9	433.3	376.3	51.6	122.8	59.0	230.7	27.9	80.6	30.4	15.9
21	Finance	11.8	108.9	215.4	64.9	41.3	34.9	2000.0	478.4	56.2	33.8	181.0	14.2	90.8	11.8	9.3
22	Real Estate	6.8	121.2	473.0	53.0	34.7	34.4	240.2	51.0	27.0	21.7	223.9	15.4	85.2	9.3	9.1
23	Professional & Scientific	26.0	520.7	527.7	186.9	116.8	196.5	668.7	178.9	1144.1	311.6	420.0	58.6	276.8	58.3	63.6
24	Admin Support	52.2	430.6	361.6	311.4	129.1	172.7	369.4	63.4	436.6	581.5	189.3	166.1	228.7	104.8	44.2
25	Public administration & defence	3.4	92.4	28.8	147.4	8.9	4.5	16.1	304.1	689.3	8.5	33.8	0.4	9.6	2.4	2.2
26	Education	2.5	17.1	27.4	37.3	16.4	39.5	94.4	11.0	104.1	20.2	280.4	429.9	36.4	6.7	12.1
27	Health and Social Work	1.4	5.6	12.7	7.9	12.9	10.1	63.5	0.2	20.3	5.8	25.0	9.8	2265.0	8.2	14.0
28	Art & Recreation	3.1	7.0	26.5	12.8	22.9	49.4	89.1	3.5	26.6	22.3	50.9	11.5	16.0	145.9	52.4
29	Other Services Activities	1.8	6.6	16.3	20.8	25.6	31.2	34.9	2.3	26.4	33.8	103.1	13.1	62.9	82.5	81.3
	Total Intermediate	304.1	8934.0	5643.2	3630.9	1552.8	1478.9	5288.7	2386.8	3164.1	1505.2	3492.6	1128.6	4906.7	636.5	414.6
	Imports from rest of UK	250.2	2098.5	2510.4	1686.4	699.5	804.5	2364.2	1936.8	1344.9	964.2	2143.9	446.6	1588.1	272.7	186.1
	Imports from rest of world	94.5	561.5	498.8	445.0	319.1	223.1	391.5	151.6	248.7	135.7	843.6	130.0	709.6	64.0	47.3
	Taxes less subsidies on products	97.3	55.5	110.4	420.8	377.0	24.5	627.3	29.7	43.0	25.1	848.1	152.0	656.3	48.0	43.3
	Taxes less subsidies on product	13.2	80.4	825.9	81.3	190.3	96.7	155.4	-16.1	70.3	69.5	0.0	19.1	18.7	53.4	33.2
	Compensation of employees	458.4	5194.4	6879.5	3528.4	2011.2	2314.2	3730.8	599.0	4802.7	2753.0	5634.8	6081.5	8641.1	1016.1	699.6
	Gross operating surplus	200.1	2739.2	3466.3	1037.5	929.9	1071.2	3657.6	9546.8	1869.6	1490.5	986.4	460.1	1682.9	1024.9	421.8
	Additional payment row	165.1	-713.3	-75.2	-6.4	-24.8	-0.8	2.5	-7.4	-1.5	-14.1	81.9	-9.3	21.5	-11.5	-2.1
	Total Primary Input	1278.9	10016.2	14216.1	7192.9	4502.3	4533.3	10929.4	12240.4	8377.7	5423.8	10538.6	7280.0	13318.2	2467.6	1429.2
	Total Input	1583.1	18950.1	19859.3	10823.9	6055.1	6012.3	16218.1	14627.2	11541.8	6929.1	14031.2	8408.6	18224.9	3104.1	1843.8

Appendix 3c continued

		Total intermediate demand	Household	Government	Gross fixed Capital Formation	Stocks	Non-resident households	Rest of UK exports	Rest of world exports	Total demand	Gross Output
1	Agriculture Forestry and Fishing	1603.4	884.7	0.5	95.6	45.4	20.1	739.8	409.0	2195.0	3798.5
2	Mining and Quarry	1101.8	174.0	0.0	77.2	35.9	9.1	5249.2	1047.2	6592.7	7694.5
3	Food Drink & Manufacture	1557.1	2016.1	0.0	10.7	9.1	39.5	2219.1	2829.0	7123.4	8680.6
4	Textiles	345.4	467.6	0.0	8.2	1.9	26.4	143.2	184.1	831.3	1176.7
5	Manufacturing of Wood	484.6	65.9	0.0	9.3	4.9	2.4	303.2	49.4	435.0	919.7
6	Paper and Printing	683.0	54.4	0.5	8.1	1.3	6.7	297.4	227.0	595.4	1278.4
7	Coke & Petroleum	1372.4	800.4	0.0	5.3	33.4	59.5	1819.3	3092.6	5810.5	7182.9
8	Chemical Manufacture	1779.4	280.1	0.0	30.9	27.3	6.7	464.1	727.7	1536.8	3316.2
9	Non Metallic Minerals	489.2	56.1	0.0	9.8	4.7	3.5	84.4	90.9	249.4	738.6
10	Metals	1720.4	110.6	0.0	299.6	24.6	4.3	404.9	507.1	1351.2	3071.6
11	Machinery & equipment	2511.4	637.9	0.0	1060.6	22.4	18.2	1453.4	2220.7	5413.2	7924.6
12	Misc Manufacture	893.1	423.7	0.0	193.6	-1.2	9.3	298.0	396.9	1320.4	2213.4
13	PoIr Industry	5684.3	2241.4	0.0	61.1	1.2	6.1	1580.3	125.5	4015.5	9699.8
14	Water Industry	388.8	829.3	0.0	11.9	-1.5	0.6	5.6	2.0	848.0	1236.8
15	Waste management	1270.5	312.6	0.0	0.0	0.0	0.0	0.0	0.0	312.6	1583.1
16	Construction	7729.3	307.9	0.0	9413.9	83.1	9.3	1232.2	174.5	11221.0	18950.3
17	Wholesale and Retail	3665.3	11323.1	22.1	712.9	0.1	368.8	1964.8	1802.3	16194.0	19859.3
18	Transport	6262.0	2167.0	0.0	99.5	0.4	88.8	1338.2	868.0	4562.0	10823.9
19	Hotel and Restaurant	881.4	3867.2	0.0	15.4	0.1	1272.6	13.4	5.0	5173.7	6055.1
20	Communication	2045.3	1411.1	117.1	368.7	-0.3	19.7	1410.0	640.7	3967.0	6012.3
21	Finance	3660.4	2892.6	0.0	47.4	0.1	16.8	7477.8	2123.1	12557.7	16218.1
22	Real Estate	1487.5	12195.9	0.0	442.7	-0.1	23.2	416.5	61.4	13139.7	14627.2
23	Professional & Scientific	5673.0	313.1	19.0	930.5	-6.8	8.9	3070.3	1533.8	5868.8	11541.8
24	Admin Support	4225.7	436.6	22.5	86.3	2.1	26.4	1547.5	582.0	2703.4	6929.1
25	Public administration & defence	1420.0	406.1	11912.1	278.5	0.1	0.7	10.1	3.6	12611.2	14031.2
26	Education	1187.9	1757.0	4758.4	4.9	-1.8	13.9	464.0	224.5	7220.8	8408.6
27	Health and Social Work	2507.1	2336.1	13367.5	1.0	0.0	6.2	5.3	1.7	15717.9	18225.0
28	Art & Recreation	596.9	1709.4	367.2	33.3	-2.4	104.0	203.3	92.4	2507.2	3104.1
29	Other Services Activities	578.0	1141.6	0.7	14.3	-1.5	10.9	67.4	32.5	1265.8	1843.8
	Total Intermediate	63804.6	51619.4	30587.6	14331.2	282.6	2182.3	34282.7	20054.6	153340.5	217145.1
	Imports from rest of UK	30915.7	13382.7	0.0	3595.1	181.1	595.7	3970.7	3118.7	24844.0	55759.8
	Imports from rest of world	10354.1	4457.9	0.0	1314.6	170.7	294.6	2981.9	55.3	9275.1	19629.2
	Taxes less subsidies on products	4480.3	7987.4	0.0	2068.2	0.0	477.6	0.0	0.0	10533.2	15013.4
	Taxes less subsidies on production	1494.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1494.5
	Compensation of employees	65320.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	65320.5
	Gross operating surplus	41620.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	41620.7
	Additional payment row	-845.7	-289.4	543.8	4.4	0.0	0.4	288.6	297.9	845.7	0.0
	Total Primary Input	153340.1	25538.6	543.8	6982.2	351.9	1368.3	7241.3	3471.8	45498.0	198838.1
	Total Input	217144.7	77158.1	31131.4	21313.4	634.5	3550.6	41524.0	23526.5	198838.5	415983.2

Appendix 4a: Sectoral aggregation scheme of production sectors/activities identified in the Wales IO table, 2007

	Sectors	SIC 2007 code	IO 2007 groups
1	Agriculture, Forestry & Fishing	A	1,2
2	Mining & Quarrying	B	3,4
3	Food & Drink	C10/11/12	5,6,7,8,9,10,11
4	Clothing & Textiles	C13,14,15	12,13
5	Wood	C16	14
6	Paper & Paper Products	C17	15
7	Printing	C18	16
8	Coke & Refined Petroleum	C19	17
9	Chemicals & Pharmaceutical	C20/C21	18,19,20
10	Rubber & Plastic	C22	21,22
11	Non-Metallic Mineral	C23	23,24
12	Basic Metals	C24/C25	25,26,27,28
13	Electronics & Electrical Engineering	C26/C27/C28/C32/C33	29-37,41
14	Motor Vehicles	C29	38
15	Other Transport	C30	39
16	Furniture	C31	40
17	Electricity, Gas, Waste & Sewerage	D	42,43,44,45,46,47,48,87
18	Water	E	49
19	Construction	F	50
20	Wholesale & Retail	G	51,52,53
21	Transportation	H	60-63
22	Accommodation	I	54-59
23	Finance & Insurance	K	67,68,69
24	Other Business Services	LMN	70,71,72,73-79
25	Public Administration	O	80
26	Education	P	81
27	Health	Q	82
28	Other Services	JRSTU	65,66,83-86, 88

Appendix 4b: Wales Industry-by-Industry (28x28) conventional IO tables for 2007 (£Million)

	Wales	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	Regional Purchases	Agriculture Forestry & Fish	Mining & Quarrying	Food & Drink	Clothing and textile	Wood	Paper and Paper Products	Printing media	Coke and refined petroleum	Chemicals and Pharms	Rubber and plastic	Non-Metallic minerals	Basic Metals Products	Computer/ Electronic/ manufacturing	Motor Vehicles trailers
1	Agriculture, Forestry & Fish	95.0	0.1	336.9	0.0	20.8	2.8	0.1	0.1	2.0	0.3	0.1	0.4	0.3	0.2
2	Mining	0.4	13.6	0.7	0.1	0.1	1.2	0.0	0.3	5.8	0.2	6.9	7.9	0.6	0.4
3	Food/beverage/Tobacco	79.5	0.3	199.4	1.2	0.4	1.5	0.4	8.5	6.7	1.0	0.8	6.8	4.5	3.5
4	Clothing & Textile	0.5	0.0	0.3	3.1	0.0	0.1	0.0	0.4	0.2	0.3	0.0	0.4	0.4	3.1
5	Wood	1.1	0.2	1.8	0.1	6.6	3.9	0.3	1.0	4.9	1.8	0.6	4.0	5.3	4.9
6	Paper and Paper products	2.4	0.2	16.0	0.6	0.2	59.1	4.4	1.3	4.8	4.0	1.0	4.0	8.0	3.8
7	Printing/Reproduction Media	2.1	0.5	7.6	0.7	0.3	2.9	16.0	6.4	12.7	4.2	1.6	13.0	17.6	13.3
8	Coke and refined petroleum	21.2	4.1	8.7	0.7	0.5	2.8	0.6	56.3	26.6	4.3	1.5	11.8	10.1	3.7
9	Chemicals & Pharmaceuticals	19.7	2.0	9.7	1.0	1.0	3.0	1.2	17.0	45.5	13.6	2.0	19.0	13.7	13.1
10	Rubber & plastic	5.4	0.6	43.9	0.7	6.2	4.0	2.2	4.4	29.1	72.2	1.9	12.9	50.2	91.8
11	Non-metallic Mineral	3.2	5.7	5.7	0.0	0.8	0.3	0.1	0.8	2.5	8.4	29.2	12.3	5.2	12.1
12	Basic Metals & Metal Products	2.7	5.7	23.0	0.9	3.1	2.7	1.7	17.3	15.9	16.3	8.0	434.0	127.0	170.5
13	Electronics and electrical engineering	2.7	3.8	18.8	1.1	3.2	5.8	4.1	16.3	18.2	9.8	5.8	105.6	148.1	57.5
14	Motor Vehicles	1.7	1.4	6.6	0.4	1.2	1.5	0.7	12.3	4.7	2.7	1.8	21.3	15.4	76.3
15	Other Transport	2.2	0.5	1.6	0.1	0.3	0.4	0.2	2.1	1.3	0.7	0.7	5.9	3.6	3.0
16	Furniture	1.1	0.5	4.3	0.2	8.6	6.4	0.6	2.3	9.1	3.9	1.2	12.2	13.6	16.7
17	Electricity, Gas, Waste, Sewerage	14.6	12.3	45.8	4.4	7.1	19.7	4.5	42.0	103.0	21.6	25.7	253.2	50.4	20.6
18	Water	5.5	0.7	6.3	0.5	0.3	1.0	0.4	5.0	13.3	1.1	1.6	10.5	3.7	1.3
19	Construction	9.2	2.2	11.4	1.4	1.5	4.3	1.1	23.3	9.0	3.1	2.6	34.0	7.9	25.2
20	Wholesale and Retail	48.4	5.5	69.3	4.7	12.1	15.3	7.9	183.0	51.2	26.1	12.2	217.2	148.1	86.2
21	Transportation and storage	5.1	21.1	41.4	3.3	5.3	11.1	5.4	10.9	38.1	20.6	35.2	160.2	37.6	35.6
22	Accommodation	3.1	0.6	5.7	0.8	0.8	1.2	0.7	7.3	5.3	2.0	1.0	11.5	8.4	2.4
23	Financial & Insurance	29.6	16.4	75.6	10.4	11.5	18.7	10.6	65.9	61.1	38.4	13.8	209.8	110.2	18.2
24	Other Business Services	53.2	5.8	65.7	6.3	7.3	11.9	19.3	49.1	84.8	27.4	7.4	94.4	112.6	33.1
25	Public Administration	2.1	0.2	0.7	0.1	0.1	0.3	0.0	0.9	1.0	0.4	0.0	1.6	1.3	0.7
26	Education	0.8	0.1	2.7	0.3	0.1	0.8	0.2	1.5	5.6	1.5	0.4	3.5	6.4	3.3
27	Health	7.4	0.1	2.3	0.2	0.1	0.7	0.3	2.3	5.1	1.3	0.4	3.1	5.7	2.3
28	Other Services	23.5	0.9	13.6	4.0	1.4	4.1	19.6	14.0	20.7	4.8	4.4	31.5	20.3	5.2
	Total Intermediate Inputs	**443.6**	**105.2**	**1025.5**	**47.4**	**101.0**	**187.2**	**102.7**	**552.0**	**588.1**	**292.1**	**167.7**	**1702.1**	**936.4**	**708.0**
a	Imports RUK	267.9	63.9	830.9	67.0	151.1	199.8	147.8	672.2	696.4	299.8	126.1	1796.4	1113.9	775.8
b	Imports ROW	78.0	47.8	310.0	54.7	70.5	229.4	54.2	3142.1	606.6	202.6	76.9	1244.4	861.1	518.7
c	Income from employment	381.9	52.0	450.6	69.7	82.0	118.1	144.1	324.7	443.7	287.5	140.4	1118.8	862.4	315.3
d	Gross Operating Surplus	201.0	48.2	353.0	29.7	72.5	108.0	87.5	313.6	356.2	98.2	134.6	481.8	508.9	83.2
e	Taxes less subsidies on production	-9.2	6.2	13.5	1.6	5.3	6.4	3.3	17.9	14.9	8.3	7.0	107.5	27.8	10.3
f	Taxes on Products	41.9	6.9	56.1	4.1	9.7	28.2	12.4	112.6	74.9	17.3	10.8	98.4	66.2	43.6
	Total Primary Inputs	**961.5**	**225.0**	**2014.2**	**226.8**	**391.1**	**689.9**	**449.3**	**4583.1**	**2192.6**	**913.7**	**495.8**	**4847.3**	**3440.3**	**1746.8**
	TOTAL INPUTS	**1405.1**	**330.3**	**3039.7**	**274.2**	**492.1**	**877.2**	**551.9**	**5135.1**	**2780.8**	**1205.8**	**663.5**	**6549.5**	**4376.6**	**2454.8**

Appendix 4b continued

	Wales	15	16	17	18	19	20	21	22	23	24	25	26	27	28	
	Regional Purchases	Other transport	Furniture	Electricity, gas, waste ,water, sewage	Water	Constructi on	Wholesale & Retail	Transpor t	Accommodati on a	Financial & Insuranc e	Other Business Services	Public Admini stration	Educati on	Health	Other Services	**Sales to ID**
1	Agriculture,Forestry & Fish	0.2	0.6	0.6	0.1	3.0	13.7	0.6	28.1	0.5	1.6	1.9	5.9	2.0	1.3	**519.3**
2	Mining and Quarrying	0.1	0.1	70.1	0.1	30.2	2.5	1.1	0.4	0.2	1.2	1.6	1.0	0.8	0.4	**148.1**
3	Food	1.9	0.3	2.2	0.2	2.3	73.3	5.3	183.8	5.4	7.7	7.2	9.6	23.0	11.3	**648.0**
4	Clothing &,Textiles	0.1	0.6	0.1	0.0	0.8	3.0	0.4	1.6	0.7	1.1	2.7	2.7	0.3	4.3	**27.3**
5	Wood	1.5	32.0	0.6	0.0	13.5	3.0	0.7	1.3	0.9	2.8	4.6	2.9	1.4	0.8	**102.6**
6	Paper and Paper products	1.5	1.2	1.1	0.2	2.2	6.7	1.8	2.4	3.6	5.2	15.7	4.6	16.8	0.8	**173.5**
7	Printing/Reproduction of	10.7	2.0	7.7	2.5	6.6	33.1	15.3	0.2	67.0	39.2	44.7	28.7	19.6	6.6	**382.7**
8	Coke and refined petroleum	1.6	2.8	22.4	0.9	13.9	72.5	70.0	14.1	13.7	20.1	24.2	9.1	6.9	8.7	**434.0**
9	Chemicals and Pharms	3.8	3.7	7.6	0.3	12.1	14.8	4.3	5.2	2.6	5.5	8.8	13.6	75.5	13.7	**333.1**
10	Rubber and plastic	5.3	13.3	4.7	0.7	75.0	35.5	12.3	2.2	4.9	6.4	4.6	3.7	6.6	15.4	**516.2**
11	Non-metallic Mineral	1.8	0.2	5.4	0.2	138.9	12.3	3.2	0.5	0.3	1.0	8.2	7.9	3.8	2.0	**272.0**
12	Basic Metals & Metal Products	83.7	13.1	7.7	1.2	56.3	18.4	4.7	2.4	3.6	6.9	12.0	5.0	5.7	3.7	**1053.4**
13	Electronics, & electrical engineering	45.0	5.0	11.7	2.5	27.9	28.0	7.4	3.1	6.9	18.6	58.4	7.6	42.6	31.5	**697.2**
14	Motor Vehicles	5.0	1.7	3.6	0.4	8.9	18.7	4.2	1.6	2.6	7.2	6.8	1.9	3.9	3.4	**217.8**
15	Other Transport	99.5	0.4	1.4	0.1	4.2	5.7	10.5	0.8	1.9	3.1	99.6	1.0	3.9	2.2	**256.9**
16	Furniture	7.0	55.6	1.1	0.1	24.5	5.6	1.4	2.3	1.6	5.0	8.1	5.1	2.7	1.5	**202.4**
17	Electricity,Gas,Waste, & Sewerage	28.2	3.1	2126.8	83.8	23.6	58.1	18.2	47.8	18.8	32.1	86.6	31.3	56.4	26.7	**3266.6**
18	Water	2.7	0.2	2.9	0.3	6.4	4.6	1.5	10.2	1.1	4.2	12.9	6.5	6.5	3.2	**114.3**
19	Construction	8.8	2.1	32.2	42.4	785.0	35.8	25.3	12.4	32.7	363.8	221.3	21.2	18.4	17.2	**1755.0**
20	Wholesale & Retail	31.1	16.9	48.4	1.3	71.8	120.3	52.2	28.2	33.3	59.5	56.5	30.6	42.1	49.8	**1529.3**
21	Transportation	13.8	7.8	20.5	2.3	22.1	392.3	329.8	33.9	64.8	72.8	44.5	46.6	43.9	46.3	**1572.3**
22	Accommodation	4.2	0.5	2.5	0.8	6.7	84.0	13.6	6.1	20.8	24.0	22.7	6.6	10.1	6.6	**259.9**
23	Financial & Insurance	68.2	11.1	39.1	273.8	54.4	191.4	66.4	38.0	277.5	150.2	177.8	18.3	35.4	31.9	**2123.6**
24	Other Business Services	92.3	14.1	91.3	37.2	284.9	651.8	221.9	99.8	337.9	742.9	266.7	108.9	212.2	186.2	**3926.5**
25	Public Administration	0.6	0.3	2.8	12.5	0.8	0.5	4.7	0.4	0.1	37.3	13.2	0.4	0.2	1.4	**84.8**
26	Education	4.0	0.5	5.6	0.5	3.2	8.9	9.3	6.3	24.7	44.1	110.5	121.3	18.7	13.7	**398.5**
27	Health	3.6	0.4	5.2	0.9	3.9	7.9	3.9	5.5	5.7	5.7	2.0	3.8	2231.6	7.3	**2318.9**
28	Other Services	12.5	2.5	20.9	15.9	14.1	88.8	44.3	47.1	221.7	106.3	123.4	38.7	72.6	225.7	**1202.4**
	Total Intermediate Inputs	**538.5**	**192.2**	**2546.4**	**481.2**	**1697.4**	**1991.0**	**934.6**	**585.7**	**1155.5**	**1775.6**	**1447.3**	**544.6**	**2963.8**	**723.7**	**24536.3**
a	Imports RUK	398.9	216.5	714.5	79.8	1111.1	1644.1	913.4	502.0	867.0	1291.5	794.8	323.0	1650.2	779.8	**18495.5**
b	Imports ROW	564.9	144.0	432.1	18.6	253.7	384.8	138.4	8.0	204.0	283.6	745.0	136.3	454.9	195.5	**11460.9**
c	Income from employment	411.1	181.7	593.4	18.1	1192.0	2709.6	1193.3	901.7	914.2	2546.9	2699.5	2398.9	2348.0	1318.4	**24218.1**
d	Gross Operating Surplus	269.7	157.3	747.3	67.7	685.0	1424.0	324.2	487.7	604.7	6488.4	476.3	176.4	661.0	516.8	**15962.6**
e	Taxes less subsidies on production	8.1	8.1	146.9	20.2	26.5	255.1	45.2	93.5	49.7	16.4	33.3	34.6	4.8	25.2	**988.5**
f	Taxes on Products	71.2	21.2	99.8	12.2	133.4	172.7	105.4	46.6	104.7	149.5	150.5	38.4	79.6	72.5	**1840.8**
	Total Primary Inputs	**1723.8**	**728.8**	**2734.0**	**216.6**	**3401.8**	**6590.3**	**2720.0**	**2039.4**	**2744.3**	**10776.2**	**4899.5**	**3107.5**	**5198.5**	**2908.3**	**72966.4**
	TOTAL INPUTS	**2262.3**	**921.0**	**5280.5**	**697.8**	**5099.2**	**8581.3**	**3654.6**	**2625.1**	**3899.8**	**12551.8**	**6346.8**	**3652.1**	**8162.2**	**3631.9**	**97502.8**

Appendix 4b continued

	Sales to Final demand	Households	Tour 1-3	Tour 4+	Tour Intl	Tour Bus	Government	GFCF	Stock 2007	Exports RUK	Exports ROW	Total Demand	Gross Output
1	Agriculture Forestry & Fish	124.2	0.4	1.6	0.6	0.3	0.1	11.5	4.2	604.9	137.9	885.8	1405.1
2	Mining and Quarrying	7.1	0.1	0.3	0.1	0.1	0.0	6.1	1.8	136.5	30.1	182.1	330.3
3	Food/beverage/Tobacco	796.6	2.4	8.4	2.9	2.1	0.0	1.2	8.5	1531.9	37.7	2391.8	3039.7
4	Weaaring Apparel,Textiles & Leather	16.1	0.1	0.9	0.3	0.1	0.0	0.2	0.9	175.5	52.8	246.9	274.2
5	Wood	49.2	0.6	4.6	1.4	0.9	0.0	19.0	0.9	254.5	58.4	389.5	492.1
6	Paper and Paper products	28.2	0.1	0.6	0.2	0.2	0.0	0.9	3.3	549.7	120.6	703.7	877.2
7	Printing/Reproduction recorded med	32.1	0.1	0.7	0.2	0.2	0.0	0.8	0.9	116.9	17.2	169.2	551.9
8	Coke and refined petroleum	221.7	2.7	22.0	4.1	2.0	0.0	16.7	135.6	3191.7	1104.6	4701.1	5135.1
9	Chemicals and Pharms	180.2	1.0	6.5	1.8	1.4	0.0	5.5	5.7	1194.5	1051.0	2447.7	2780.8
10	Rubber and plastic	38.0	0.3	1.5	0.5	0.4	0.0	4.4	5.5	581.0	58.1	689.6	1205.8
11	Non-metallic Mineral	26.4	0.8	6.2	1.7	1.2	0.0	7.0	1.7	314.1	32.4	391.5	663.5
12	Basic Metals & Metal Products	78.7	0.6	2.7	0.8	0.7	0.0	76.6	30.5	3519.1	1786.2	5496.0	6549.5
13	Computer/Electronics/other man	155.7	0.8	3.8	1.2	0.9	0.0	99.1	25.7	1454.9	1937.3	3679.4	4376.6
14	Motor Vehicles/Trailers	70.9	0.5	2.3	0.7	0.5	0.0	12.7	8.2	1488.0	653.2	2236.9	2454.8
15	Other Transport	47.7	0.4	1.8	0.6	0.5	0.0	49.3	5.0	1696.3	203.8	2005.4	2262.3
16	Furniture	87.7	1.0	8.0	2.4	1.5	0.0	34.0	1.5	472.4	110.0	718.7	921.0
17	Electricity,gas,waste,Sewage	820.9	0.3	1.6	0.7	0.4	433.5	32.9	34.9	684.7	3.9	2013.9	5280.5
18	Water	512.4	0.1	0.6	0.2	0.1	0.0	15.4	38.6	15.2	0.8	583.6	697.8
19	Construction	218.2	0.0	0.1	0.0	0.0	0.0	2294.9	11.2	734.8	84.8	3344.2	5099.2
20	Wholesale and Retail	5187.7	25.7	150.6	41.5	23.9	0.0	46.7	277.7	1025.5	272.7	7052.0	8581.3
21	Transportation and storage	667.5	28.6	95.6	19.5	12.9	0.0	10.0	-35.6	1217.6	66.2	2082.3	3654.6
22	Accommodation and food	1123.7	135.0	584.2	192.9	148.2	0.0	27.8	-8.3	160.0	1.7	2365.2	2625.1
23	Financial & Insurance	849.1	0.7	2.7	1.0	0.6	0.0	53.6	-38.6	583.0	324.1	1776.2	3899.8
24	Real estate,Prof,Sci,Tech Services	5411.6	1.4	5.6	1.7	6.5	0.0	160.0	2.1	2766.6	269.6	8625.3	12551.8
25	Public Admin	123.3	0.0	0.0	0.0	0.0	5871.0	0.0	0.0	267.7	0.0	6262.0	6346.8
26	Education	833.6	0.2	0.8	0.3	0.2	1795.2	0.0	-1.3	624.4	0.2	3253.6	3652.1
27	Human Health/Social work	319.1	0.6	2.7	1.8	0.6	5431.8	0.0	0.8	85.5	0.4	5843.4	8162.2
28	Info,Comms,Arts,Entertainment	1216.2	12.6	48.5	17.6	10.8	254.2	33.0	15.6	408.2	413.0	2429.6	3631.9
	Total Intermediate Inputs	**19243.7**	**217.5**	**964.9**	**296.5**	**217.2**	**13785.9**	**3019.3**	**537.1**	**25855.4**	**8828.9**	**72966.4**	**97502.8**
a	Imports RUK	8464.7	3.7	20.5	4.1	2.6	408.8	1481.7	138.9	2092.0	427.8	13044.9	31540.4
b	Imports ROW	5081.3	1.6	15.1	1.9	0.9	0.0	630.3	33.2	411.3	0.0	6175.5	17636.4
c	Income from employment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24218.1
d	Gross Operating Surplus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15962.6
e	Taxes less subsidies on production	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	988.5
f	Taxes on Products	4093.6	20.9	123.9	36.0	24.6	72.9	301.1	17.2	2944.8	954.4	8589.4	10430.1
	Total Primary Inputs	**17639.6**	**26.2**	**159.5**	**41.9**	**28.2**	**481.7**	**2413.1**	**189.3**	**5448.1**	**1382.2**	**27809.8**	**100776.2**
	TOTAL INPUTS	**36883.4**	**243.7**	**1124.4**	**338.4**	**245.3**	**14267.6**	**5432.4**	**726.4**	**31303.5**	**10211.1**	**100776.2**	**198279.0**

Appendix 4c: Wales Industry-by-Industry (28x28) environmental IO tables for 2007(£Million)

		1	2	3	4	5	6	7	8	9	10	11	12	13	14
	Regional Purchases	Agricultur e, Forestry & Fish	Mining	Food & drink	Clothing & textiles	Wood	Paper & Paper Products	Printing	Coke & refined petroleum	Chemicals & Pharmaceutic als	Rubber & plastic	Non-Metallic minerals	Basic Metals	Electronics & electrical engineering	Motor Vehicles
1	Agriculture, Forestry & Fish	95.0	0.1	336.9	0.0	20.8	2.8	0.1	0.1	2.0	0.3	0.1	0.4	0.3	0.2
2	Mining and Quarrying	0.4	13.6	0.7	0.1	0.1	1.2	0.0	0.3	5.8	0.2	6.9	7.9	0.6	0.4
3	Food & drink	79.5	0.3	199.4	1.2	0.4	1.5	0.4	8.5	6.7	1.0	0.8	6.8	4.5	3.5
4	Clothing & textiles	0.5	0.0	0.3	3.1	0.0	0.1	0.0	0.4	0.2	0.3	0.0	0.4	0.4	3.1
5	Wood	1.1	0.2	1.8	0.1	6.6	3.9	0.3	1.0	4.9	1.8	0.6	4.0	5.3	4.9
6	Paper and Paper products	2.4	0.2	16.0	0.6	0.2	59.1	4.4	1.3	4.8	4.0	1.0	4.0	8.0	3.8
7	Printing	2.1	0.5	7.6	0.7	0.3	2.9	16.0	6.4	12.7	4.2	1.6	13.0	17.6	13.3
8	Coke & refined petroleum	21.2	4.1	8.7	0.7	0.5	2.8	0.6	56.3	26.6	4.3	1.5	11.8	10.1	3.7
9	Chemicals & Pharmaceuticals	19.7	2.0	9.7	1.0	1.0	3.0	1.2	17.0	45.5	13.6	2.0	19.0	13.7	13.1
10	Rubber & plastic	5.4	0.6	43.9	0.7	6.2	4.0	2.2	4.4	29.1	72.2	1.9	12.9	50.2	91.8
11	Non-metallic Mineral	3.2	5.7	5.7	0.0	0.8	0.3	0.1	0.8	2.5	8.4	29.2	12.3	5.2	12.1
12	Basic Metals	2.7	5.7	23.0	0.9	3.1	2.7	1.7	17.3	15.9	16.3	8.0	434.0	127.0	170.5
13	Electronics & electrical engineering	2.7	3.8	18.8	1.1	3.2	5.8	4.1	16.3	18.2	9.8	5.8	105.6	148.1	57.5
14	Motor Vehicles	1.7	1.4	6.6	0.4	1.2	1.5	0.7	12.3	4.7	2.7	1.8	21.3	15.4	76.3
15	Other Transport	2.2	0.5	1.6	0.1	0.3	0.4	0.2	2.1	1.3	0.7	0.7	5.9	3.6	3.0
16	Furniture	1.1	0.5	4.3	0.2	8.6	6.4	0.6	2.3	9.1	3.9	1.2	12.2	13.6	16.7
17	Electricity,gas,waste,Sewage	14.6	12.3	45.8	4.4	7.1	19.7	4.5	42.0	103.0	21.6	25.7	253.2	50.4	20.6
18	Water	34.1	3.2	19.5	0.5	1.6	1.1	0.3	0.8	10.8	0.7	1.7	6.3	3.3	6.3
19	Construction	9.2	2.2	11.4	1.4	1.5	4.3	1.1	23.3	9.0	3.1	2.6	34.0	7.9	25.2
20	Wholesale & Retail	48.4	5.5	69.3	4.7	12.1	15.3	7.9	183.0	51.2	26.1	12.2	217.2	148.1	86.2
21	Transportation and storage	5.1	21.1	41.4	3.3	5.3	11.1	5.4	10.9	38.1	20.6	35.2	160.2	37.6	35.6
22	Accommodation and	3.1	0.6	5.7	0.8	0.8	1.2	0.7	7.3	5.3	2.0	1.0	11.5	8.4	2.4
23	Financial & Insurance	29.6	16.4	75.6	10.4	11.5	18.7	10.6	65.9	61.1	38.4	13.8	209.8	110.2	18.2
24	Other business services	53.2	5.8	65.7	6.3	7.3	11.9	19.3	49.1	84.8	27.4	7.4	94.4	112.6	33.1
25	Public Administration	2.1	0.2	0.7	0.1	0.1	0.3	0.0	0.9	1.0	0.4	0.0	1.6	1.3	0.7
26	Education	0.8	0.1	2.7	0.3	0.1	0.8	0.2	1.5	5.6	1.5	0.4	3.5	6.4	3.3
27	Health	7.4	0.1	2.3	0.2	0.1	0.7	0.3	2.3	5.1	1.3	0.4	3.1	5.7	2.3
28	Other services	23.5	0.9	13.6	4.0	1.4	4.1	19.6	14.0	20.7	4.8	4.4	31.5	20.3	5.2
	Total Intermediate Inputs	**472.1**	**107.7**	**1038.7**	**47.4**	**102.2**	**187.3**	**102.6**	**547.8**	**585.7**	**291.7**	**167.7**	**1697.9**	**936.0**	**713.0**
a	Imports RUK	267.9	63.9	830.9	67.0	151.1	199.8	147.8	672.2	696.4	299.8	126.1	1796.4	1113.9	775.8
b	Imports ROW	78.0	47.8	310.0	54.7	70.5	229.4	54.2	3142.1	606.6	202.6	76.9	1244.4	861.1	518.7
c	Income from employment	381.9	52.0	450.6	69.7	82.0	118.1	144.1	324.7	443.7	287.5	140.4	1118.8	862.4	315.3
d	Gross Operating Surplus	201.0	48.2	353.0	29.7	72.5	108.0	87.5	313.6	356.2	98.2	134.6	481.8	508.9	83.2
f	Taxes less subsidies on production	-9.2	6.2	13.5	1.6	5.3	6.4	3.3	17.9	14.9	8.3	7.0	107.5	27.8	10.3
g	Taxes on Products	41.9	6.9	56.1	4.1	9.7	28.2	12.4	112.6	74.9	17.3	10.8	98.4	66.2	43.6
	Total Primary Inputs	**932.9**	**222.6**	**2001.1**	**226.8**	**389.9**	**689.8**	**449.4**	**4587.3**	**2195.1**	**914.0**	**495.8**	**4851.6**	**3440.6**	**1741.8**
	TOTAL INPUTS	**1405.1**	**330.3**	**3039.7**	**274.2**	**492.1**	**877.2**	**551.9**	**5135.1**	**2780.8**	**1205.8**	**663.5**	**6549.5**	**4376.6**	**2454.8**

Appendix 4c continued

		15	16	17	18	19	20	21	22	23	24	25	26	27	28	
	Regional Purchases	Other transport	Furniture	Electricity, gas, waste ,water, sewage	Water	Construction	Wholesale and Retail	Transportation	Accommodation	Financial & Insurance	Other business services	Public Administration	Education	Health	Other Service	Sales to ID
1	Agriculture ,Forestry & Fish	0.2	0.6	0.6	0.1	3.0	13.7	0.6	28.1	0.5	1.6	1.9	5.9	2.0	1.3	519.3
2	Mining	0.1	0.1	70.1	0.1	30.2	2.5	1.1	0.4	0.2	1.2	1.6	1.0	0.8	0.4	148.1
3	Food & Drink	1.9	0.3	2.2	0.2	2.3	73.3	5.3	183.8	5.4	7.7	7.2	9.6	23.0	11.3	648.0
4	Clothing & Textiles	0.1	0.6	0.1	0.0	0.8	3.0	0.4	1.6	0.7	1.1	2.7	2.7	0.3	4.3	27.3
5	Wood	1.5	32.0	0.6	0.0	13.5	3.0	0.7	1.3	0.9	2.8	4.6	2.9	1.4	0.8	102.6
6	Paper & Paper products	1.5	1.2	1.1	0.2	2.2	6.7	1.8	2.4	3.6	5.2	15.7	4.6	16.8	0.8	173.5
7	Printing	10.7	2.0	7.7	2.5	6.6	33.1	15.3	0.2	67.0	39.2	44.7	28.7	19.6	6.6	382.7
8	Coke and Refined Petroleum	1.6	2.8	22.4	0.9	13.9	72.5	70.0	14.1	13.7	20.1	24.2	9.1	6.9	8.7	434.0
9	Chemicals & Pharmaceuticals	3.8	3.7	7.6	0.3	12.1	14.8	4.3	5.2	2.6	5.5	8.8	13.6	75.5	13.7	333.1
10	Rubber and plastic	5.3	13.3	4.7	0.7	75.0	35.5	12.3	2.2	4.9	6.4	4.6	3.7	6.6	15.4	516.2
11	Non-metallic Mineral	1.8	0.2	5.4	0.2	138.9	12.3	3.2	0.5	0.3	1.0	8.2	7.9	3.8	2.0	272.0
12	Basic Metals &	83.7	13.1	7.7	1.2	56.3	18.4	4.7	2.4	3.6	6.9	12.0	5.0	5.7	3.7	1053.4
13	Electronics and electrical engineering	45.0	5.0	11.7	2.5	27.9	28.0	7.4	3.1	6.9	18.6	58.4	7.6	42.6	31.5	697.2
14	Motor Vehicles	5.0	1.7	3.6	0.4	8.9	18.7	4.2	1.6	2.6	7.2	6.8	1.9	3.9	3.4	217.8
15	Other Transport	99.5	0.4	1.4	0.1	4.2	5.7	10.5	0.8	1.9	3.1	99.6	1.0	3.9	2.2	256.9
16	Furniture	7.0	55.6	1.1	0.1	24.5	5.6	1.4	2.3	1.6	5.0	8.1	5.1	2.7	1.5	202.4
17	Electricity, Gas,Waste,Sewerage	28.2	3.1	2126.8	83.8	23.6	58.1	18.2	47.8	18.8	32.1	86.6	31.3	56.4	26.7	3266.6
18	Water	4.8	2.6	5.2	0.6	1.8	9.2	4.4	16.0	2.7	12.6	9.4	9.9	14.6	6.1	190.0
19	Construction	8.8	2.1	32.2	42.4	785.0	35.8	25.3	12.4	32.7	363.8	221.3	21.2	18.4	17.2	1755.0
20	Wholesale & Retail	31.1	16.9	48.4	1.3	71.8	120.3	52.2	28.2	33.3	59.5	56.5	30.6	42.1	49.8	1529.3
21	Transportation	13.8	7.8	20.5	2.3	22.1	392.3	329.8	33.9	64.8	72.8	44.5	46.6	43.9	46.3	1572.3
22	Accommodation	4.2	0.5	2.5	0.8	6.7	84.0	13.6	6.1	20.8	24.0	22.7	6.6	10.1	6.6	259.9
23	Financial & Insurance	68.2	11.1	39.1	273.8	54.4	191.4	66.4	38.0	277.5	150.2	177.8	18.3	35.4	31.9	2123.6
24	Other business services	92.3	14.1	91.3	37.2	284.9	651.8	221.9	99.8	337.9	742.9	266.7	108.9	212.2	186.2	3926.5
25	Public Administration	0.6	0.3	2.8	12.5	0.8	0.5	4.7	0.4	0.1	37.3	13.2	0.4	0.2	1.4	84.8
26	Education	4.0	0.5	5.6	0.5	3.2	8.9	9.3	6.3	24.7	44.1	110.5	121.3	18.7	13.7	398.5
27	Health	3.6	0.4	5.2	0.9	3.9	7.9	3.9	5.5	5.7	5.7	2.0	3.8	2231.6	7.3	2318.9
28	Other Services	12.5	2.5	20.9	15.9	14.1	88.8	44.3	47.1	221.7	106.3	123.4	38.7	72.6	225.7	1202.4
	Total Intermediate Inputs	**540.6**	**194.6**	**2548.8**	**481.5**	**1692.8**	**1995.7**	**937.5**	**591.5**	**1157.0**	**1784.0**	**1443.8**	**547.9**	**2971.9**	**726.5**	**24612.1**
a	Imports RUK	398.9	216.5	714.5	79.8	1111.1	1644.1	913.4	502.0	867.0	1291.5	794.8	323.0	1650.2	779.8	18495.5
b	Imports ROW	564.9	144.0	432.1	18.6	253.7	384.8	138.4	8.0	204.0	283.6	745.0	136.3	454.9	195.5	11460.9
c	Income from employment	411.1	181.7	593.4	18.1	1192.0	2709.6	1193.3	901.7	914.2	2546.9	2699.5	2398.9	2348.0	1318.4	24218.1
d	Gross Operating Surplus	269.7	157.3	747.3	67.7	685.0	1424.0	324.2	487.7	604.7	6488.4	476.3	176.4	661.0	516.8	15962.6
e	Taxes less subsidies on production	8.1	8.1	146.9	20.2	26.5	255.1	45.2	93.5	49.7	16.4	33.3	34.6	4.8	25.2	988.5
f	Taxes on Products	71.2	21.2	99.8	12.2	133.4	172.7	105.4	46.6	104.7	149.5	150.5	38.4	79.6	72.5	1840.8
	Total Primary Inputs	**1721.7**	**726.4**	**2731.7**	**216.3**	**3406.4**	**6585.6**	**2717.1**	**2033.6**	**2742.7**	**10767.8**	**4903.0**	**3104.2**	**5190.3**	**2905.4**	**72890.7**
	TOTAL INPUTS	**2262.3**	**921.0**	**5280.5**	**697.8**	**5099.2**	**8581.3**	**3654.6**	**2625.1**	**3899.8**	**12551.8**	**6346.8**	**3652.1**	**8162.2**	**3631.9**	**97502.8**

Appendix 4c Continued

	Sales to Final Demand	Households	Tour 1-3	Tour 4+	Tour Intl	Tour Bus	Government	Gross Fixed Capital formation	Stock 2007	Exports RUK	Exports ROW	Total Demand	Gross Output
1	Agriculture ,Forestry & Fish	124.2	0.4	1.6	0.6	0.3	0.1	11.5	4.2	604.9	137.9	885.8	1405.1
2	Mining and Quarrying	7.1	0.1	0.3	0.1	0.1	0.0	6.1	1.8	136.5	30.1	182.1	330.3
3	Food and Drink	796.6	2.4	8.4	2.9	2.1	0.0	1.2	8.5	1531.9	37.7	2391.8	3039.7
4	Clothing & Textile	16.1	0.1	0.9	0.3	0.1	0.0	0.2	0.9	175.5	52.8	246.9	274.2
5	Wood	49.2	0.6	4.6	1.4	0.9	0.0	19.0	0.9	254.5	58.4	389.5	492.1
6	Paper & Paper Products	28.2	0.1	0.6	0.2	0.2	0.0	0.9	3.3	549.7	120.6	703.7	877.2
7	Printing	32.1	0.1	0.7	0.2	0.2	0.0	0.8	0.9	116.9	17.2	169.2	551.9
8	Coke & refined petroleum	221.7	2.7	22.0	4.1	2.0	0.0	16.7	135.6	3191.7	1104.6	4701.1	5135.1
9	Chemicals & Pharmaceuticals	180.2	1.0	6.5	1.8	1.4	0.0	5.5	5.7	1194.5	1051.0	2447.7	2780.8
10	Rubber & Plastic	38.0	0.3	1.5	0.5	0.4	0.0	4.4	5.5	581.0	58.1	689.6	1205.8
11	Non-metallic Mineral	26.4	0.8	6.2	1.7	1.2	0.0	7.0	1.7	314.1	32.4	391.5	663.5
12	Basic Metals & Metal Products	78.7	0.6	2.7	0.8	0.7	0.0	76.6	30.5	3519.1	1786.2	5496.0	6549.5
13	Electronic & electrical engineering	155.7	0.8	3.8	1.2	0.9	0.0	99.1	25.7	1454.9	1937.3	3679.4	4376.6
14	Motor Vehicles/Trailers	70.9	0.5	2.3	0.7	0.5	0.0	12.7	8.2	1488.0	653.2	2236.9	2454.8
15	Other Transport	47.7	0.4	1.8	0.6	0.5	0.0	49.3	5.0	1696.3	203.8	2005.4	2262.3
16	Furniture	87.7	1.0	8.0	2.4	1.5	0.0	34.0	1.5	472.4	110.0	718.7	921.0
17	Electricity, Gas, Waste, Sewerage	820.9	0.3	1.6	0.7	0.4	433.5	32.9	34.9	684.7	3.9	2013.9	5280.5
18	Water	436.7	0.1	0.6	0.2	0.1	0.0	15.4	38.6	15.2	0.8	507.8	697.8
19	Construction	218.2	0.0	0.1	0.0	0.0	0.0	2294.9	11.2	734.8	84.8	3344.2	5099.2
20	Wholesale & Retail	5187.7	25.7	150.6	41.5	23.9	0.0	46.7	277.7	1025.5	272.7	7052.0	8581.3
21	Transportation and storage	667.5	28.6	95.6	19.5	12.9	0.0	10.0	-35.6	1217.6	66.2	2082.3	3654.6
22	Accommodation	1123.7	135.0	584.2	192.9	148.2	0.0	27.8	-8.3	160.0	1.7	2365.2	2625.1
23	Financial & Insurance	849.1	0.7	2.7	1.0	0.6	0.0	53.6	-38.6	583.0	324.1	1776.2	3899.8
24	Other business Services	5411.6	1.4	5.6	1.7	6.5	0.0	160.0	2.1	2766.6	269.6	8625.3	12551.8
25	Public Administration	123.3	0.0	0.0	0.0	0.0	5871.0	0.0	0.0	267.7	0.0	6262.0	6346.8
26	Education	833.6	0.2	0.8	0.3	0.2	1795.2	0.0	-1.3	624.4	0.2	3253.6	3652.1
27	Health	319.1	0.6	2.7	1.8	0.6	5431.8	0.0	0.8	85.5	0.4	5843.4	8162.2
28	Other Services	1216.2	12.6	48.5	17.6	10.8	254.2	33.0	15.6	408.2	413.0	2429.6	3631.9
	Total Intermediate Inputs	**19168.0**	**217.5**	**964.9**	**296.5**	**217.2**	**13785.9**	**3019.3**	**537.1**	**25855.4**	**8828.9**	**72890.7**	**97502.8**
a	Imports RUK	8464.7	3.7	20.5	4.1	2.6	408.8	1481.7	138.9	2092.0	427.8	13044.9	31540.4
b	Imports ROW	5081.3	1.6	15.1	1.9	0.9	0.0	630.3	33.2	411.3	0.0	6175.5	17636.4
c	Income from employment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24218.1
d	Gross Operating Surplus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15962.6
e	Taxes less subsidies on production	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	988.5
f	Taxes on Products	4093.6	20.9	123.9	36.0	24.6	72.9	301.1	17.2	2944.8	954.4	8589.4	10430.1
	Total Primary Inputs	**17715.4**	**26.2**	**159.5**	**41.9**	**28.2**	**481.7**	**2413.1**	**189.3**	**5448.1**	**1382.2**	**27885.6**	**100776.2**
	TOTAL INPUTS	**36883.4**	**243.7**	**1124.4**	**338.4**	**245.3**	**14267.6**	**5432.4**	**726.4**	**31303.5**	**10211.1**	**100776.2**	**198279.0**