

UNIVERSITY OF STRATHCLYDE

MODELLING THE IMPACT OF POLICY AND OTHER DISTURBANCES ON SUSTAINABILITY POLICY INDICATORS IN JERSEY: AN ECONOMIC-ENVIRONMENTAL REGIONAL COMPUTABLE GENERAL EQUILIBRIUM ANALYSIS

VOLUME 2

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Chapter 7. Environmental IO Accounting: Attribution of Pollution Generation to Production and Final Demand Activities in Jersey 1998

1. Introduction - Potential Uses of the Jersey Environmental IO System

In Chapter 6 I construct a KxI (9x25) matrix of Jersey-specific output-pollution coefficients, $\mathbf{M_i}$, which states the physical amount of each pollutant, k, that is directly generated in the production of £1million of sectoral output by each production sector, i, in the Jersey economy (for the base year, long-run equilibrium, case). I also construct a KxZ (9x6 or 9x2) matrix of final demand expenditure-pollution coefficients, $\mathbf{M_z}$, which states the physical amount of each pollutant, k that is directly generated per £1million of final consumption expenditure by each final demand sector, z (again, for the base year, 1998, case). Together with the standard input-output (IO) tables constructed in Chapter 5 (Tables 5.3 and 5.4), these two matrices of direct emissions coefficients form a set of environmental IO tables that I can use to account for and model pollution generation in the Jersey economy.

There are two main types of analyses that an environmental IO system can be used for. The first is descriptive analysis, involving the attribution of pollution generation (or resource use) for a given 'snapshot' of the economy (represented by the IO tables for any given point in time) to the different production or final demand activities that occur within the economy. The second is impact analysis, involving the simulation of demand-side disturbances in order to examine the potential impact on economic and environmental variables from changes in demand patterns in the economy.

In the latter case, my argument in this thesis is that it is important to be aware of the restrictive assumptions that are implicitly invoked if the environmental IO system is used for this type of modelling application:

1. Due to the assumption of universal Leontief (constant proportions) technology in all functional relationships, there is no possibility of price-induced substitution between commodities in production or consumption.

2. In a conventional IO system, the supply-side of the economy is assumed to be entirely passive, with all activity being demand-driven and an infinitely elastic supply of all factors.

In the case of an economy like Jersey, where we know that there are important constraints on supply (particularly in the labour market), these restrictions render IO an unsuitable framework for modelling the effects of disturbances on the system. This is why I have taken the decision in the present study to construct a more flexible CGE modelling framework for this type of application. Therefore, in this chapter my use of the environmental IO system for Jersey is limited to the first type of application identified above. This is attribution of pollution generation to different production and final demand activities for a given snapshot of the economy (represented by the base year described in the economic and environmental accounts constructed in Chapters 5 and 6). However, I do engage in a fuller discussion of the problems inherent in using the environmental IO system for impact analyses in Appendix 7A, where I carry out three illustrative simulations. One of these involves investigating how a demand-driven IO system could be used to analyse the impacts of an increase in demand in the presence of supply-side constraints by exogenously imposing a substitution between different types of activity. For the illustrative case of Jersey, this involves attempting to introduce a scenario under which an expansion in activity in the sectors serving tourist demand can take place without breaching the labour supply constraint that exists in the Jersey economy by introducing a reduction in demand elsewhere in the economy.

The use of the environmental IO system to attribute pollution generation amongst the various production and final demand activities that occur within an economy is essentially an accounting exercise. However, this does not imply that it is any sense atheoretical or value-free. As I explain in Section 2 below, the interpretation of attribution results is dependent on the explicit or implicit theorising used to generate them, and the method of attribution adopted can reveal or conceal particular relationships. Moreover, it may be argued that environmental IO attribution

techniques, subject as they are to the assumption of universal Leontief technology, are also subject to the type of restrictions that I identify above with respect to the environmental IO impact model. However, in Section 2 I also argue that a much weaker set of assumptions is required to support the use of the environmental IO system as an accounting framework for attribution purposes than is required for its use as an impact model.

I present attribution results for Jersey in 1998 in Section 3 of this chapter, and offer a summary and conclusions in Section 4. As noted above, I also present results from the Jersey environmental IO impact model in Appendix 7A at the end of the Chapter. In a second appendix to this chapter, Appendix 7B, I augment the analysis presented in Section 5 of Chapter 6, where I assess the value-added gained from constructing a set of region-specific environmental database in terms of measuring the *direct* contribution of different activities to total local pollution generation. This is done by comparing the results that are generated using the pollution coefficients that are derived from the Jersey-specific accounts against a set of adjusted national (UK) coefficients. In Appendix 7B I extend this comparison to accounting for direct, indirect and induced pollution effects comparing the attribution results that would be found using the UK-adjusted coefficients with what is reported in Section 3.

2. The Theory And Principles Underlying Pollution Attribution Analysis

2.1 Standard IO Attribution Methodology

As I explain in Chapter 6 (Section 5), the Kx1 vector of total pollution generated in the economy in a given time period (e.g. our base year of 1998), **P**, is derived by summing pollution directly generated in production (subscript i) and final consumption (subscript z):

$$\mathbf{(7.1)} \quad \mathbf{P = P_i + P_z = M_i.X + M_z.C^T}$$

where **X** is the Ix1 vector of sector outputs (with elements X_i), $\mathbf{M_i}$ is a KxI matrix of the direct industry output-pollutant coefficients, with $m_{k,i}$ as the amount of pollutant k directly produced per unit of output of sector i, and $\mathbf{M_z}$ is a KxZ matrix of the final demand pollutant coefficients, with $m_{k,z}$ as the amount of pollutant k directly generated per unit of final demand expenditure **C** (with elements C_z).[1]

In Chapter 6 (Section 5) I also explain that the relationship in (7.1) is an identity when base year data are used. This is because I have derived each of the individual elements of matrix $\mathbf{M_i}$, $m_{k,i}$, as the total pollutant of type k directly produced by sector i divided by the total output of sector i. Similarly for $\mathbf{M_z}$, each individual element $m_{k,z}$ is the total pollutant of type k produced by final demand activity z, divided by the total expenditure on activity z. That is to say, I state the coefficients as the average pollution intensities observed in the base time period. Therefore the construction of the pollution coefficient matrices is such that equation (7.1) must hold for base year data.

Equation (7.1) allocates pollution generation to the i production activities and z final demand activities that occur in the economy. However, production itself is undertaken in order to meet final demand. A set of IO accounts (for example, those I present here in Tables 5.3 and 5.4 for Jersey) allocates the output of individual sectors to intermediate and final demand. With 25 production sectors, total output, the Ix1 (25x1) vector **X**, in the IO table can be expressed by the following linear equations:

(7.2)
$$X_1 = x_{1,1} + x_{1,2} + \ldots . x_{1,25} + c_1$$
$$X_2 = x_{2,1} + x_{2,2} + \ldots . x_{2,25} + c_2$$
$$\ldots\ldots\ldots$$
$$X_{25} = x_{25,1} + x_{25,2} + \ldots . x_{25,25} + c_{25}$$

[1] Note that I state final demand as **C** using when referring to *total* final demand expenditure broken down by final demand category – i.e. the (1xZ) vector **C** is composed of the column totals of the full (((I+Y)xZ) where y = 1,...,Y primary commodities) final demand block from the IO table (including imports and expenditure taxes). I use subscript i when referring to total final demand expenditures broken down by commodity – i.e. the (Ix1) vector $\mathbf{C_i}$, with elements c_i, is composed of the row totals of the (IxZ) block of final demands for locally produced commodities.

Where X_1 is the total output of sector i=1, $x_{1,1}$ is the output that firms in sector 1 sells to other firms in sector 1, $x_{1,2}$ is the output that firms in sector 1 sell to firms in sector 2, and so on, and c_1 is the output that sector 1 sells to final demand (summing c_1 to c_{25} gives the (25x1) vector of final demand by commodity, $\mathbf{C_i}$). The elements $x_{i,j}$ (which can also be interpreted as the purchases of firms in sector j from firms in sector i) can also be expressed in terms of the input requirement of sector j, $a_{i,j} = x_{i,j}/X_j$ (where the total inputs to sector j = the total output of sector j). Together all the elements $a_{i,j}$ across the i (where i = j = 25) sectors give us the IxI (25x25) matrix **A**.[2]

Rearranging and substituting the general formula $a_{i,j} = x_{i,j}/X_j$ into equation (7.2) we have:

(7.3)
$$X_1 = a_{1,1}X_1 + a_{1,2}X_2 + \ldots.a_{1,25}X_{25} + c_1$$
$$X_2 = a_{2,1}X_1 + a_{2,2}X_2 + \ldots.a_{2,25}X_{25} + c_2$$
$$\ldots\ldots\ldots$$
$$X_{25} = a_{25,1}X_1 + a_{25,2}X_2 + \ldots.a_{25,25}X_{25} + c_{25}$$

If all the Xs are transferred to the left hand-side and regrouped we have:

(7.4)
$$(1-a_{1,1})X_1 - a_{1,2}X_2 - \ldots. - a_{1,25}X_{25} = c_1$$
$$a_{2,1}X_1 - (1-a_{2,2})X_2 - \ldots. - a_{2,25}X_{25} = c_2$$
$$\ldots\ldots\ldots$$
$$a_{25,1}X_1 - a_{25,2}X_2 - \ldots. - (1-a_{25,25})X_{25} = c_{25}$$

The equations in (7.4) can be written in matrix form as:

(7.5) $\mathbf{(I-A)X = C_i}$

[2] This is similar to the derivation of matrix $\mathbf{E_i}$ in Chapter 6, Section 4. The distinction is that the elements $f_{i,j}$ of matrix $\mathbf{E_i}$ are expressed in physical units per monetary unit of output, whereas the elements $a_{i,j}$ of matrix **A** are expressed entirely in monetary units.

Where **I** is an (IxI) identity matrix with all diagonal elements (i.e. where I=J) equal to 1 and all off-diagonal elements (where I≠J) equal to zero. Rearranging equation (7.5) we have:

(7.6) $\mathbf{X = [I-A]^{-1}C_i}$

where $\mathbf{[I-A]^{-1}}$ is the square (IxJ) Leontief inverse matrix. Each element of the Leontief inverse, $b_{i,j}$, is the output of sector i needed, directly or indirectly, in the production of one unit of final demand in sector j. The column totals of the Leontief inverse are the output multipliers for each sector j - i.e. the total amount of output from all I production sectors needed, directly or indirectly, in the production of one unit of final demand in sector j. Using base year data (as is the case with the 1998 IO accounts for Jersey given in Tables 5.3 and 5.4) expression (7.6) is an identity.

Expression (7.6) allows us to attribute all production in the economy to elements of final demands for local output. The (Ix1) vector $\mathbf{C_i}$ is composed of the row totals of the (IxZ) block of final demands for local produced outputs, where each element $c_{i,z}$ is the expenditure on commodity i by final demand category, z. Therefore by substituting each (Ix1) vector $(\mathbf{c_i})_z$ (expenditure on all locally produced commodities by final demand category z) into (7.6) we can determine how much output is supported, directly and indirectly, by final demand category z. It is also possible to isolate a single element $c_{i,z}$ of each vector $(\mathbf{c_i})_z$ (by making all other elements equal to zero) in order to determine how much output is supported by demand for commodity i by final demand sector z.

Using expression (7.6) for **X**, I can therefore attribute the vector of pollutants directly generated in production to the final demand (for locally produced commodities) vector $\mathbf{C_i}$ through the expression:

(7.7) $\mathbf{P_i = M_i[I-A]^{-1}C_i}$

The term $\mathbf{M_i[I-A]^{-1}}$ is a KxI (here 9x25) matrix of output-pollution multipliers, where each element $\varepsilon_{k,i}$ is the amount of pollution of type k generated, directly or indirectly in the production of one unit of final demand in sector i – i.e. the amount of pollutant k directly or indirectly attributable to one unit of final demand for the output of sector i. Substituting (7.7) into (7.1) implies that all pollution can thereby be attributed to final demand, as:

(7.8) $\mathbf{P = M_i[I-A]^{-1}C_i + M_z.C^T}$

Equation (7.8) demonstrates that once appropriate pollution and production coefficients are identified (matrices $\mathbf{M_i}$ and $\mathbf{M_z}$, and **A**), the production of pollutants can be attributed to elements of the matrix of final demands, just as (7.6) allows attribution of the production of all commodities to elements of final demand. The separate terms on the right-hand side of (7.8) identify respectively the pollutants generated in the production of output for final demand and the pollutants generated by the consumption of these commodities in final demand activities. Thus (7.8) implies a clear causal pathway from final demands to pollution generation. Just as it is possible to use (7.6) to attribute total production of economic outputs to final demand disaggregated by industrial sector (commodity) and/or by final demand category, it is therefore possible to attribute total pollution using (7.8).

As I assert above, equation (7.8) holds as an identity when base year data are used. However, the value of the attribution procedure as an accounting device depends upon the implicit theorising that supports it. Conventional IO analysis overlays the IO accounts with a demand-driven theory of the determination of economic activity (as expressed in equation (7.6)). This theory embodies the following assumptions:

- Universal linear production functions with fixed input coefficients (given by the matrix **A** – see equation (7.3))
- Exogenously determined final demands
- No supply constraints

This is a Keynesian theory of how the economy works where exogenous changes in final demand drive the level and composition of economic activity in the face of a passive supply side. It is this theory that is explicitly or implicitly invoked where IO is used in conventional impact analysis.

One issue that is frequently raised concerns the degree of exogeneity implied in the analysis. For example, conventional IO systems typically offer the option of treating local household consumption as being exogenous or endogenous. Where it is exogenous, it is included as an element of final demand. Where it is endogenous, or partly endogenous, the household sector that supplies labour services is treated as if it were a production sector, with consumption representing its inputs and the labour supplied to production sectors as its outputs. In equations (7.6) and (7.7), the values taken by the output and output-pollution multipliers depend on the degree of endogeneity assumed in the economy. 'Type I' multipliers have consumption exogenous while 'Type II' multipliers have the consumption linked to wage income endogenous. Type I multiplier values will therefore be less than or equal to Type II multiplier values. The results of these standard IO attribution procedures for Jersey are given in Section 3.

2.2 Problems: Resource Constraints, Production Vs Consumption, Imports And The Introduction Of a Neo-Classical Linear Attribution System (NCLAS)

In Section 2.1 I have identified the usefulness of the IO system in terms of the rigour and consistency that is possible in its use as an accounting framework. However, there are a number of concerns over the appropriateness of the standard IO approach, particularly when dealing with environmental attribution. These are the existence of resource constraints, the distinction between production and consumption as sources of pollution, and the treatment of imports. In this section I consider each of these concerns in turn.

2.2.1 Resource Constraints

Environmentalists stress the importance of natural-resources scarcity. However, as I argue in Sections 1 and 2.1 above, the validity of the IO impact model is based upon the assumed linearity of production and consumption and the lack of supply constraints. It may be argued that this renders the whole environmental IO attribution approach inappropriate. This point seems especially relevant in considering the case of a supply-constrained economy like Jersey, where the problem of labour supply is currently a pressing political concern. However, my argument is that a much weaker set of assumptions is required to support the use of IO as an accounting framework for attribution purposes than its use as an impact model. Specifically, I argue in this section that it is possible retain the demand-side focus of IO attribution analysis without having to impose a totally passive supply response.

I attempt to verify this claim firstly by showing that the conventional environmentalists' approach to pollution attribution is consistent with the IO method. Atkinson *et al* (1997) and Pearce & Atkinson (1995) argue in favour of using an inter-regional accounting framework to relate resource extraction and use anywhere in the world to the region where final consumption takes place. The perspective of placing consumption at the heart of the environmental problem is also the focus of what is perhaps the best-known empirical approach to pollution attribution. This method, reviewed in Van den Burgh and Verbruggen (1999), involves the identification of a region's "ecological footprint" (Birknell *et al*, 1998; Proops *et al*, 1999; Wackernagel and Rees, 1996, 1997). Essentially the ecological footprint approach attempts to trace back all the implied pollutants (and resource use) generated in the production of commodities for consumption. It is instructive to investigate the similarity between this and the standard IO pollution-attribution accounts (indeed Bircknell *et al*, 1998, adopt an IO approach in their 'ecological footprint' analysis of land requirements to support consumption in the New Zealand economy).

If we start with the final demand block from the IO table (shown for Jersey as the third and fourth quadrants of Table 5.3) and the associated final demand by commodity and category vectors, respectively $\mathbf{C}_i$ and $\mathbf{C}$ (as defined in Section 2.1). I

calculate the (Kx1) vector, $\mathbf{P_z}$, of direct pollution generated in the final demand activities by multiplying the (KxZ) matrix $\mathbf{M_z}$ of final demand expenditure-pollution coefficients by the transpose of the (1xZ) vector of total final demand expenditure – i.e. $\mathbf{P_z}$ equals $\mathbf{M_zC^T}$. However, I want to further identify the vector of direct and indirect pollution, $\mathbf{P_i}$, generated by the production of these final demand commodities through backward attribution.

I find the physical of amount direct pollution generated in the production of outputs that are sold to final demand by pre-multiplying the (KxI) matrix of direct industry pollutant coefficients, $\mathbf{M_i}$ by the (Ix1) vector $\mathbf{C_i}$, of final demand expenditure on locally produced commodities. However, this does not include the pollutants generated in the production of the intermediate inputs required in the production of the vector of final commodities. I determine these intermediate demands by pre-multiplying the (IxI) matrix of direct production coefficients (the **A** matrix) by the (Ix1) final demand vector $\mathbf{C_i}$. Then I derive the resulting pollutants by again pre-multiplying the (KxI) matrix of industry pollutant coefficients, $\mathbf{M_i}$, by the resultant (Ix1) vector, to give $\mathbf{M_iAC_i}$.

However, the process does not finish here: $\mathbf{M_iAC_i}$ only gives us the first round effects. We need also to identify the pollution generated in the production of the second-round intermediates needed to produce these initial intermediate inputs. I do this by once again pre-multiplying the (IxI) matrix of direct production coefficients, **A**, by the (Ix1) vector of intermediate demands, $\mathbf{AC_i}$, generating the (Ix1) vector of second round intermediate inputs, $\mathbf{A^2C_i}$. I find the associated pollution by pre-multiplying the (KxI) matrix of output-pollution coefficients, $\mathbf{M_i}$, by the (Ix1) second-round intermediate inputs vector, $\mathbf{A^2C_i}$, giving $\mathbf{M_iA^2C_i}$. Of course, the backward attribution needs to be pushed even further, in that there is an infinite number of rounds of intermediate inputs and their associated pollutant impacts. I find the total direct and indirect effects of this production by summing over all these rounds, giving:

$$\mathbf{(7.9)} \quad \mathbf{P_i = M_iC_i + M_iAC_i + M_iA^2C_i + \ldots + M_iA^nC_i + \ldots. = M_i(\Sigma_{n=0}^{\infty}A^n)C_i}$$

In this approach I am attempting to quantify the pollutants that can be attributed to the production of a set of commodities. This process identifies not only the pollutants generated directly in the production of the commodities but also traces back pollutants generated indirectly in the production of all implied intermediate inputs. When applied to a particular observed economic outcome, as captured in a particular IO table, such as the one constructed here for Jersey in 1998, the validity of the approach rests on two basic assumptions. The first is that there is homogeneity within sectors so that each unit of a particular commodity is produced in an identical manner (and generates an identical amount of direct pollutants). The second is that the economy is in long run equilibrium in the year that the IO accounts are constructed for so that the conditions that occurred in the past when the rounds of intermediates were actually produced, are the same as in the present.

Whilst these assumptions might seem restrictive, they are less demanding that those implied by standard IO impact analysis, which also imposes constant returns in production and no resource constraints. The notion that such an attribution process does not require linearity in production is stimulated by a rather similar decomposition of intermediate inputs to dated labour in Sraffa (1960). Sraffa is quite explicit. He states that the reader: "may be inclined ... to suppose that the argument rests on a tacit assumption of constant returns in all industries. ... In fact no such assumption is made" (Sraffa, 1960, p. v).

The argument that I am presenting here is that equation (7.9), which expresses the backward attribution process in IO terms, does not depend upon the assumption of linearity or resource availability. However, it is possible to simplify equation (7.9). In particular, it is a standard result from the Input-Output approach that (ten Raa, 1995):

(7.10) $\Sigma_{n=0}^{\infty} \mathbf{A}^n = [\mathbf{I}-\mathbf{A}]^{-1}$

This means that the backward attribution procedure favoured by environmentalists generates exactly the same results as the standard IO process though it does not rest on the same extreme assumptions that are normally necessary for demand-driven IO analysis. The crucial point is that in the attribution analysis what we are attempting to do is determine the size and nature of the pollution problem at a given point in time (the base year to which the data apply). My argument is that this analysis does not involve making any attempt to speculate as to the impact of any marginal change in activity: it is an *historical* analysis of a situation described by existing economic and environmental accounts. It is therefore possible to retain the demand-driven focus afforded by conventional IO analysis whilst not requiring production coefficients to be constant and/or supply to react passively to changes in demand. This is useful in a Jersey context, if we take the perspective that the economy is driven by the export (increasingly finance) sectors. Although expansion in the economy does hit against supply constraints, my argument is that it is still valid to take the data *at one point in time* and, using the arguments embedded in equations (7.9) and (7.10), compare the pollution intensities of various elements of final demand.

2.2.2 Production vs Consumption

One problem raised by the standard IO pollution attribution method as described in Section 2.1 (and reported for Jersey in Sections 3.2-3.4 below) concerns the role it attributes to consumption. Where Type II pollution-output multipliers are used, private consumption typically disappears or becomes very small as an independent source of pollution. For consumption financed by wage income, the pollution generated directly in the consumption process and directly and indirectly in the production of goods consumed is allocated to the sectors in which the wage income is generated that finances this consumption. This is a perfectly valid perspective, especially if one thinks that the population level is linked directly to economic activity. However, many environmentalists seek to locate the source and responsibility for pollution in human private or public consumption. My argument in this section is that this perspective is lost in the context of an IO attribution based on Type II multipliers.

Even where Type I output-pollution multipliers are used, the standard IO pollution attribution analysis might be thought to give misleading results if one wished to focus on consumption as the ultimate source of pollution. The use of Type I multipliers does mean that domestic private and public consumption is typically attributed a significant portion of pollutant outputs (see, for example, the results for Jersey in Section 3.4 below). However, in an open economy pollutants will also be allocated to exports, which are, directly or indirectly, entering the consumption of individuals, firms and governments operating outwith the domestic jurisdiction. I would argue that it would seem to go against the spirit of this kind of approach to attribute to an economy like Jersey the pollution generated by Jersey exports because these are ultimately meeting consumption demand from the rest of the world.

This raises the issue that the concerns of environmentalists seem to be suggesting the merit of at least one other attribution accounting concept, which should mirror the differences in the conventional national accounting concepts, GDP and GNP. Gross Domestic Product (GDP) is the value of goods and services generated within a particular economy. Gross National Product (GNP) is the income of the residents within a particular economy. GDP and GNP may differ in that, for example, residents of one country might own productive resources located in another country. The output of those resources contributes to one country's GDP but the other country's GNP. Similarly I would define Gross Domestic Pollution as the pollution generated by activity located within a particular country, whilst Gross National Pollution would be the pollution generated directly or indirectly by the consumption of the residents of that economy.

Unfortunately, IO accounts are built around production and the national accounting figure that can be derived from them is GDP. However, such a measure could be operationalised with the aid of a Social Accounting Matrix (SAM) (Pyatt and Round, 1985). As I explain in Chapter 5, a SAM provides an appropriate framework for measuring GNP: containing information additional to that captured in the IO accounts on sources and flows of income, the SAM permits a better understanding

of what drives consumption in the economy. For example, in Section 3.2 below, I question the classification of endogenously and exogenously driven elements of household consumption that is possible in the IO framework. There the only endogenous driver of household consumption is income from employment. However in a SAM it would also be possible to identify what share of household consumption is funded by other types of income that are generated in the local economy, such as profit income from ownership of local firms. Therefore, I conclude that attribution analysis using the Jersey SAM would be an advance on the basic IO analyses contained in this chapter.

2.2.3 Imports

The second problem associated with the standard IO attribution method concerns imports. In Equation (7.9) I show how the pollution indirectly generated in the production of goods and services can be identified. However, this is only the pollution generated by the intermediate production that takes place in the geographical area covered by the IO table. What the standard IO method of attribution does not do is to identify the pollution associated with the imports consumed directly as final demand or used as intermediate inputs. This is the approach that those adopting Ecological Footprint analysis attempt to follow. Therefore, again even where Type I output-pollution multipliers are used, the pollution generated by imports directly or indirectly associated with domestic consumption is not being so allocated.

Here, I argue that the problem of imports raises both practical and conceptual issues. I will discuss the practical issues first, using Jersey as an example of the domestic economy. In order to attribute the pollution associated with imports (in the manner proposed by authors such as Atkinson *et al*, 1997 and Pearce & Atkinson, 1995) I would require information on:

- the direct imports to consumption in the domestic economy (e.g. Jersey), broken down by commodity and country of origin

- the imports used as intermediate inputs for each local industry, broken down by commodity and country of origin
- an I-O table for each country from which imports are drawn.

These I-O tables from the countries exporting to Jersey would themselves need to have the following characteristics:

- a compatible sector classification
- a comparable set of pollution-output coefficients
- a similarly complex set of import coefficients

Of course, in so far as the countries exporting to Jersey import from other countries not already included in the analysis (i.e. countries that do not themselves directly export to Jersey), they too would need a full set of compatible IO and pollution accounts plus detailed import information.

None of these data are available in the current study, with the implication that it is not possible to take even the first step in the attribution of pollution associated with Jersey's imports. This is not a problem that is peculiar to the case of Jersey. Typically in IO tables imports to final and intermediate demand are not broken down by commodity and this is the convention we have followed in the construction of the Jersey IO data. However, even if these data were available to me, I do not have access to the voluminous information set needed to complete this attribution. Essentially, unless a small group of countries make up a closed trading enclave, what is needed is a consistent world IO table, with commodities broken down by location of production, together with a compatible set of pollution coefficients. Generally, environmental IO analysis is some way away from being able to construct such a table.

One feasible information source that would allow limited across-border attribution of pollutants would be an appropriate multi-regional IO table. If sectorally and

regionally disaggregated data on imports are available, pollution attribution between the regions should be possible.

The second issue relating to imports is a conceptual one. If the pollution associated with Jersey's imports is to be attributed to Jersey's economic activity, consistency requires that the pollution associated with Jersey's exports should be attributed to the countries that are importing these traded goods and services. In not incorporating the pollution generated by the production of imports, conventional IO attribution is not incomplete. Rather it is simply focussing on the allocation of pollutants to the locations where pollution emission takes place. However, such a focus might seem appropriate. After all, an importer does not know the direct and indirect pollutants that were generated in the production of an imported good. As I have explained already, the data needed to make such a calculation are simply not available. Moreover, the importing country has typically no jurisdiction over the production processes employed by the exporting country. One could argue that the exporting country, in allowing the pollutants to be produced, is the country to which the pollution should be attributed.

One way in which both the informational and conceptual problems raised with the incorporation of the pollution associated with imports can be met, whilst still maintaining the consumption orientation of that measure, is to adopt a neo-classical, rather than the standard Keynesian economic approach to attribution in the IO framework. In such an approach, rather than exports being seen as exogenous, they are treated as endogenous: the country exports simply to finance its imports. That is to say, rather than endogenising the household sector, as in the standard Type II pollution-output multipliers, one endogenises the trade sector, to generate what I refer to here as a neo-classical output-pollution multiplier. I introduce an NCLAS system for Jersey in Section 3.5 below.

In this analysis, I identify a trade sector that transforms exports into imports. Its inputs are therefore Jersey exports and its outputs are the imports that are used directly in consumption and indirectly as intermediates in the production process. In

so far as production or consumption requires imports, the pollution that is attributed is the pollution generated in the production of exports required to finance these imports. I also identify an investment sector where I endogenise capital formation. This allows me to isolate local private (households) and public (government) *present* final consumption as the only exogenously determined final demands that drive activity and therefore pollution generation in the economy. I call this process a *neo-classical* linear attribution system because it focuses on local final consumption as the exogenous driver of economic activity, for example by taking the perspective that export production is driven by the need to import, and recognising the existence of supply constraints.

The NCLAS results that I report in Section 3.5 are based around the Jersey IO table and pollution coefficients. As such the focus is still on production and the pollution generated within the Jersey borders. However, the NCLAS approach attributes this pollution to consumption and the data give the different pollution intensities of different consumption expenditures. Again the validity of the NCLAS system does not require linearity or a lack of resource constraints.

3. Attribution Results For Jersey (1998)

3.1 Direct Emissions By Sector In Jersey In 1998

In Chapter 6 I derive the matrices $\mathbf{M_i}$ and $\mathbf{M_z}$ of direct emissions coefficients for the eight individual and one composite pollutants across the twenty-five production sectors and six final demand sectors that are responsible for the direct generation of emissions in the Jersey economy. I present these matrices in Table 6.15. Together with the standard IO tables for Jersey (constructed in Chapter 5) this provides the basis for conducting environmental IO analysis.

The most basic accounting exercise that can be done with an environmental IO system in the form of an IO table and a set of direct emissions coefficients for a given year is the estimation of the amount of different pollutants generated in the

economy during that year. See equation (7.1), where I multiply matrix $\mathbf{M_i}$ by the sectoral gross outputs ($\mathbf{X}$) vector and matrix $\mathbf{M_z}$ by the vector of total final demand expenditures ($\mathbf{C^T}$). Summing the results of these two calculations gives the vector $\mathbf{P}$ of total pollution output. The direct contribution of each individual production sector, i, to the total output of pollution in the economy is calculated by multiplying each element of the ith column in Matrix $\mathbf{M_i}$ by the total sectoral output of sector i, X_i. A similar procedure is used to allocate direct pollution generation to final demand each final demand sector, C_z. Formally, if matrices $\mathbf{M_i}$ and $\mathbf{M_z}$ are broken down into (Kx1) column vectors $\mathbf{m_i}$ and $\mathbf{m_z}$, the (Kx1) vectors of pollutants directly generated by sector i and activity z, $\mathbf{p_i}$ and $\mathbf{p_z}$, are given by

(7.11) $\mathbf{p_i} = \mathbf{m_i}.X_i, \forall i$

(7.12) $\mathbf{p_z} = \mathbf{m_z}.C_z, \forall z$

where X_i and C_z and the scalars of total sectoral output/expenditure. I present the results of estimating total pollution by sector in this manner below in Table 7.1 (the matrices $\mathbf{P_i}$ and $\mathbf{P_z}$ of total pollution by sector in the Jersey economy for 1998)[3].

From the results in Table 7.1 (I report these in percentage terms in Table 6.18, Chapter 6) I can determine the main sources of direct pollution generation in the Jersey economy. The size of any one sector's direct contribution to the total output of any one pollutant in the economy is determined by two factors: the emissions intensity of production/final consumption and the absolute size of the sector in terms of its gross output/total final demand expenditure.

For four of the eight individual pollutants the largest shares of total emissions are directly generated in the household sector. This is because household consumption is

[3] As I explain in Section 5 of Chapter 6, because I have already estimated emissions-by-sector in order to derive matrices $\mathbf{M_i}$ and $\mathbf{M_z}$ for Jersey (in Chapter 6, Section 3), the main purpose of carrying out this calculation here is to check that the environmental IO system successfully recreates base. If the reader compares the results shown in Table 7.1 with the estimates shown in Table 6.18 (Chapter 6), it is clear that the Jersey environmental IO system satisfies this restriction for all sectors (Table 6.13 is effectively the transpose of the matrices $\mathbf{P_i}$ and $\mathbf{P_z}$ shown in Table 7.1).

a relatively pollution-intensive activity in Jersey, with the household sector having the third highest physical fuel consumption per £1million of activity (production of output or final demand expenditure) and relatively high levels of total expenditure. In countries with heavier industrial bases and where production is more transport-intensive the contribution of the household sector to pollution generation will not be so great (though the absolute level of pollution produced by each household may be bigger). For example, my findings show that in Jersey the household sector is directly responsible for 41% of the global warming potential of the economy (measured by the composite GWP pollution indicator[4]). In economies like Scotland and the UK the contribution of households is half this figure or less (around 16% and 21% respectively), despite the fact that UK household expenditure is more GWP intensive than in Jersey[5]. (The higher GWP intensity of UK household expenditure most likely results from the fact that it is more fuel intensive both in terms of motive (personal transport) and non-motive (heating) fuel use due to greater abundance of roads to drive on and what is, on average, a colder climate. However the proportionate contribution of households to total global warming potential in the UK will be lower than in Jersey because the structure of the UK economy is different, with a greater prevalence of polluting industrial activities, particularly in the manufacturing sector.)

The Jersey economy does not have a heavy industrial base. Therefore, the direct generation of emissions in production activities tends to be concentrated in several key sectors. Generally, there are four sectors which dominate in terms of direct generation of emissions of all pollutants: 'Electricity', 'Agriculture & Fishing', 'Sea & Air Transport and Transport Support' ('SATTS') and 'Public Services'. However, the contribution of these sectors to total emissions does vary across pollutants and is clearly related to production processes and activities with relatively high emissions intensities.

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[4] The GWP index is a weighted sum of emissions of CO_2 (with a weight of 1), methane (weight 21) and N_2O (weight 310).

[5] I derive comparative figures for Scotland and the UK using the UK NAMEA database (see Chapter 6, Section 5, and Appendix 6B), which was supplied to me by Rocky Harris, Head of the Environmental Accounts Branch at National Statistics (see National Statistics, 2000, McGregor *et al*, 2001c).

Table 7.1 Total Direct Emissions (kilograms[1]) in Jersey, 1998, Generated in The Production Of Sectoral And Total Output, And During Final Consumption by Households and Tourists

Sector / Pollutant	Agriculture & Fishing	Quarrying & Construction	Manufacturing	Electricity	Water	Gas, Oil & Fuel Dist.	Jersey Telecom.	Wholesale & Retail Trade	Hotels, Rest. & Catering	Land Transport	Sea & Air Trans. & Trans Supp	Jersey Post	Banks & Building Soc.	Insurance Companies	Inv. Trusts & Fund Mgrs	Computer Services	Legal Activities	Accountancy	Other Bus. Activities
Global warming potential (GWP) composite	31601128.04	7108226.41	5855754.23	61198692.39	162118.75	922019.03	230605.60	8682985.35	9809295.07	1293560.51	19513710.46	260406.46	69706.27	82951.20	1128459.42	254161.47	279969.84	54539.68	968000.41
Carbon dioxide (CO2) as carbon	14876951.45	7053355.26	5833039.98	61192461.89	160446.81	912873.17	228548.04	8601616.77	9789896.98	1280798.70	19478886.60	258969.79	69617.37	81883.01	1117011.02	251097.69	277268.17	53837.35	958203.10
Methane (CH4)	795207.35	267.23	334.25	170.48	31.97	140.31	23.43	1659.96	443.17	248.18	1436.82	6.33	2.99	35.62	381.94	94.58	58.64	23.42	179.48
Sulphur dioxide (SO2)	307605.36	3207.67	66503.43	443513.40	0.00	0.00	28.40	4448.49	30139.62	343.39	18265.49	443.22	352.66	0.00	936.60	14.68	0.00	0.00	0.00
Nitrous oxides (NOx)	127371.26	23503.05	34078.70	808207.23	782.78	6699.54	726.08	58674.89	47579.66	7986.55	357521.31	902.17	444.39	438.59	5838.54	1241.87	1028.01	288.37	3453.44
Non-methane volatile organic compounds (NMVOC)	15088.94	10341.19	12324.92	11072.17	1160.33	4956.95	876.18	59443.00	17050.15	8930.86	100305.16	256.17	114.73	1297.69	13933.15	3450.13	2160.78	853.22	6614.69
Carbon monoxide (CO)	65775.63	28588.89	66779.86	43797.56	6829.06	26919.21	4553.86	349245.83	96086.77	52252.72	294942.24	649.47	692.40	8326.67	89239.75	21946.22	13074.91	5474.71	38999.77
Nitrogen dioxide (N20)	80.07	158.90	50.63	8.55	3.23	20.00	5.05	150.03	32.55	24.35	15.00	4.21	0.08	1.03	11.06	3.54	4.74	0.68	19.45
Black smoke	0.00	0.00	0.00	53852.00	0.00	0.00	0.00	0.00	0.00	0.00	19575.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Sector / Pollutant	Other Service Activities	Recreation, Culture & Sport	Education	Health, Social Work & Housing	Public Services	Public Admin. & Defence	Total emissions from production	Household 1	Household 2	Household 3	Household 4	Household 5	Tourists	Total emissions from final consumption	TOTAL EMISSIONS (kg)
Global warming potential (GWP) composite	1902575.79	1604743.10	1261871.13	3757739.22	15169330.84	353806.92	173546377.59	9484762.74	20693669.05	24408538.50	31357181.14	42938989.92	9421446.81	138304588.15	311850965.74
Carbon dioxide (CO2) as carbon	1868953.77	1600809.91	1260708.64	3755254.59	15097454.20	353719.24	156451663.50	9007117.42	20066179.12	23729696.49	30599539.90	42109111.00	9101674.81	134613318.74	291065182.24
Methane (CH4)	286.39	62.91	7.83	22.59	3409.36	2.03	604537.26	21644.74	26971.26	28822.61	31607.70	34154.84	13523.38	156724.52	961261.78
Sulphur dioxide (SO2)	18365.34	2927.54	2798.31	5623.92	783.85	125.81	906427.55	16517.97	19587.17	37487.40	28074.85	16699.62	0.00	118367.00	1024794.55
Nitrous oxides (NOx)	8626.05	6102.07	4868.84	13240.12	94940.59	1057.73	1615601.83	37126.66	88914.83	105910.00	136265.55	176623.44	45450.88	590291.37	2205893.20
Non-methane volatile organic compounds (NMVOC)	10576.74	2504.37	464.97	1473.29	276336.29	153.25	561739.32	111103.17	282085.76	346317.76	432757.89	510691.25	158815.80	1841771.63	2403510.94
Carbon monoxide (CO)	62370.15	12858.15	752.44	2050.76	1111528.29	170.35	2403905.68	649143.18	1664677.98	2034931.15	2554113.17	3025129.09	945344.71	10873339.25	13277244.93
Nitrogen dioxide (N20)	30.99	8.43	3.22	6.48	0.90	0.15	643.33	74.54	197.08	237.31	302.84	363.31	114.78	1289.85	1933.18
Black smoke	0.00	0.00	0.00	0.00	0.00	0.00	73427.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	73427.00

Notes:
1. The GWP (Global Warming Potential) index is a weighted sum of CO_2 (weight 1), methane (weight 21) and N_2O (weight 310): it therefore should not be read as 'kilograms' but simply as an index that is comparable across sectors within an economy and across different economies

For example, electricity is generated in Jersey using a particularly pollution-intensive method which involves burning significant quantities of heavy fuel oil. 'Electricity' is the only sector that uses heavy fuel oil in production. Stationary combustion of heavy fuel oil using electricity generation technology has a high emissions intensity of air pollutants like NO_X and SO_2 (relative to stationary combustion of other fuel types in Jersey). Table 7.1 reveals that 'Electricity' is the production sector with the highest level of direct emissions of these two pollutants (accounting for 36.6% and 43.3% of total NO_X and SO_2 emissions respectively – see Table 6.18). However, the scale of stationary fuel combustion is also an important determining factor to the contribution of 'Electricity' to emissions of all pollutants. For example, while combustion of heavy fuel oil in electricity generation has a similar CO_2 intensity to stationary combustion of other fuels, 'Electricity' is the production sector with the highest contribution to total CO_2 emissions on the Island (21%), and also to the GWP index (19.6%). For black smoke, only two sectors are direct emitters, 'Electricity' (73.3%) and 'SATTS' (26.7%).

Emissions in the 'SATTS' sector are mainly non-stationary emissions relating to aircraft takeoff and landing cycles. 'SATTS' is the main public transport sector on Jersey (it is three times the size of the 'Land Transport' sector, in terms of output produced, which is limited due to the small geographical size of the Island), and its activities are relatively pollution intensive. However, pollution intensity in this sector is not generally as high as the other three main polluting sectors identified above. The absolute size of the sector is the key factor determining the relative contribution of 'SATTS' to total pollution: it is the 11^{th} largest sector (of the 25) in the Jersey economy in terms of gross output produced and the largest of the four main polluting sectors named above.

While scale is still important, the contributions of 'Public Services' and 'Agriculture & Fishing', on the other hand, are more related to the emissions intensity of production. In the 'Public Services' sector the process of waste incineration is highly intensive in the production of gases like NO_X and CO_2, the latter leading to this

sector having the second highest GWP intensity. 'Agriculture & Fishing' has relatively high emissions intensity across most of the pollutants identified here. This is due to the fuel-intensity of production in this sector (only 'Electricity' uses more fuel per unit of output produced) and, in the case of methane (CH_4), to the emissions intensity of using livestock in production.

Together, the four main direct polluting sectors ('Electricity', 'Agriculture & Fishing', 'SATTS' and 'Public Services') account for the bulk (between 63% and 100%) of all emissions directly generated in production for seven out of the eight individual pollutants identified here. The only exception is N_2O. Note that in the current Jersey environmental IO model I only report N_2O emissions as being generated by a single source – automotive fuel use[6]. The two biggest automotive fuel users on the island are households (70.5% of total petrol and diesel) and tourists (6.9%), and therefore the bulk (66.7%[7]) of N_20 emissions are directly generated by these final demand sectors. In the production sector, the contribution of individual sectors to total N_2O emissions also correlates with automotive fuel use, with 'Wholesale & Retail Trade' (7.8%), 'Quarrying & Construction' (8.2%), 'Manufacturing' (2.6%) and 'Hotels, Restaurants & Catering' (1.7%) being the main direct contributors (along with 'Agriculture & Fishing' (4.1%)).

So far I have only examined the *direct* contribution of production and final demand sectors by estimating total emissions generation by each individual sector using the direct emissions intensity coefficients and the output and final demand expenditure data from the standard IO table. However, in a conventional IO system *all* activity is driven by demand: by looking along the rows of an IO table we see that the total sectoral output of each sector can be accounted for as being produced to meet intermediate or final demand. This has two main implications in terms of

[6] As I explain in Chapter 6, Section 3.3.4, I would also expect to see N_2O emissions arising from at least one non-fuel-combustion related source. This is agricultural production in Jersey, where the use of fertilisers would be expected to give rise to N_2O emissions. However, at this time appropriate data are not available on the physical use of fertilisers in agriculture or on emissions factors for this source.
[7] Households and tourists mainly combust automotive fuel in petrol-fuelled vehicles. From Table 6.2 in Chapter 6 we can see that these are less N_2O-intensive than diesel-fuelled vehicles. This explains why the share of direct N_2O emissions generated by these final demand sectors is lower than their share of automotive fuel use.

determining the actual contribution of individual sectors to total pollution generated in the economy.

The first implication is that in order to produce their output, each sector purchases inputs from other sectors of the economy, and this means that there will be additional *indirect* emissions attributable to the production of that output. Put another way, the direct emissions generated in the production of any sector's output, e.g. that of the 'Electricity' sector, means that there is pollution generation *embodied* in that output. This has the implication that when other sectors purchase electricity in order to produce their own output they are indirectly responsible for emissions generated in the 'Electricity' sector. The IO table (Table 5.3) tells us that in the base year (long-run equilibrium) case only 47% of the output of the Jersey 'Electricity' sector is produced to meet its own final demand requirements. The other 53% is produced to meet intermediate demand from other production sectors in order to meet *their* final demand requirements, or further intermediate demand. If we want to determine the full pollution impact of each sector's production to meet its own final demand requirements, taking into account the emissions embodied in all inputs used, the environmental IO system can be used for output-pollution multiplier analysis.

In an IO system conventionally all production activity can be represented as being ultimately driven by final demand. So far I have only reported the *direct* contribution of final demand sectors to total pollution: in Chapter 6 I explain that in Jersey these arise from human waste and from consumption activities that involve combusting energy commodities. However, all other goods and services consumed by final demand sectors are likely to have some degree of embodied pollution. If we want to determine the full pollution impact of each final demand sector's consumption activities, taking into account all the pollution engendered in the production/provision of consumption goods and services, the multiplier analyses can be extended to conduct what is referred to as 'attribution to final demand'.

Table 7.2 Type I Leontief Inverse - Jersey 1998

Sectors	Agriculture & Fishing	Quarrying & Construction	Manufacturing	Electricity	Water	Gas, Oil & Fuel Dist.	Jersey Telecom.	Wholesale & Retail Trade	Hotels, Rest. & Catering	Land Transport	Sea & Air Trans. & Trans Supp	Jersey Post	Banks & Building Soc.	Insurance Companies	Inv. Trusts & Fund Mgrs	Computer Services	Legal Activities	Accountancy	Other Bus. Activities	Other Service Activities	Recreation, Culture & Sport	Education	Health, Social Work & Housing	Public Services	Public Admin. & Defence
Agriculture & Fishing	1.01099	0.00095	0.11213	0.00034	0.00076	0.00140	0.00261	0.00180	0.03233	0.00139	0.00009	0.00200	0.00017	0.00130	0.00206	0.00093	0.00180	0.00082	0.00129	0.00060	0.02053	0.00052	0.00263	0.00069	0.00014
Quarrying & Construction	0.02760	1.04597	0.01982	0.00512	0.03979	0.06069	0.05024	0.01182	0.02555	0.00624	0.02905	0.02125	0.00100	0.01647	0.00480	0.00539	0.00900	0.00700	0.00280	0.00115	0.05183	0.05741	0.03281	0.16599	0.02444
Manufacturing	0.00667	0.00797	1.01885	0.00306	0.00598	0.01258	0.02224	0.00713	0.01637	0.01222	0.00078	0.01595	0.00142	0.01067	0.01816	0.00662	0.01445	0.00700	0.01124	0.00720	0.01079	0.00192	0.01136	0.00564	0.00078
Electricity	0.02684	0.00377	0.02791	1.00052	0.04515	0.00455	0.01117	0.01883	0.02180	0.00565	0.03434	0.00735	0.00035	0.00388	0.00280	0.00611	0.00605	0.00533	0.00428	0.00688	0.02430	0.01079	0.01574	0.03737	0.00527
Water	0.00580	0.00021	0.00587	0.00478	1.00033	0.00034	0.00036	0.00063	0.00468	0.00060	0.00242	0.00049	0.00002	0.00056	0.00031	0.00021	0.00045	0.00013	0.00039	0.00066	0.00446	0.00375	0.00572	0.01456	0.00205
Gas, oil & fuel distribution	0.01101	0.00170	0.00449	0.00048	0.00089	1.00229	0.00067	0.00148	0.00681	0.00325	0.00142	0.00091	0.00002	0.00030	0.00035	0.00078	0.00041	0.00016	0.00084	0.00301	0.00840	0.00506	0.00780	0.02014	0.00281
Jersey Telecommunications	0.00769	0.00619	0.00620	0.00456	0.00622	0.01052	1.00210	0.01037	0.00843	0.00644	0.00135	0.00458	0.00105	0.01510	0.00647	0.01314	0.01020	0.01160	0.01185	0.00312	0.00996	0.00666	0.00969	0.01720	0.00202
Wholesale & Retail Trade	0.04588	0.02623	0.02425	0.00177	0.02555	0.00318	0.12517	1.00737	0.01079	0.00146	0.00099	0.00375	0.00020	0.00425	0.00138	0.00197	0.00233	0.00184	0.00245	0.00102	0.01159	0.04511	0.05291	0.03089	0.00430
Hotels, Restaurants & Catering	0.00050	0.00137	0.00175	0.00003	0.00029	0.00016	0.00044	0.00024	1.00152	0.00132	0.00018	0.00428	0.00018	0.00130	0.00103	0.00033	0.00009	0.00121	0.00082	0.00016	0.00193	0.00186	0.00414	0.00127	0.00030
Land Transport	0.00107	0.00111	0.00182	0.00002	0.00008	0.00009	0.00034	0.00019	0.00129	1.00006	0.00003	0.00023	0.00001	0.00081	0.00062	0.00003	0.00017	0.00220	0.00008	0.00004	0.00061	0.00175	0.00212	0.02218	0.00019
Sea & Air Transport & Transport Support	0.00104	0.00080	0.01099	0.00192	0.00065	0.00092	0.00298	0.00633	0.00665	0.00420	1.00034	0.04283	0.00035	0.00198	0.00320	0.00289	0.00137	0.00110	0.00084	0.00057	0.00264	0.00183	0.00299	0.00185	0.00027
Jersey Post	0.00679	0.00292	0.00560	0.00329	0.01042	0.01365	0.00766	0.01525	0.00412	0.07061	0.00039	1.00601	0.00136	0.02585	0.00658	0.00283	0.00589	0.00257	0.01040	0.00327	0.00836	0.00476	0.00570	0.01271	0.00133
Banks & Building Societies	0.06724	0.01770	0.02247	0.00256	0.13857	0.00722	0.00345	0.00619	0.10605	0.01022	0.00115	0.00262	1.00013	0.00583	0.01371	0.00130	0.00319	0.00125	0.00377	0.01296	0.00963	0.00585	0.00635	0.00577	0.00112
Insurance Companies	0.01143	0.00405	0.00503	0.00054	0.01044	0.00074	0.00244	0.00373	0.00558	0.00557	0.00118	0.00093	0.00006	1.00171	0.00227	0.00511	0.00734	0.00143	0.01058	0.00602	0.00311	0.00332	0.00230	0.00334	0.00019
Investment Trusts & Fund Managers	0.00039	0.00007	0.00801	0.00002	0.00005	0.00010	0.00020	0.00027	0.00025	0.00010	0.00001	0.00013	0.00001	0.00009	1.00014	0.00005	0.00011	0.00008	0.00009	0.00006	0.00009	0.00002	0.00010	0.00005	0.00001
Computer Services	0.00251	0.00288	0.00243	0.00016	0.00187	0.00787	0.01205	0.00432	0.00288	0.00472	0.00018	0.00301	0.00043	0.00248	0.00392	1.00062	0.00230	0.04782	0.00815	0.00056	0.00320	0.00237	0.00405	0.00120	0.00074
Legal Activities	0.02751	0.00676	0.02044	0.00750	0.01103	0.00773	0.00974	0.03288	0.03248	0.03143	0.00066	0.00661	0.00339	0.04826	0.03042	0.02542	1.03166	0.00674	0.03738	0.00592	0.03337	0.00272	0.01781	0.00732	0.00166
Accountancy	0.00807	0.00389	0.00482	0.00081	0.00352	0.00159	0.00131	0.00571	0.00534	0.00648	0.00021	0.00081	0.00036	0.01407	0.00248	0.00318	0.00354	1.00073	0.00952	0.00799	0.00304	0.00186	0.00206	0.00132	0.00032
Other Business Activities	0.15659	0.02400	0.05547	0.00581	0.18209	0.02691	0.02206	0.05920	0.02854	0.04455	0.00430	0.06487	0.00178	0.05290	0.02496	0.03340	0.02427	0.05005	1.05438	0.01204	0.04524	0.01699	0.03061	0.03131	0.00359
Other Services Activities	0.03054	0.00564	0.01139	0.00012	0.00260	0.01390	0.00336	0.00905	0.00488	0.01435	0.00237	0.00266	0.00012	0.00107	0.00053	0.00207	0.00079	0.00052	0.00182	1.00118	0.00691	0.00289	0.00209	0.00865	0.00183
Recreation, Culture & Sport	0.00001	0.00000	0.00000	0.00000	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	1.00207	0.00000	0.00001	0.00000	0.00154
Education	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	1.00000	0.00000	0.00000	0.00000
Health, Social Work & Housing	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	1.00000	0.00000	0.00000
Public Services	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	1.00000	0.00000
Public Administration & Defence	0.00448	0.00018	0.00188	0.00203	0.00523	0.00194	0.00094	0.00191	0.00093	0.00180	0.00063	0.00010	0.00008	0.00093	0.00031	0.00118	0.00137	0.00068	0.00011	0.00028	0.00279	0.00093	0.00803	0.00288	1.00012
Total - Type I output multipliers	1.4610	1.1641	1.3894	1.0455	1.4897	1.1802	1.2816	1.2043	1.3269	1.2325	1.0821	1.1926	1.0125	1.2098	1.1263	1.1136	1.1268	1.1522	1.1729	1.0829	1.2548	1.1781	1.2251	1.3920	1.0548

Table 7.3 Direct Plus Indirect Emissions Intensities (kg[1]) Per £1million Final Demand For Outputs Of Local Production Sectors in Jersey 1998 - With All Final Demands Determined Exogenously (Type I Output-Pollution Multipliers)

Sectors / Pollutants	Agriculture & Fishing	Quarrying & Construction	Manufacturing	Electricity	Water	Gas, Oil & Fuel Dist.	Jersey Telecom.	Wholesale & Retail Trade	Hotels, Rest. & Catering	Land Transport	Sea & Air Trans. & Trans Supp	Jersey Post	Banks & Building Soc.
Global warming potential (GWP) composite	606039.114	40386.705	164837.190	1312998.241	77405.676	73605.245	29208.770	52113.102	95802.352	76965.054	325164.857	39815.605	925.476
Carbon dioxide (CO2) as carbon	308064.402	39838.400	131526.963	1312758.528	77001.679	72542.946	28333.753	51322.113	86156.989	75896.543	324624.687	39104.070	873.735
Methane (CH4)	14166.119	14.853	1575.247	8.535	14.010	29.471	38.125	30.549	455.535	32.217	22.054	29.637	2.416
Sulphur dioxide (SO2)	5763.733	65.804	1558.220	9510.040	440.486	70.688	141.459	193.967	533.700	99.658	590.315	129.970	5.713
Nitrous oxides (NOx)	2775.760	191.021	1152.549	17335.147	869.674	556.620	269.028	503.766	714.218	532.998	5707.106	413.121	9.491
Non-methane volatile organic compounds (NMVOC)	317.677	61.367	195.476	242.548	126.868	351.792	60.661	196.202	113.699	462.614	1444.756	88.763	1.410
Carbon monoxide (CO)	1437.035	207.471	984.326	960.158	715.935	1902.730	316.365	1115.510	593.663	2681.961	4263.212	287.104	6.360
Nitrogen dioxide (N20)	1.568	0.763	0.742	0.195	0.354	1.430	0.240	0.482	0.255	1.264	0.249	0.288	0.003
Black smoke	31.248	4.574	35.273	1154.695	52.318	5.508	13.716	20.950	27.008	7.694	319.234	20.448	0.497

Sectors / Pollutants	Insurance Companies	Inv. Trusts & Fund Mgrs	Computer Services	Legal Activities	Accountancy	Other Bus. Activities	Other Service Activities	Recreation, Culture & Sport	Education	Health, Social Work & Housing	Public Services	Public Admin. & Defence
Global warming potential (GWP) composite	11801.404	11429.914	25067.616	14326.549	10660.002	19422.770	87680.157	86213.792	39476.333	51330.456	631019.560	14672.747
Carbon dioxide (CO2) as carbon	11361.791	10772.053	24607.802	13810.164	10388.457	18917.969	86817.750	80030.700	39268.164	50498.670	628017.229	14617.753
Methane (CH4)	19.731	30.347	18.568	23.324	12.251	20.338	22.794	289.780	7.914	37.720	139.217	2.155
Sulphur dioxide (SO2)	53.340	54.509	70.765	76.955	60.783	57.094	799.801	424.943	156.301	211.086	402.229	55.419
Nitrous oxides (NOx)	106.221	98.727	198.978	136.179	113.560	129.378	509.345	644.284	294.777	402.047	4276.876	117.677
Non-methane volatile organic compounds (NMVOC)	57.669	59.496	206.652	35.925	29.425	86.588	434.278	91.096	29.189	39.008	10446.577	8.810
Carbon monoxide (CO)	347.985	357.122	1292.094	204.390	173.871	503.808	2520.089	452.240	118.880	160.242	42060.747	31.402
Nitrogen dioxide (N20)	0.082	0.066	0.225	0.086	0.046	0.251	1.238	0.315	0.135	0.128	0.254	0.031
Black smoke	5.021	4.124	7.855	7.360	6.452	5.176	10.334	28.771	12.876	18.998	43.538	6.161

Notes:

1. The GWP (Global Warming Potential) index is a weighted sum of CO2 (weight 1), methane (weight 21) and N_2O (weight 310): it therefore should not be read as 'kilograms' but simply as an index that is comparable across sectors within an economy and across different economies

3.2 Jersey Output-Pollution Multipliers

In standard IO analysis Type I (direct plus indirect) output multipliers are given by the column totals of the Type I Leontief inverse. The Leontief inverse is expressed as $[\mathbf{I-A}]^{-1}$, where **I** is the IxI identity matrix and **A** is the ixi matrix of input coefficients derived from the base year IO table (see Section 2). Each element in the ith column of the Leontief inverse tells us how the output of each of the other production sectors is affected by one monetary unit of final demand for the output of sector i. Therefore the column total for sector i tells us how much output in the economy is supported by one unit of final demand for the output of sector i – i.e. this is the output multiplier for sector i. I show the (25x25) Type I Leontief inverse for Jersey in 1998 in Table 7.2.

To determine how much local *pollution* is supported by one monetary unit of final demand for each sector's output, given the fixed output-pollution relationship assumed in the environmental IO system, I multiply the Leontief inverse by the (KxI) matrix of output-pollution coefficients. The result is a KxI matrix of Type I output-pollution multipliers, $\mathbf{M_{i1}}$, expressed as

(7.13) $\mathbf{M_{i1} = M_i[I-A]^{-1}}$

I show the (9x25) matrix of Type I output-pollution multipliers for Jersey (in 1998) in Table 7.3. The Type I output-pollution multipliers give us the direct plus indirect emissions intensities of each production sector for each of the pollutants identified. In other words, each element of matrix $\mathbf{M_{i1}}$ is the amount (in kilograms) of pollutant k that is generated directly or indirectly throughout the economy by one monetary unit of the output of each sector i produced to meet final demand.

Note that the direct plus indirect emissions intensities shown in Table 7.3 are all necessarily higher than their counterparts in Table 6.15, which only reports the *direct* emissions intensities. The size of the difference between the direct and the direct plus indirect emissions intensities will vary from sector to sector. This will depend on

whether the pollution that the sector in question is responsible for is largely generated during its own production activities, or whether it is mainly a consequence of its pattern of intermediate purchases. For example sectors like 'Water', 'Telecommunications' and 'Hotels, Restaurants & Catering' show significant indirect effects: all have relatively strong backward linkages in the local economy and low direct pollution intensities. 'Agriculture & Fishing' also has relatively strong backward linkages in the local economy; however the resulting indirect intensities are small relative to the direct intensity of production in this sector.

However, the Type I output-pollution multipliers ignore the fact that for each unit of output produced in any one sector, the associated wage payments for household labour services fund consumption in the economy. In other words, I have so far not allowed for any income and consumption effects associated with the production of one unit of output in each sector. This is because until now I have treated household consumption as an element of *exogenously* determined final demand in the IO system. However, the income from employment associated with final demand for one unit of any given one sector's output will affect the total level of household expenditure and emissions in the economy. This is because households are responsible for generating domestic emissions both directly, by purchasing and burning fuels, and indirectly by purchasing locally produced goods and services which have entailed pollution generation in their production. Therefore, in addition to the direct and indirect emissions effects captured in the Type I output-pollution multipliers, we may also want to consider any *induced* increase in emissions resulting from additional consumer expenditure funded by increased income from employment.

In order to incorporate induced effects, along with the direct and indirect ones captured in the Type I output-pollution multipliers, I have to treat the share of household consumption that is financed by income from employment in local production sectors as being endogenous to the system. What this essentially means is that I treat households as being like a production sector whose output is the labour sold to the other production sectors (with 'input' purchases being consumer

expenditure in the local economy) rather than as a standard final demand sector. In this, way that part of consumer expenditure that is funded by income from employment becomes endogenously determined from within the system, rather than being exogenously determined in the way that final demands in an IO system are set.

The output-pollution multipliers that incorporate this induced impact on emissions are referred to as Type II and are derived using the Type II Leontief inverse. In addition to the direct and indirect effects of the Type I case, the Type II multipliers incorporate the induced output effects on all sectors resulting from a unitary increase in final demand for any one sector's output. This is achieved through the additions of an extra row, for income from employment in each sector, i, (as a proportion of total sectoral output, X_i), and an extra column, for consumer expenditure on the outputs of each local production sector, i (as a proportion of total income from employment). Therefore, in the Jersey case the Type II Leontief inverse will be a 26x26 matrix, $\mathbf{[I-A^*]^{-1}}$: see Table 7.4 (below).

Because Jersey households are responsible for direct emissions generation, in order to derive the matrix of Type II output-pollution multipliers I also have to introduce a vector of direct emissions coefficients reflecting the amount of pollution generated by one monetary unit (£1million) of income from employment. (Income from employment, the revenue on selling labour services, reflects the value of household output just as revenue from sales of output reflects the value of output from standard production sectors.) In matrix $\mathbf{M_z}$ (the 9x2 version[8]) I already have a vector, $\mathbf{m_h}$, of direct emissions coefficients for (aggregate) households, expressing the amount of pollution directly generated per £1million of total household expenditure. If I make the assumption that total IO expenditure is funded by present income, $\mathbf{m_h}$ can also be regarded as a vector of household income-pollution coefficients[9]. However, the only

[8] Table 6.15 includes a 9x6 matrix $\mathbf{M_z}$ of direct emissions coefficients for five household groups and tourists. However, as I explain in Section 4 of Chapter 6, because data were not available on sources of income from employment disaggregated by income band, Table 6.15 also includes an alternative vector of household emissions coefficients for aggregate households. Substituting this into $\mathbf{M_z}$ gives us a 9x2 matrix.

[9] In fact, the Jersey SAM (Table 5.7) tells us that total household income in 1998 was £1,563.4million. The excess over the £1059.2million IO expenditure is spread over other payments to corporations (e.g. rents, interest payments), government (income taxes and social security contributions) and savings.

type of income recorded in the IO system is income from employment. From the Jersey IO table (Table 5.3) it is clear that consumer expenditure exceeds income from employment, with a portion being funded by non-wage income.

Therefore I endogenise that part of household expenditure that is equal to income from employment. This involves combining the vector of household direct emissions intensities with the existing direct emissions intensities matrix, $\mathbf{M_i}$, for the production sector of the economy. The result is a new (Kx(I+1)) matrix $\mathbf{M_{i(+h)}}$, where

(7.14) $\mathbf{M_{i(+h)} = [M_i \vdots m_h]}$

The (9x26) matrix $\mathbf{M_{i2}}$ of Type II output-pollution multipliers will then take the form

(7.15) $\mathbf{M_{i2} = M_{i(+h)} [I\text{-}A^*]^{-1}}$

However, because part of household expenditure remains exogenously determined (i.e. not funded from income from employment), the vector of household direct emissions intensities, $\mathbf{m_h}$, also remains in the matrix $\mathbf{M_z}$ of final demand expenditure-pollution coefficients.

I should point out that the manner in which I have split household consumption into endogenous and exogenous components is based on the assumption that all wage income goes to local household income (none remitted abroad) and that other elements of household income are exogenous. However some other household consumption may also be determined endogenously, for example if it is funded by profit income earned from businesses owned and/or operated by local households. A more sophisticated treatment of household income and expenditure could be attempted in a system based on the social accounting matrix (SAM) for Jersey, which is constructed in Chapter 5 and includes fuller information on income flows. At this stage, however, the analysis is limited to the more basic treatment that is possible using the Jersey IO system.

Table 7.4 Type II Leontief Inverse - Jersey 1998

Sectors	Agriculture & Fishing	Quarrying & Construction	Manufacturing	Electricity	Water	Gas, Oil & Fuel Dist.	Jersey Telecom.	Wholesale & Retail Trade	Hotels, Rest. & Catering	Land Transport	Sea & Air Trans. & Trans Supp	Jersey Post	Banks & Building Soc.	Insurance Companies	Inv. Trusts & Fund Mgrs	Computer Services	Legal Activities	Accountancy	Other Bus. Activities	Other Service Activities	Recreation, Culture & Sport	Education	Health, Social Work & Housing	Public Services	Public Admin. & Defence
Agriculture & Fishing	1.01674	0.00470	0.11689	0.00302	0.00428	0.00516	0.00602	0.00555	0.03594	0.00518	0.00338	0.00774	0.00163	0.00692	0.00522	0.00454	0.00590	0.00535	0.00663	0.00573	0.02472	0.00720	0.00792	0.00643	0.00734
Quarrying & Construction	0.06317	1.06905	0.04787	0.02159	0.06143	0.06382	0.07122	0.03484	0.04777	0.02957	0.04929	0.05650	0.00997	0.05106	0.02408	0.02761	0.03543	0.03486	0.03566	0.03149	0.07755	0.09853	0.06536	0.20128	0.06873
Manufacturing	0.02999	0.02174	1.03360	0.01290	0.01891	0.02640	0.03477	0.02087	0.02964	0.02615	0.01287	0.03901	0.00679	0.03132	0.02980	0.01989	0.03023	0.02364	0.03098	0.02531	0.02817	0.02647	0.03062	0.02671	0.02722
Electricity	0.05190	0.02012	0.04779	1.01220	0.06049	0.02095	0.02604	0.03294	0.03754	0.02218	0.04866	0.03233	0.00671	0.02839	0.01660	0.02186	0.02479	0.02507	0.02757	0.02836	0.04255	0.03993	0.03981	0.06237	0.03866
Water	0.01113	0.00389	0.01010	0.00726	1.00360	0.00382	0.00352	0.00410	0.00602	0.00412	0.00547	0.00561	0.00137	0.00577	0.00325	0.00356	0.00443	0.00433	0.00535	0.00523	0.00634	0.00994	0.01063	0.01969	0.00873
Gas, oil & fuel distribution	0.01965	0.00733	0.01134	0.00450	0.00617	1.00794	0.00579	0.00711	0.01204	0.00695	0.00937	0.00952	0.00221	0.00874	0.00514	0.00621	0.00686	0.00697	0.00867	0.01042	0.01468	0.01513	0.01575	0.02876	0.01363
Jersey Telecommunications	0.03440	0.02362	0.02738	0.01702	0.02257	0.02799	1.01794	0.02776	0.02521	0.02406	0.01663	0.03121	0.00784	0.04123	0.02118	0.02993	0.03016	0.03285	0.03857	0.02603	0.02941	0.03772	0.03427	0.04386	0.03547
Wholesale & Retail Trade	0.17212	0.10858	0.12435	0.06055	0.10280	0.09574	0.20003	1.08951	0.09007	0.06471	0.07321	0.12956	0.03225	0.12787	0.07091	0.06131	0.09664	0.10128	0.11973	0.10929	0.10349	0.19186	0.16907	0.15681	0.16234
Hotels, Restaurants & Catering	0.04523	0.03054	0.03721	0.02098	0.02763	0.02944	0.02697	0.02934	1.02961	0.03082	0.02577	0.04886	0.01154	0.04503	0.02567	0.02644	0.03351	0.03644	0.04236	0.03854	0.03449	0.05366	0.04530	0.04589	0.05630
Land Transport	0.00346	0.00267	0.00352	0.00113	0.00154	0.00166	0.00179	0.00175	0.00279	1.00164	0.00140	0.00261	0.00062	0.00316	0.00194	0.00154	0.00196	0.00409	0.00230	0.00209	0.00235	0.00453	0.00433	0.02455	0.00319
Sea & Air Transport & Transport Support	0.02013	0.01328	0.02513	0.01082	0.01253	0.01341	0.01428	0.01676	0.01665	0.01679	1.01127	0.06186	0.00520	0.02063	0.01372	0.01469	0.01563	0.01614	0.01858	0.02495	0.01654	0.02373	0.02057	0.02060	0.02419
Jersey Post	0.01212	0.00640	0.00993	0.00578	0.01369	0.01714	0.01092	0.01672	0.00747	0.07413	0.00344	1.01133	0.00271	0.03106	0.00950	0.00619	0.00966	0.00677	0.01536	0.00765	0.01224	0.01098	0.01061	0.01803	0.00901
Banks & Building Societies	0.11327	0.04773	0.05697	0.02400	0.16474	0.03733	0.03075	0.03814	0.13496	0.04058	0.02749	0.04650	1.01161	0.05094	0.03907	0.03023	0.03757	0.03751	0.04654	0.05244	0.04314	0.05936	0.04871	0.05169	0.05675
Insurance Companies	0.02872	0.01533	0.01674	0.00659	0.02102	0.01205	0.01270	0.01496	0.01644	0.01698	0.01106	0.01817	0.00445	1.01662	0.01179	0.01598	0.02026	0.01505	0.02563	0.02085	0.01570	0.02343	0.01622	0.02059	0.02184
Investment Trusts & Fund Managers	0.00059	0.00020	0.00017	0.00012	0.00017	0.00023	0.00032	0.00040	0.00037	0.00023	0.00012	0.00033	0.00008	0.00026	1.00025	0.00018	0.00026	0.00021	0.00027	0.00023	0.00024	0.00026	0.00026	0.00025	0.00026
Computer Services	0.00424	0.00378	0.00361	0.00098	0.00272	0.00860	0.01307	0.00544	0.00397	0.00586	0.00117	0.00473	0.00087	0.00417	0.00488	1.00171	0.00359	0.04898	0.00975	0.00205	0.00446	0.00438	0.00564	0.00292	0.00291
Legal Activities	0.05437	0.03080	0.04967	0.02465	0.03358	0.03184	0.03160	0.05667	0.05563	0.05574	0.02175	0.04355	0.01275	0.08430	0.05072	0.04859	1.05940	0.03778	0.07163	0.03753	0.06021	0.04556	0.05173	0.04410	0.04781
Accountancy	0.00965	0.00557	0.00666	0.00201	0.00509	0.00328	0.00284	0.00739	0.00698	0.00618	0.00166	0.00339	0.00101	0.01659	0.00390	0.00480	0.00547	1.00276	0.01192	0.01020	0.00492	0.00486	0.00446	0.00389	0.00355
Other Business Activities	0.17967	0.03840	0.07298	0.01609	0.17559	0.04335	0.03518	0.07357	0.04241	0.05911	0.01693	0.06667	0.00738	0.07446	0.03713	0.04726	0.04076	0.06744	1.07490	0.03098	0.06131	0.04266	0.05093	0.05333	0.03120
Other Services Activities	0.04635	0.01598	0.02393	0.00749	0.01247	0.02424	0.01276	0.01935	0.01461	0.02476	0.01142	0.01842	0.00413	0.01654	0.00924	0.01201	0.01260	0.01297	0.01851	1.01474	0.01842	0.02127	0.01664	0.02443	0.02142
Recreation, Culture & Sport	0.02299	0.01499	0.01822	0.01070	0.01407	0.01503	0.01383	0.01495	0.01443	0.01518	0.01315	0.02290	0.00583	0.02247	0.01266	0.01444	0.01717	0.01810	0.02135	0.01971	1.01880	0.02571	0.02118	0.02293	0.03031
Education	0.01867	0.01218	0.01481	0.00870	0.01143	0.01221	0.01107	0.01215	0.01173	0.01232	0.01068	0.01861	0.00474	0.01826	0.01029	0.01174	0.01395	0.01471	0.01735	0.01602	0.01359	1.02171	0.01718	0.01863	0.02336
Health, Social Work & Housing	0.06786	0.04426	0.05381	0.03160	0.04152	0.04438	0.04024	0.04418	0.04262	0.04475	0.03883	0.06763	0.01723	0.06635	0.03737	0.04265	0.05070	0.05345	0.06305	0.05820	0.04940	0.07889	1.06244	0.06759	0.08496
Public Services	0.00011	0.00007	0.00008	0.00005	0.00006	0.00007	0.00006	0.00007	0.00007	0.00007	0.00006	0.00011	0.00003	0.00010	0.00006	0.00007	0.00008	0.00008	0.00010	0.00009	0.00008	0.00012	0.00010	1.00011	0.00013
Public Administration & Defence	0.01044	0.00406	0.00661	0.00481	0.00868	0.00563	0.00447	0.00579	0.00467	0.00553	0.00404	0.00604	0.00157	0.00675	0.00359	0.00493	0.00582	0.00537	0.00565	0.00539	0.00713	0.00766	0.01151	0.00863	1.00758
Income from Employment	0.65573	0.55815	0.67853	0.39847	0.52362	0.55969	0.50748	0.55682	0.53743	0.56436	0.48960	0.65265	0.21722	0.53666	0.47131	0.53784	0.63932	0.67407	0.79504	0.73392	0.62297	0.99480	0.78743	0.85362	1.07132
Total - Type II output multipliers	2.9007	2.1032	2.5110	1.7159	2.3506	2.1218	2.1353	2.1411	2.2310	2.1820	1.9058	2.6274	1.3779	2.6174	1.9193	2.0184	2.2024	2.2863	2.5104	2.3178	2.3129	2.8518	2.5498	2.8292	2.8572

Table 7.5 Direct Plus Indirect Plus Induced Emissions Intensities (kg[1]) Per £1million Final Demand For Outputs Of Local Production Sectors In Jersey 1998 - With Household Expenditure Determined Endogenously (Type II Output-Pollution Mu

Sectors / Pollutants	Agriculture & Fishing	Quarrying & Construction	Manufacturing	Electricity	Water	Gas, Oil & Fuel Dist.	Jersey Telecom.	Wholesale & Retail Trade	Hotels, Rest. & Catering	Land Transport	Sea & Air Trans. & Trans Supp	Jersey Post	Banks & Building Soc.
Global warming potential (GWP) composite	764503.408	143743.774	290486.437	1386786.364	174368.418	177247.929	123180.703	155224.121	195322.944	181472.588	415828.701	197746.133	41149.335
Carbon dioxide (CO2) as carbon	462023.750	140257.155	253604.156	1384448.945	171207.889	173239.195	119634.179	151501.811	182848.332	177433.055	412711.069	192544.826	39954.079
Methane (CH4)	14364.146	144.015	1732.267	100.746	135.181	158.990	155.559	159.403	579.902	162.816	135.354	226.997	52.682
Sulphur dioxide (SO2)	6172.220	332.236	1882.116	9700.250	690.435	337.857	383.698	459.765	790.243	369.056	824.026	537.081	109.402
Nitrous oxides (NOx)	3825.514	875.715	1984.919	17823.960	1512.009	1243.206	891.550	1186.830	1373.497	1225.313	6307.713	1459.340	275.956
Non-methane volatile organic compounds (NMVOC)	1759.635	1001.873	1338.831	913.988	1009.188	1294.896	915.766	1134.469	1019.294	1413.589	2269.759	1525.864	367.430
Carbon monoxide (CO)	9832.870	5683.588	7641.538	4869.638	5853.264	7393.979	5295.234	6578.591	5866.513	8219.033	9066.810	8654.660	2137.521
Nitrogen dioxide (N20)	2.686	1.491	1.628	0.715	1.038	2.161	0.903	1.209	0.957	2.001	0.888	1.401	0.287
Black smoke	65.501	26.916	62.433	1170.645	73.278	27.911	34.029	43.238	48.520	30.284	338.832	54.586	9.191

Sectors / Pollutants	Insurance Companies	Inv. Trusts & Fund Mgrs	Computer Services	Legal Activities	Accountancy	Other Bus. Activities	Other Service Activities	Recreation, Culture & Sport	Education	Health, Social Work & Housing	Public Services	Public Admin. & Defence
Global warming potential (GWP) composite	166734.379	98706.749	124665.426	132715.475	135483.555	166647.031	223586.673	201575.599	223692.547	197145.621	789092.639	213058.436
Carbon dioxide (CO2) as carbon	161890.211	95567.715	121374.168	128833.438	131663.429	161956.825	218860.610	192112.912	218247.337	192168.488	781596.484	207363.580
Methane (CH4)	213.345	139.414	143.032	171.270	168.239	204.319	192.632	433.944	238.123	219.941	336.756	250.071
Sulphur dioxide (SO2)	452.724	279.490	327.507	382.136	382.552	436.606	1150.139	722.321	631.171	586.966	809.708	566.815
Nitrous oxides (NOx)	1132.582	676.897	858.769	920.452	940.460	1104.672	1409.665	1408.504	1515.126	1368.007	5324.039	1431.893
Non-methane volatile organic compounds (NMVOC)	1467.494	853.678	1112.950	1113.215	1165.267	1426.266	1670.970	1140.840	1705.479	1365.865	11884.976	1814.037
Carbon monoxide (CO)	8556.722	4981.268	6569.036	6476.933	6787.336	8304.119	9720.757	6564.398	9879.117	7885.895	50435.855	10542.373
Nitrogen dioxide (N20)	1.174	0.682	0.928	0.921	0.926	1.289	2.196	1.129	1.434	1.156	1.369	1.430
Black smoke	38.510	22.990	29.384	32.951	33.433	37.000	39.711	53.708	52.696	50.517	77.706	49.044

Notes:

1. The GWP (Global Warming Potential) index is a weighted sum of CO2 (weight 1), methane (weight 21) and N_2O (weight 310): it therefore should not be read as 'kilograms' but simply as an index that is comparable across sectors within an economy and across different economies

Figure 7.1 Comparison of Direct, Direct Plus Indirect, And Direct Plus Indirect Plus Induced Global Warming Potential Of Production To Meet Final Demand And Of Exogenous Final Consumption In Jersey, 1998

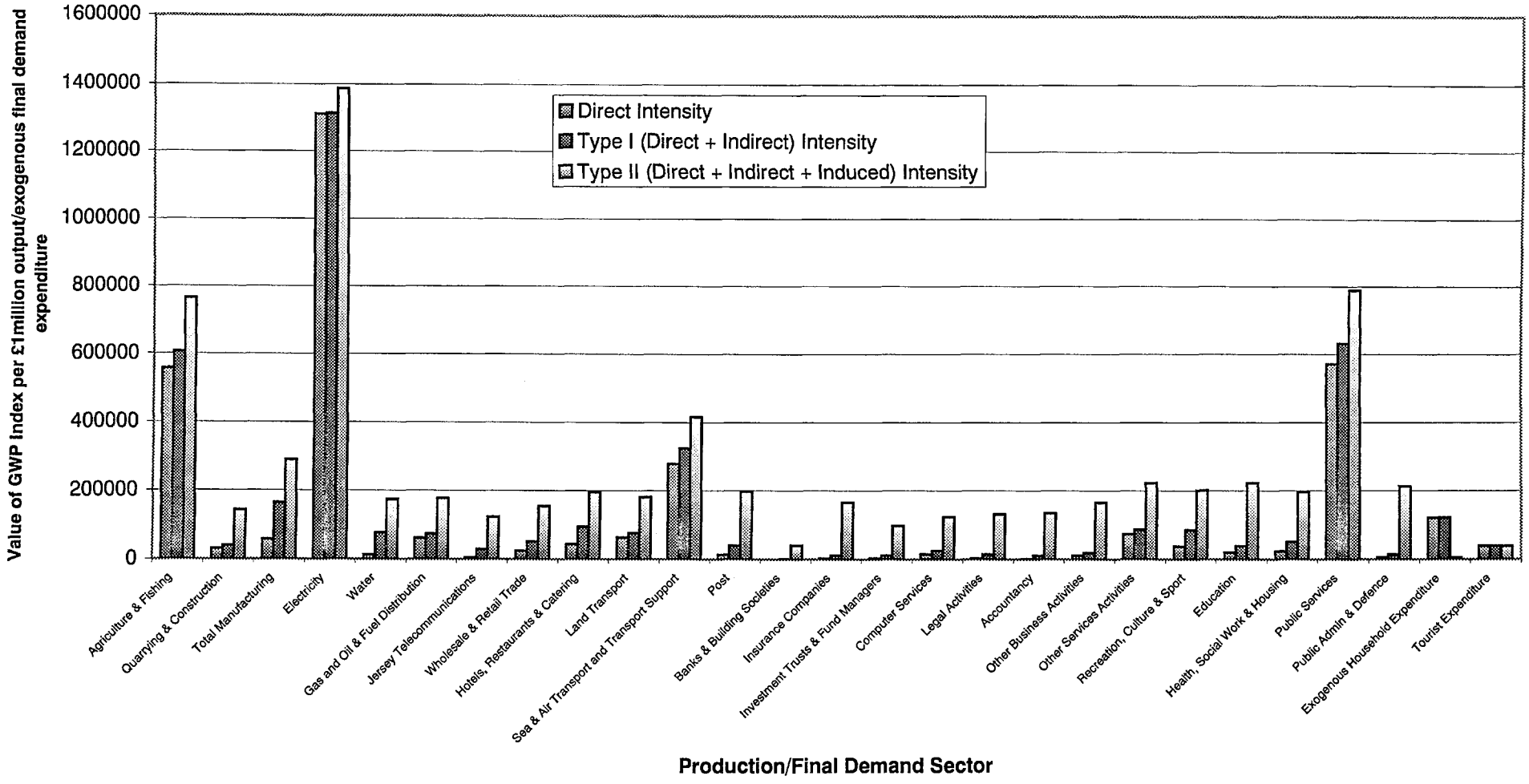
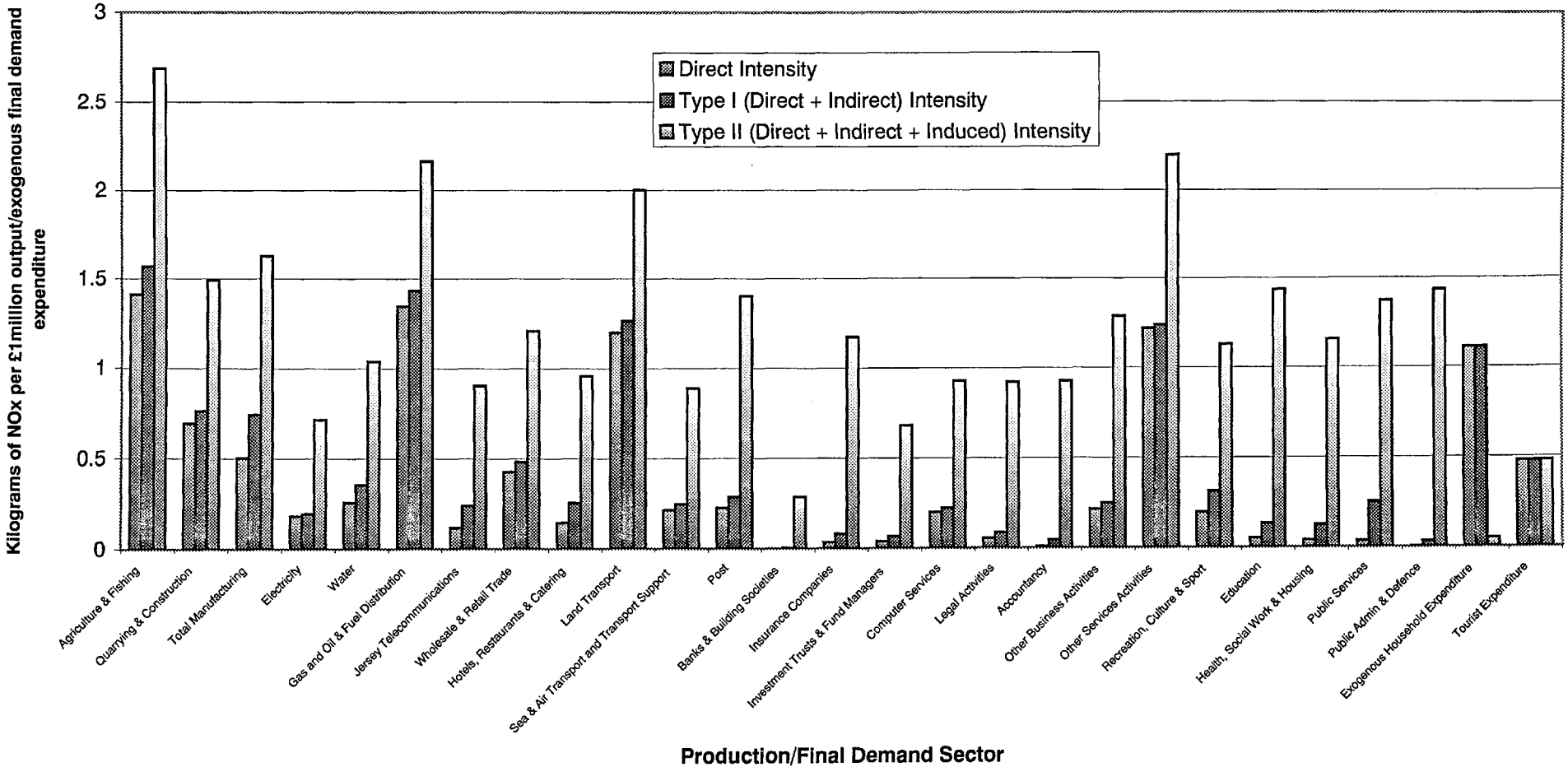


Figure 7.2 Comparison Of Direct, Direct Plus Indirect, And Direct Plus Indirect Plus Induced N2O Intensity Of Production To Meet Final Demand and Of Exogenous Final Consumption In Jersey, 1998



I show matrix $\mathbf{M_{i2}}$ for Jersey (1998) in Table 7.5. Note again that the direct plus indirect plus induced emissions coefficients in Table 7.5 are all necessarily higher than their counterparts in Tables 6.15 (matrix $\mathbf{M_i}$) and 7.3 (matrix $\mathbf{M_{i1}}$). The size of the increase in emissions intensities when induced effects are taken into account varies across sectors depending on the labour intensity of production and/or the level of wages paid in the sector in question. For comparative purposes I illustrate the direct emissions intensities of all 25 production sectors with the Type I and Type II output-pollution multipliers across the GWP composite pollutant and the individual (automotive fuel-related) pollutant N_2O in Figures 7.1 and 7.2 respectively.

Note, for example, that both the GWP and N_2O intensity of sectors 'Other Service Activities', 'Post' and 'Land Transport' increases quite dramatically when induced effects are taken into account – these are sectors where production is relatively labour intensive. The importance of induced effects is also apparent in sectors like 'Banks & Building Societies' and 'Investment Trusts and Fund Managers', where labour intensity is relatively low, but average wages are significantly above the average wage in Jersey. Moreover both these sector have relatively low direct GWP and N_2O intensities and weak backward linkages with other sectors in the local economy – i.e. the Type I output-GWP and output-N_2O intensities are comparatively low. 'Electricity' is another sector that pays a relatively high sectoral wage. However the Type I (direct plus indirect) GWP intensity is so strong in the 'Electricity' sector that the induced effects are small by comparison. On the other hand, 'Electricity' has a relatively low Type I N_2O intensity (due to the relatively low intensity of automotive fuel-use in this sector) so the induced effect is proportionately more significant for this pollutant.

3.3 Attribution To Final Demand By Commodity (To Production Sectors/ Intermediate Demand)

In Section 3.1 above I explain how the *direct* contribution of each individual production sector, i, to total emissions generation in the Jersey economy is determined using the vector of output-pollution (direct emissions) coefficients for

that sector and the scalar of total sector output, X_i, from the standard IO accounts. However, if I want to account for the full contribution of each sector in terms of the commodities it produces to sell to final demand – i.e. including indirect and induced effects – I use the output-pollution multipliers shown in Table 7.3 (matrix $\mathbf{M_{i1}}$) and/or 7.5 (matrix $\mathbf{M_{i2}}$).

I have explained above how the output-pollution multipliers reflect the full environmental pressure of producing one unit of output to meet final demand in terms of the direct plus indirect emissions intensities (Type I output-pollution multipliers) and direct plus indirect plus induced emissions intensities (Type II output-pollution multipliers).

By multiplying each sector i's vector of output-pollution multipliers[10] by the scalar of total final demand for its outputs, c_i in the Type I case or $c_{i(-h)}$ (= $(c_i - c_{i(h)})$) in the Type II case (where households are endogenous), I can determine the full amount of pollution attributable to each sector i. In formal terms, for the Type I case (where household expenditure is determined exogenously) I have a vector of total emissions (across all K pollutants) attributable to each production sector i, $\mathbf{p_{i1}}$:

(7.16) $\mathbf{p_{i1}} = \mathbf{m_{i1}}.c_i$

Where $\mathbf{m_{i1}}$ is the Kx1 vector of Type I output-pollution multipliers for sector i and c_i is the scalar of total final demand for the outputs of sector i. I report the results of calculating (7.16) for each sector i in kilograms in Table 7.6, and in percentage terms in Table 7.7 (i.e. $(\mathbf{p_{i1}}/\mathbf{P})*100$, where $\mathbf{P}$ is the vector of total emissions generated in the economy as given by the final column of Table 7.1). Note that in Table 7.7 I also report the share of total emissions attributable to exogenous final consumption. These are emissions directly generated in final demand activities that cannot be attributed to production activities.

[10] In the general discussion in Section 2 I define the elements of the output-pollution multiplier matrix as $\varepsilon_{k,i}$. Here, for the specific cases of Type I and Type II analysis, I define these as $(\mathbf{m_{i1}})_k$ and $(\mathbf{m_{i2}})_k$, respectively.

Table 7.6 Total Direct Plus Indirect Emissions Generation (kg[1]) Attributable To The Production Of Sectoral Outputs To Meet Final Demand In Jersey (1998)

Sectors / Pollutants	Agriculture & Fishing	Quarrying & Construction	Manufacturing	Electricity	Water	Gas, Oil & Fuel Dist.	Jersey Telecom.	Wholesale & Retail Trade	Hotels, Rest. & Catering	Land Transport	Sea & Air Trans. & Trans Supp	Jersey Post	Banks & Building Soc.
Global warming potential (GWP) composite	22480630	7405391	13015014	28814139	637144	648821	783769	16737473	21225088	1395993	20377479	118143	999585
Carbon dioxide (CO2) as carbon	11427450	7304852	10384945	28808879	633819	639457	760289	16483426	19088150	1376613	20343628	116032	943701
Methane (CH4)	525483	2723	124376	187	115	260	1023	9812	100924	584	1382	88	2609
Sulphur dioxide (SO2)	213802	12066	123032	208701	3626	623	3796	62298	118242	1808	36994	386	6171
Nitrous oxides (NOx)	102965	35026	91002	380425	7158	4907	7219	161798	158236	9668	357654	1226	10251
Non-methane volatile organic compounds (NMVOC)	11784	11252	15434	5323	1044	3101	1628	63015	25190	8391	90540	263	1523
Carbon monoxide (CO)	53306	38042	77719	21071	5893	16772	8489	358275	131526	48645	267168	852	6869
Nitrogen dioxide (N20)	58.2	139.8	58.6	4.3	2.9	12.6	6.4	154.8	56.6	22.9	15.6	0.9	3.5
Black smoke	1159	839	2785	25340	431	49	368	6729	5984	140	20006	61	536

Sectors / Pollutants	Insurance Companies	Inv. Trusts & Fund Mgrs	Computer Services	Legal Activities	Accountancy	Other Bus. Activities	Other Service Activities	Recreation, Culture & Sport	Education	Health, Social Work & Housing	Public Services	Public Admin. & Defence	Total Emissions (kg) Attributable to Production
Global warming potential (GWP) composite	274728	3409026	194421	589855	829536	398993	1419350	3671893	2431466	8122086	16771570	794786	173546378
Carbon dioxide (CO2) as carbon	264494	3212816	190854	568594	808405	388623	1405389	3408552	2418644	7990471	16691772	791807	156451664
Methane (CH4)	459	9051	144	960	953	418	369	12342	487	5969	3700	117	804537
Sulphur dioxide (SO2)	1242	16258	549	3168	4730	1173	12947	18099	9627	33400	10691	3002	906428
Nitrous oxides (NOx)	2473	29446	1543	5607	8837	2658	8245	27440	18156	63616	113673	6374	1615602
Non-methane volatile organic compounds (NMVOC)	1342	17745	1603	1479	2290	1779	7030	3880	1798	6172	277655	477	561739
Carbon monoxide (CO)	8101	106513	10021	8415	13530	10350	40795	19261	7322	25355	1117913	1701	2403906
Nitrogen dioxide (N20)	1.9	19.8	1.7	3.5	3.6	5.1	20.0	13.4	8.3	20.2	6.8	1.7	643
Black smoke	117	1230	61	303	502	106	167	1225	793	3006	1157	334	73427

Notes:

1. The GWP (Global Warming Potential) index is a weighted sum of CO2 (weight 1), methane (weight 21) and N_2O (weight 310): it therefore should not be read as 'kilograms' but simply as an index that is comparable across sectors within an economy and across different economies

Table 7.7 Percentage Share In Total Emissions Generated In Jersey (1998) Attributable To Production Sectors And Exogenous Final Consumption: Type I Attribution To Final Demand By Commodity

Sectors / Pollutants	Agriculture & Fishing	Quarrying & Construction	Manufacturing	Electricity	Water	Gas, Oil & Fuel Dist.	Jersey Telecom.	Wholesale & Retail Trade	Hotels, Rest. & Catering	Land Transport	Sea & Air Trans. & Trans Supp	Jersey Post	Banks & Building Soc.	Insurance Companies	Inv. Trusts & Fund Mgrs
Global warming potential (GWP) composite	7.21	2.37	4.17	9.24	0.20	0.21	0.25	5.37	6.81	0.45	6.53	0.04	0.32	0.09	1.09
Carbon dioxide (CO2) as carbon	3.93	2.51	3.57	9.90	0.22	0.22	0.26	5.66	6.56	0.47	6.99	0.04	0.32	0.09	1.10
Methane (CH4)	54.67	0.28	12.94	0.02	0.01	0.03	0.11	1.02	10.50	0.06	0.14	0.01	0.27	0.05	0.94
Sulphur dioxide (SO2)	20.86	1.18	12.01	20.37	0.35	0.06	0.37	6.08	11.54	0.18	3.61	0.04	0.60	0.12	1.59
Nitrous oxides (NOx)	4.67	1.59	4.13	17.25	0.32	0.22	0.33	7.33	7.17	0.44	16.21	0.06	0.46	0.11	1.33
Non-methane volatile organic compounds (NMVOC)	0.49	0.47	0.64	0.22	0.04	0.13	0.07	2.62	1.05	0.35	3.77	0.01	0.06	0.06	0.74
Carbon monoxide (CO)	0.40	0.29	0.59	0.16	0.04	0.13	0.06	2.70	0.99	0.37	2.01	0.01	0.05	0.06	0.80
Nitrogen dioxide (N20)	3.01	7.23	3.03	0.22	0.15	0.65	0.33	8.01	2.93	1.19	0.81	0.04	0.18	0.10	1.02
Black smoke	1.58	1.14	3.79	34.51	0.59	0.07	0.50	9.16	8.15	0.19	27.25	0.08	0.73	0.16	1.68

Sectors / Pollutants	Computer Services	Legal Activities	Accountancy	Other Bus. Activities	Other Service Activities	Recreation, Culture & Sport	Education	Health, Social Work & Housing	Public Services	Public Admin. & Defence	Exogenous Final Consumption	Total
Global warming potential (GWP) composite	0.06	0.19	0.27	0.13	0.46	1.18	0.78	2.60	5.38	0.25	44.35	100
Carbon dioxide (CO2) as carbon	0.07	0.20	0.28	0.13	0.48	1.17	0.83	2.75	5.73	0.27	46.25	100
Methane (CH4)	0.01	0.10	0.10	0.04	0.04	1.28	0.05	0.62	0.38	0.01	16.30	100
Sulphur dioxide (SO2)	0.05	0.31	0.46	0.11	1.26	1.77	0.94	3.26	1.04	0.29	11.55	100
Nitrous oxides (NOx)	0.07	0.25	0.40	0.12	0.37	1.24	0.82	2.88	5.15	0.29	26.76	100
Non-methane volatile organic compounds (NMVOC)	0.07	0.06	0.10	0.07	0.29	0.16	0.07	0.26	11.55	0.02	76.63	100
Carbon monoxide (CO)	0.08	0.06	0.10	0.08	0.31	0.15	0.06	0.19	8.42	0.01	81.89	100
Nitrogen dioxide (N20)	0.09	0.18	0.19	0.27	1.04	0.69	0.43	1.05	0.35	0.09	66.72	100
Black smoke	0.08	0.41	0.68	0.14	0.23	1.67	1.08	4.09	1.58	0.45	0.00	100

However, if it is thought that household expenditure is determined endogenously – i.e. by income from employment in the local production sector - total emissions (across all K pollutants) attributable to each production sector i, $\mathbf{p}_{i2}$ will be:

(7.17) $\mathbf{p}_{i2} = \mathbf{m}_{i2}.\mathbf{c}_{i(-h)}$

I report the results of calculating (7.16) for each sector i in kilograms in Table 7.8, and in percentage terms in Table 7.9. Again in Table 7.9 I also report the share of total emissions attributable to exogenous final consumption. Note from the final column of Table 7.8 that in the Type II case a higher level of total emissions are attributable to production: this is because the direct and indirect emissions generation that accompanies wage funded household expenditure is allocated to production in the Type II analysis.

In Figures 7.3 and 7.4 I compare the results for the three methods of attribution used so far (direct, Type I and Type II) in percentage terms across all 25 sectors of the Jersey economy for the GWP index and for N_2O. As in Tables 7.7 and 7.9, Figures 3 and 4 also show the share of total emissions attributable to exogenous final consumption (i.e. the emissions directly generated in final demand activities that cannot be attributed to production activities).

The first thing to note in Figures 7.3 and 7.4 is that for both the GWP index and N_2O the largest contribution to total emissions in the direct and Type I cases are direct emissions from final demand sectors. This is particularly true in the case of the latter; we have seen that just over 77.4% of automotive fuel (the only source of N_2O emissions in Jersey) supplied in 1998 was used directly by final consumers. However, in the Type II case this changes dramatically: with the bulk (95.5%) of IO expenditure by households taken to be endogenously determined by income from employment in the 25 production sectors, the share attributable to production sectors as a whole increases to at least 89% for all pollutants.

Table 7.8 Total Direct Plus Indirect Plus Induced Emissions Generation (kg[1]) Attributable To The Production Of Sectoral Outputs To Meet Final Demand In Jersey (1998)

Sectors / Pollutants	Agriculture & Fishing	Quarrying & Construction	Manufacturing	Electricity	Water	Gas, Oil & Fuel Dist.	Jersey Telecom.	Wholesale & Retail Trade	Hotels, Rest. & Catering	Land Transport	Sea & Air Trans. & Trans Supp	Jersey Post	Banks & Building Soc.
Global warming potential (GWP) composite	27101866	22305318	17257583	456439	570608	79366	-34488	28586341	33077403	2853922	17607858	283885	42615975
Carbon dioxide (CO2) as carbon	16378875	21764285	15066434	455670	560265	77571	-33495	27900835	30964862	2790395	17475845	276418	41378118
Methane (CH4)	509213	22347	102913	33	442	71	-44	29356	98205	2561	5731	326	54560
Sulphur dioxide (SO2)	218807	51554	111815	3193	2259	151	-107	84671	133825	5804	34893	771	113301
Nitrous oxides (NOx)	135616	135888	117923	5866	4948	557	-250	218569	232598	19270	267094	2095	285792
Non-methane volatile organic compounds (NMVOC)	62380	155465	79539	301	3302	580	-256	208926	172615	22231	96111	2191	380526
Carbon monoxide (CO)	348578	881946	453978	1603	19154	3311	-1483	1211525	993478	129256	383925	12425	2213706
Nitrogen dioxide (N20)	95.2	231.4	96.7	0.2	3.4	1.0	-0.3	222.7	162.1	31.5	37.6	2.0	297.1
Black smoke	2322	4177	3709	385	240	12	-10	7963	8217	476	14348	78	9519

Sectors / Pollutants	Insurance Companies	Inv. Trusts & Fund Mgrs	Computer Services	Legal Activities	Accountancy	Other Bus. Activities	Other Service Activities	Recreation, Culture & Sport	Education	Health, Social Work & Housing	Public Services	Public Admin. & Defence	Total Emissions (kg) Attributable to Production
Global warming potential (GWP) composite	801173	29439754	960518	1301684	10433904	2429269	50835	3121687	8838350	15375350	20874144	10281786	296670532
Carbon dioxide (CO2) as carbon	777897	28503522	935159	1263608	10139707	2360898	49761	2975144	8623204	14987185	20675846	10006964	276354971
Methane (CH4)	1025	41581	1102	1680	12956	2978	44	6720	9409	17153	8908	12068	941340
Sulphur dioxide (SO2)	2175	83359	2523	3748	29461	6365	261	11186	24938	45777	21419	27353	1019505
Nitrous oxides (NOx)	5442	201888	6617	9028	72427	16103	321	21813	59864	106691	140839	69100	2136097
Non-methane volatile organic compounds (NMVOC)	7051	254614	8575	10918	89740	20791	380	17668	67385	106524	314397	87542	2169494
Carbon monoxide (CO)	41116	1485687	50613	63526	522709	121052	2210	101659	390335	615019	1334197	508754	11888280
Nitrogen dioxide (N20)	5.6	203.3	7.1	9.0	71.3	18.8	0.5	17.5	56.7	90.2	36.2	69.0	1766
Black smoke	185	6857	226	323	2575	539	9	832	2082	3940	2056	2367	73427

Notes:

1. The GWP (Global Warming Potential) index is a weighted sum of CO2 (weight 1), methane (weight 21) and N_2O (weight 310): it therefore should not be read as 'kilograms' but simply as an index that is comparable across sectors within an economy and across different economies

Table 7.9 Percentage Share In Total Emissions Generated In Jersey (1998) Attributable To Production Sectors And Exogenous Final Consumption: Type II Attribution To Final Demand By Commodity

Sectors / Pollutants	Agriculture & Fishing	Quarrying & Construction	Manufacturing	Electricity	Water	Gas, Oil & Fuel Dist.	Jersey Telecom.	Wholesale & Retail Trade	Hotels, Rest. & Catering	Land Transport	Sea & Air Trans. & Trans Supp	Jersey Post	Banks & Building Soc.	Insurance Companies	Inv. Trusts & Fund Mgrs
Global warming potential (GWP) composite	8.69	7.15	5.53	0.15	0.18	0.03	-0.01	9.17	10.61	0.92	5.65	0.09	13.67	0.26	9.44
Carbon dioxide (CO2) as carbon	5.63	7.48	5.18	0.16	0.19	0.03	-0.01	9.59	10.64	0.96	6.00	0.09	14.22	0.27	9.79
Methane (CH4)	52.97	2.32	10.71	0.00	0.05	0.01	0.00	3.05	10.22	0.27	0.60	0.03	5.68	0.11	4.33
Sulphur dioxide (SO2)	21.35	5.03	10.91	0.31	0.22	0.01	-0.01	8.26	13.06	0.57	3.40	0.08	11.06	0.21	8.13
Nitrous oxides (NOx)	6.15	6.16	5.35	0.27	0.22	0.03	-0.01	9.91	10.54	0.87	12.11	0.09	12.96	0.25	9.15
Non-methane volatile organic compounds (NMVOC)	2.60	6.47	3.31	0.01	0.14	0.02	-0.01	8.69	7.18	0.92	4.00	0.09	15.83	0.29	10.59
Carbon monoxide (CO)	2.63	6.64	3.42	0.01	0.14	0.02	-0.01	9.12	7.48	0.97	2.89	0.09	16.67	0.31	11.19
Nitrogen dioxide (N20)	4.93	11.97	5.00	0.01	0.18	0.05	-0.01	11.52	8.38	1.63	1.94	0.10	15.37	0.29	10.52
Black smoke	3.16	5.69	5.05	0.52	0.33	0.02	-0.01	10.84	11.19	0.65	19.54	0.11	12.96	0.25	9.34

Sectors / Pollutants	Computer Services	Legal Activities	Accountancy	Other Bus. Activities	Other Service Activities	Recreation, Culture & Sport	Education	Health, Social Work & Housing	Public Services	Public Admin. & Defence	Exogenous Final Consumption	Total
Global warming potential (GWP) composite	0.31	0.42	3.35	0.78	0.02	1.00	2.83	4.93	6.69	3.30	4.87	100
Carbon dioxide (CO2) as carbon	0.32	0.43	3.48	0.81	0.02	1.02	2.96	5.15	7.10	3.44	5.05	100
Methane (CH4)	0.11	0.17	1.35	0.31	0.00	0.70	0.98	1.78	0.93	1.26	2.07	100
Sulphur dioxide (SO2)	0.25	0.37	2.87	0.62	0.03	1.09	2.43	4.47	2.09	2.67	0.52	100
Nitrous oxides (NOx)	0.30	0.41	3.28	0.73	0.01	0.99	2.71	4.84	6.38	3.13	3.16	100
Non-methane volatile organic compounds (NMVOC)	0.36	0.45	3.73	0.87	0.02	0.74	2.80	4.43	13.08	3.64	9.74	100
Carbon monoxide (CO)	0.38	0.48	3.94	0.91	0.02	0.77	2.94	4.63	10.05	3.83	10.46	100
Nitrogen dioxide (N20)	0.37	0.47	3.69	0.97	0.03	0.90	2.93	4.66	1.87	3.57	8.65	100
Black smoke	0.31	0.44	3.51	0.73	0.01	1.13	2.84	5.37	2.80	3.22	0.00	100

Figure 7.3 Percentage Share In Total Global Warming Potential Of The Jersey Economy (1998) Attributable To Production Sectors And Exogenous Final Consumption: Attribution to Final Demand by Commodity

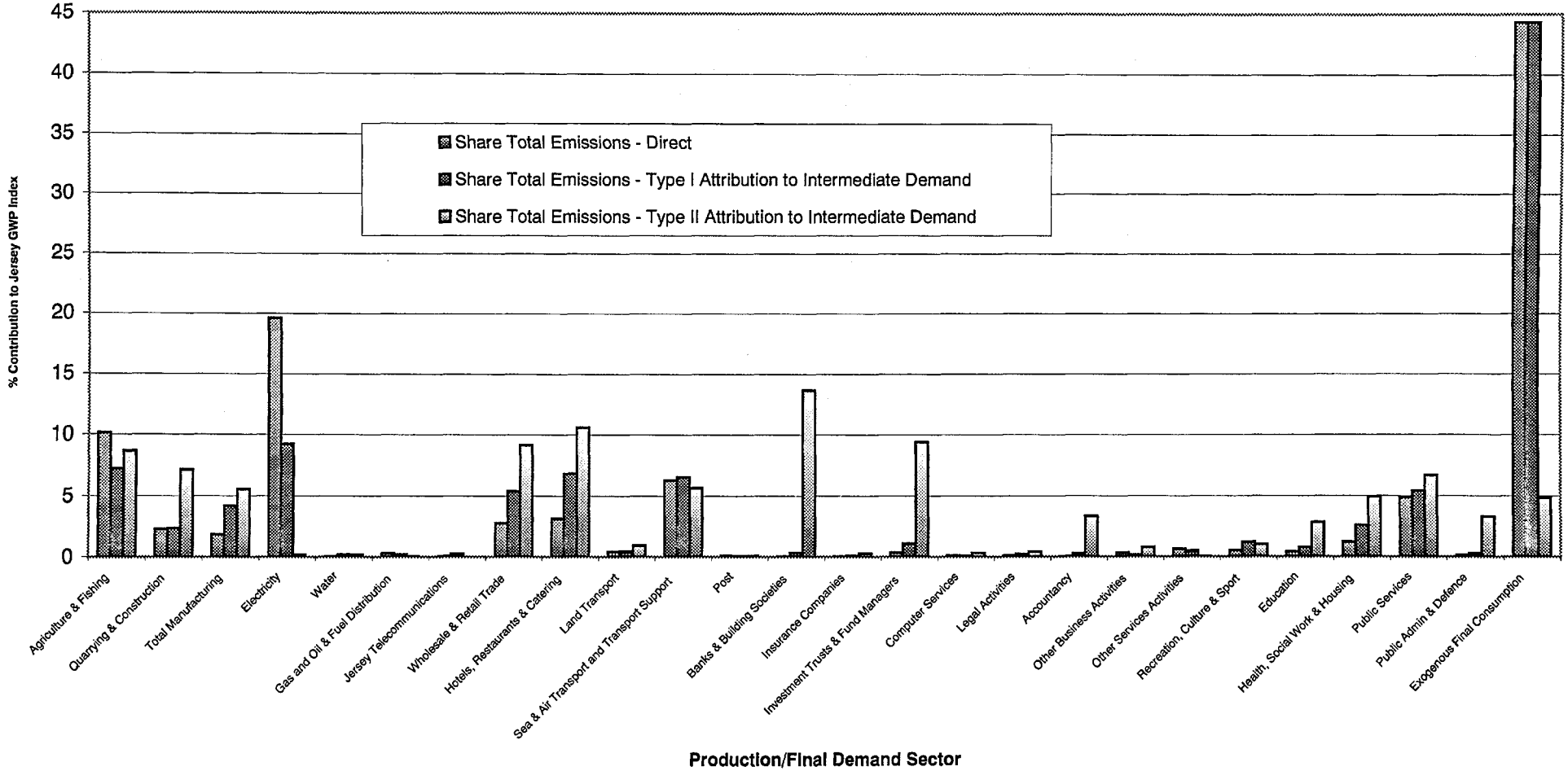
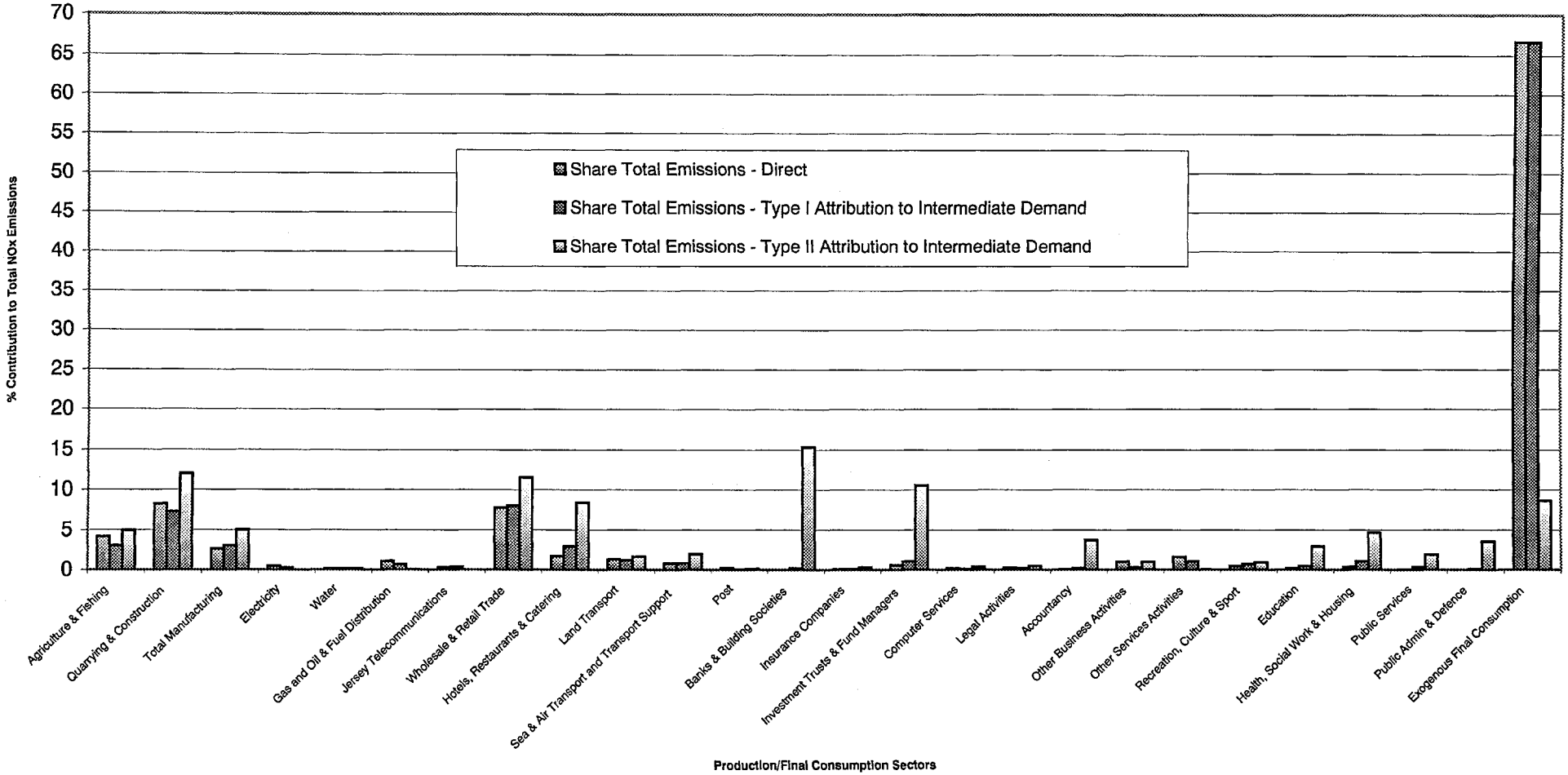


Figure 7.4 Percentage Share In Total Emissions Of N2O In Jersey (1998) Attributable To Production Sectors And Exogenous Final Consumption: Attribution To Final Demand By Commodity



Moreover, the reallocation of responsibility for emissions generation among production sectors is extremely interesting. In the case of the GWP index (Figure 7.3), I explain in Section 3.1 above that the 'Electricity' sector is the production sector with the direct highest contribution (19.6%) to the total value of the GWP index for Jersey in 1998. However when we take indirect effects into account in the Type I case, this falls to just over 9.2% reflecting the fact that more than half (53%) of the 'Electricity' sector's output is produced to meet intermediate demand. What the Type I attribution to final demand by commodities exercise does is reallocate responsibility for emissions arising from the production of this output to the sectors using it to meet their own final demand. Consequently, the contribution of other sectors increases as indirect effects are taken into account. 'Manufacturing', 'Wholesale & Retail Trade' and 'Hotels, Restaurants & Catering' show the biggest increase in their contributions to the GWP index when indirect effects are taken into account. These three sectors have relatively high backward linkages to other sectors in the Jersey economy, and in particular, are three of the four biggest purchasers of electricity as an intermediate input. ('SATTS' is the third biggest electricity purchaser, but its own direct GWP emissions are high relative to the indirect effect that electricity and other intermediate purchases create.)

From Figure 7.4 we can see that indirect effects are generally less significant in the case of N_2O. This is because most of the outputs that have embodied N_2O emissions are produced to meet non-local final demand. That is to say, the main direct generators of N_2O emissions in the production sector are sectors that sell a relatively small amount of output to intermediate demand on the Island: 'Wholesale & Retail Trade', 'Quarrying & Construction', 'Agriculture & Fishing', 'Manufacturing' and 'Hotels, Restaurants & Catering'. These are all sectors with relatively small output levels and/or are mainly export-based sectors.

However, in the case of both the GWP index and N_2O, as with most of the pollutants identified here, we see the most significant impacts both on the amount of pollution attributable to production and on the allocation between sectors in the Type II analysis. This is because, as I explain above, in the Type II attribution to final

demand by commodity, the bulk of household expenditure is treated as being endogenously determined by income from employment in the 25 production sectors. The implication of this is that responsibility for most of the direct and indirect generation of emissions from household expenditure in Jersey is attributed to the production sectors that employ household labour.

The question of course arises as to whether it is appropriate to shift responsibility for pollution generation away from households in this manner, especially when much can potentially be done to change household consumption behavour independently of production decisions or wage levels. This issue is raised in Section 2.2.2 above, and I report results for the alternative Neo-Classical Linear Attribution System later in the present section (Section 3.5).

In the case of the GWP index (Figure 7.3), note the further reallocation away from the 'Electricity' sector in the Type II attribution. The contribution of 'Electricity' to the total value of the Jersey GWP index for 1998 falls to less than 1% (from 19.6% in the direct case and 9.2% in the Type I case). This is because over 99% of 'Electricity' output is sold to local intermediate and household demand, with the sector only (directly) accounting for 0.9% of total employment and 1.3% of wage income in the local economy. (The 'Electricity' sector's own (exogenous) Type II final demand in fact only supports 0.01% of employment and 0.013% of total wage income in the economy.)

The contribution of almost all other sectors to the total value of the GWP index increases due to the reallocation away from final consumption (households) and 'Electricity' in the Type II case. As would be expected, the sectors that show the largest increases tend to be the ones that are most labour intensive and/or pay high average wages. In particular note that 'Banks & Building Societies', which has the second smallest direct contribution to the GWP Index, accounts for the largest share (13.7%) in the Type II case. 'Banks & Building Societies', while one of the least labour intensive sectors in the Jersey economy, is the second largest direct employer (12.2% of total employment), behind 'Wholesale & Retail'. However, its (Type II)

exogenous final demand actually supports the largest share of employment (17.9%). 'Banks & Building Societies' also pays one of the highest average sectoral wages, and therefore directly and indirectly supports an even higher share of wage income (17.4% direct and 22.2% supported respectively), leading to large induced output and pollution effects in the Type II analysis. A similar story underlies the reallocation towards 'Investment Trusts and Fund Managers', which actually pays the highest average sectoral wage but is a smaller sector than 'Banks & Building Societies'.

In the case of N_2O (Figure 7.4) the results of the Type II attribution also show a reallocation of contributions to total emissions towards labour intensive sectors like 'Quarrying & Construction', 'Wholesale & Retail Trade' and 'Hotels, Restaurants & Catering' and high wage sectors like 'Banks & Building Societies' and 'Investment Trusts & Fund Managers'. However, in this case most of the reallocation is away from final consumption (households) since the dominant production sectors in terms of direct and Type I contributions to total N_2O emissions tend also to be the labour intensive ones that show significant induced effects.

3.4 Attribution To Final Demand By Category (Final Consumption Sector)

However, in a conventional IO system ultimately all activity is driven by the exogenous final demand sectors. Therefore in this section I attribute pollution generation in Jersey to final demand according to the different types of final consumer, rather than the type of goods that they consume.

In Section 2 above, I explain that all emissions generated in the economy are attributable to final demand in the manner described by equation (7.7). To determine the contribution of each individual final demand sector, z, I simply calculate equation (7.7) for each final demand sector in turn:

$$\mathbf{(7.18)}\quad p_{z1} = M_i[I-A]^{-1}(C_i)_z + m_z C_z$$

Where $(C_i)_z$ is the (Ix1) vector of final demand expenditure by final demand group z on the outputs of the i local production sectors, and C_z is the scalar of gross

expenditure (including imports and expenditure taxes) by final demand group z. Substituting in the matrix of Type I output-pollution multipliers defined in equation (7.13) gives us

(7.19) $\mathbf{p_{z1} = M_{i1}(C_i)_z + m_z C_z}$

Households and tourists are the only final demand sectors in the Jersey economy that are responsible for the direct of emissions[11]. For all other sectors the second element on the right-hand side of (7.19) will drop out.

In the Type II case we have

(7.20) $\mathbf{p_{z2} = M_{i2}(C_i)_z + m_z C_z}$

As I explain in Section 3.2, it is not possible to conduct Type II analysis with households disaggregated by income bands because I do not have data on sectoral employment by income band. Therefore I use the (Kx1) vector $\mathbf{m_h}$ of *aggregate* household expenditure pollution coefficients (from the 9x2 version of matrix $\mathbf{M_z}$) here. Moreover, in Section 3.2 I also explain that in the Type II case only household expenditure that is not funded by income from employment remains exogenous. Therefore the scalar of total exogenous household expenditure, in the case z = households, ($C_z = C_h$) is smaller in absolute terms than in the Type I case. In the Type I case C_h - £1059.2million. In the Type II case I treat £1011.9million of this is as being endogenously determined (as income from employment), with the remaining £47.3million (4.5% of the total) considered exogenous.

In general, as in the Type I case, the second element on the right-hand side of (7.20) drops out in the case of all final demand sectors that are not responsible for the direct generation of emissions.

[11] See Chapter 6, Section 3.

Table 7.10 Direct Plus Indirect Emissions Intensities (kg[1]) Per £1million Expenditure By Final Demand Sectors - Type I Final Demand Expenditure-Pollution Multipliers

Final Demand Sector / Pollutant	Household Consumption 1	Household Consumption 2	Household Consumption 3	Household Consumption 4	Household Consumption 5	Tourism Expenditure	GDFCF	Jersey GGFC	Exports UK	Exports REU	Exports ROW	Stocks
Global warming potential (GWP) composite	203035.590	217591.943	194385.643	172377.947	165837.691	182342.012	115301.349	20595.898	119588.503	59181.684	13907.370	10398.477
Carbon dioxide (CO2) as carbon	194921.276	211160.085	188715.593	167805.274	161584.593	177170.591	107029.989	19850.974	118670.124	44795.736	10561.057	10013.645
Methane (CH4)	369.845	282.797	248.990	198.243	185.638	227.113	382.397	30.916	41.868	682.335	158.692	17.229
Sulphur dioxide (SO2)	738.406	568.484	582.070	414.684	334.048	461.016	404.744	57.387	191.946	395.944	91.480	45.737
Nitrous oxides (NOx)	1455.246	1436.237	1326.006	1118.966	1037.688	1194.900	781.001	128.353	843.218	537.768	120.226	95.448
Non-methane volatile organic compounds (NMVOC)	1481.439	2097.008	1902.891	1712.685	1434.030	1680.758	790.443	38.976	1448.973	123.170	31.415	41.123
Carbon monoxide (CO)	8544.730	12267.931	11025.703	9998.245	8369.488	9791.691	4622.510	171.935	5836.177	485.191	142.982	239.175
Nitrogen dioxide (N20)	1.121	1.591	1.423	1.321	1.144	1.297	0.778	0.309	0.126	0.184	0.044	0.074
Black smoke	59.046	46.716	43.829	33.852	30.969	38.239	22.416	4.410	18.146	22.134	4.983	4.143

Notes:

1. The GWP (Global Warming Potential) index is a weighted sum of CO2 (weight 1), methane (weight 21) and N_2O (weight 310): it therefore should not be read as 'kilograms' but simply as an index that is comparable across sectors within an economy and across different economies

Figure 7.5 Direct And Direct Plus Indirect GWP Intensities Of Final Demand Expenditures In Jersey (1998) - Final Demand Direct Emissions Intensities And Type I Expenditure-Pollution Multipliers

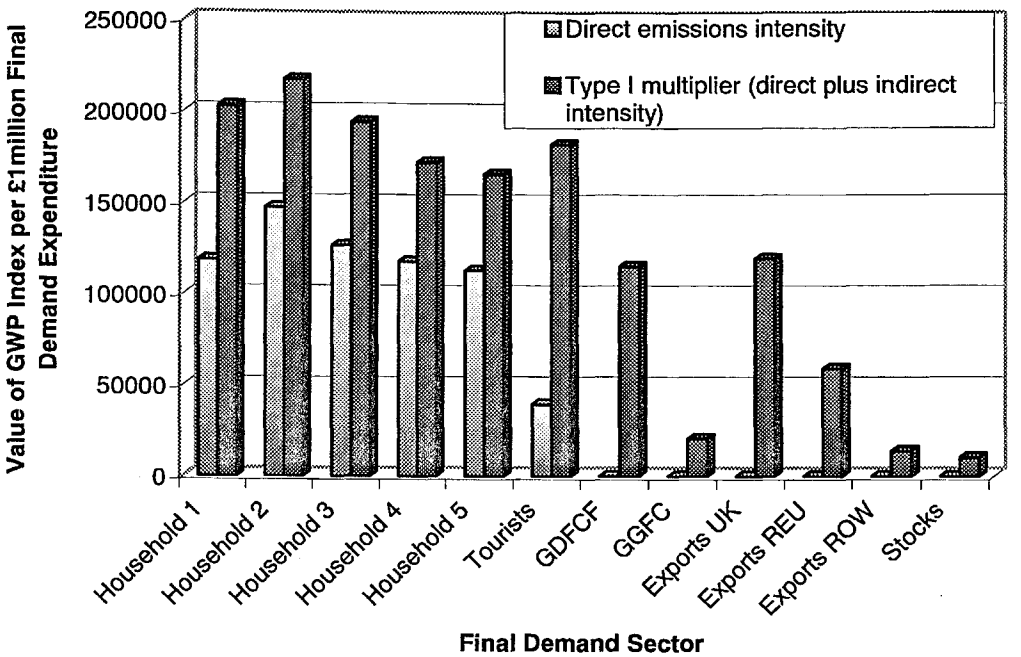
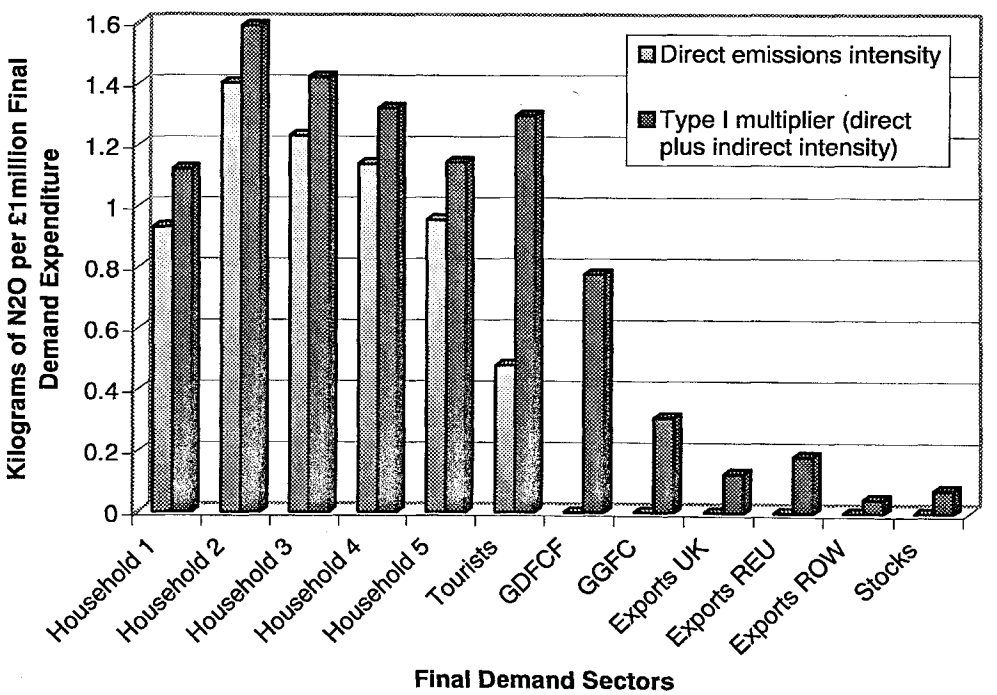


Figure 7.6 Direct And Direct Plus Indirect N2O Intensities Of Final Demand Expenditures In Jersey (1998) - Final Demand Direct Emissions Intensities And Type I Expenditure-Pollution Multipliers



Once I have calculated (7.19) and (7.20) for each final demand sector it is also possible to determine Type I and Type II final demand pollution multipliers for each final demand sector, z. These are expressed as $\mathbf{p}_{z1}/C_z$ and $\mathbf{p}_{z2}/C_z$ - i.e. total emissions attributable to sector z divided by total final demand expenditure by sector z - and indicate the Type I and Type II pollution intensities of an additional unit of final demand from each of the z sources.

3.4.1 Type I Attribution To Final Demand By Category

I report the final demand pollution multipliers for the Type I case, where all household expenditure is exogenously determined, in Table 7.10 and illustrate these for the composite GWP indicator and N_2O (alongside the direct emissions intensities for each sector) in Figures 7.5 and 7.6. The first thing to note is the relationship between the Type I final demand multipliers (direct plus indirect pollution intensities of final demand expenditure) and the direct emissions coefficients (reported for all pollutants in matrix $\mathbf{M}_z$ (Table 6.15)). Indirect pollution effects are clearly more important than direct pollution effects in the case of tourist expenditure. This is because direct emissions by tourists visiting the Island solely arise from automotive fuel use in private or rented vehicles. All other automotive fuel use by tourists (e.g. from transport in buses or taxis) and all heating fuel use by tourists is indirect. On the other hand, most household fuel use for transport and heating activities tends to be direct, and we therefore see less significant indirect effects in the case of households.

The relative (direct and Type I) emissions intensities of households in the five income bands (quintiles) vary across pollutants. Two main observations can be made. Firstly methane emissions from households are mainly related to direct emissions from human waste. In Chapter 6, Section 3.3.3 I explain that I apply a fixed per capita emissions factor for methane emissions from human waste (assuming that each income quintile contains households of the same average size). That is to say, I assume that the amount of human waste generated by the average household is independent of the level and composition of income and expenditure made by that

household. Consequently, as would be expected, my results show that emissions of this methane per unit of expenditure fall as household income and expenditure rise.

The other observation relates to different types of fuel/energy use by households. Where pollution is mainly generated from energy use for heating and lighting, the direct and Type I emissions intensities tend to be highest in the low-income band and fall as income rises. This is because energy purchases and physical fuel-use for heating/lighting purposes account for a larger proportion of each unit of household expenditure in low-income households. Therefore I find that household pollution intensities fall as income rises in the case of such pollutants as SO_2, which is mainly generated in Jersey from fuel use for heating purposes and electricity generation, and black smoke, which is mainly generated during electricity production.

On the other hand, where pollution generation mainly relates to automotive fuel use, as is the case with pollutants like carbon monoxide and N_2O, I find that the emissions intensity of household expenditure follows a different pattern. It tends to be lowest in the bottom income band, peaking in the second band, then falling as income rises. This is the pattern that is observed for the direct use of automotive fuels across household bands (see Table 6.16 in Chapter 6), where I find the first and fifth income bands to be the least intensive users. In the case of the GWP index the pattern is less clear because different types of household behaviour drive emissions of the component pollutants: methane, with weight 21, is mainly related to human waste production and its intensity therefore falls as income rises. N_2O, with weight 310, is related to automotive fuel use and intensity therefore peaks in the second income band. CO_2, which enters the GWP index with weight 1, is generated during both automotive and heating fuel-use. I note above that the intensity of fuel use for heating purposes falls as income rises. However CO_2 generation in Jersey is mainly related to automotive fuel use and therefore CO_2-intensity also peaks in the second income band.

Generally, household and tourist expenditure have the highest Type I emissions intensities across all pollutants because of the presence of a direct component.

However the relative intensities of different sources of final demand varies across the pollutants depending on the pollution intensity and contribution of producing sectors to total emissions. For example, in Figure 7.5 we can see that exports, particularly to the UK, have a higher GWP-intensity relative to other final demand categories. This is because sectors like 'SATTS' and 'Agriculture & Fishing' that are (directly and indirectly) GWP-intensive tend to sell more output to UK exports than to other final demand categories. On the other hand, sectors that are N_2O-intensive and/or where most N_2O emissions arise, such as 'Other Service Activities' and 'Wholesale & Retail Trade', tend to sell most of their outputs to local final demands or to tourists. Therefore the N_2O Type I final demand multipliers for exports are relatively small.

As with the direct contribution and attribution to intermediate demand analyses in Sections 3.1 and 3.3, the contribution of different final demand sectors to total pollution in Jersey depends on both emissions intensities and the absolute amounts of output demanded from different sectors. I determine the contribution of each final demand sector using equation (7.19) above. I report the results of the Type I attribution to final demand by category in kilograms below in Table 7.11 and in percentage terms in Table 7.12 (note from the final column of Table 7.11 that *all* emissions are attributable to the Z final demand sectors). I illustrate the results for the composite GWP pollutant and N_2O below in Figures 7.7 and 7.8 respectively.

The importance of the absolute scale of final expenditure by each different sector, z, relative to the emissions intensity of that expenditure can be clearly seen in Figures 7.7 and 7.8. As is the case for all pollutants (see Table 7.12), the contribution of households to total GWP and N_2O generation rises with income even where the final demand multipliers show that emissions intensities do not. This is reflective of the difference in the scale of total household expenditure across the five income quintiles. For example, from Table 5.4 (Chapter 5) we can see that the total expenditure in the lowest income quintile is only just over half that in the second lowest, and only around a fifth of total expenditure in the highest income quintile.

Table 7.11 Total Emissions (kg[1]) Generated In Jersey (1998) Attributable To Final Demand Sectors - With All Final Demand Expenditure Determined Exogenously

Final Demand Sector / Pollutant	Household Consumption 1	Household Consumption 2	Household Consumption 3	Household Consumption 4	Household Consumption 5	Tourism Expenditure	GDFCF	Jersey GGFC	Exports UK	Exports REU	Exports ROW	Stocks	Total Emissions (kg) Attributable to Exogenous Final Demand
Global warming potential (GWP) composite	16235701	30554416	37449130	45851037	63046790	27597070	9246904	23213039	47439711	4181107	6432043	604019	311850966
Carbon dioxide (CO2) as carbon	15586841	29651250	36356774	44634745	61429883	25617342	8912457	23034774	35908014	3175073	6194002	564027	291065182
Methane (CH4)	29575	39711	47969	52731	70574	91526	13880	8127	546956	47709	10657	1848	961262
Sulphur dioxide (SO2)	59046	79827	112138	110302	126995	96874	25765	37258	317386	27502	28291	3408	1024795
Nitrous oxides (NOx)	116368	201677	255460	297635	394500	186931	57626	163675	431072	36145	59040	5764	2205893
Non-methane volatile organic compounds (NMVOC)	118463	294463	366599	455559	545178	189190	17499	281257	98733	9444	25437	1688	2403511
Carbon monoxide (CO)	683278	1722672	2124144	2659446	3181842	1106385	77193	1132846	388927	42986	147943	9583	13277245
Nitrogen dioxide (N20)	90	223	274	351	435	186	139	25	147	13	46	4	1933
Black smoke	4722	6560	8444	9004	11773	5365	1980	3522	17743	1498	2563	253	73427

Notes:
1. The GWP (Global Warming Potential) index is a weighted sum of CO2 (weight 1), methane (weight 21) and N_2O (weight 310): it therefore should not be read as 'kilograms' but simply as an index that is comparable across sectors within an economy and across

Table 7.12 Percentage Share In Total Emissions Generated In Jersey (1998) Attributable to Final Demand Sectors - Type I Attribution To Final Demand By Category

Final Demand Sector / Pollutant	Household Consumption 1	Household Consumption 2	Household Consumption 3	Household Consumption 4	Household Consumption 5	Tourism Expenditure	GDFCF	Jersey GGFC	Exports UK	Exports REU	Exports ROW	Stocks	Total
Global warming potential (GWP) composite	5.21	9.80	12.01	14.70	20.22	8.85	2.97	7.44	15.21	1.34	2.06	0.19	100
Carbon dioxide (CO2) as carbon	5.36	10.19	12.49	15.33	21.11	8.80	3.06	7.91	12.34	1.09	2.13	0.19	100
Methane (CH4)	3.08	4.13	4.99	5.49	7.34	9.52	1.44	0.85	56.90	4.96	1.11	0.19	100
Sulphur dioxide (SO2)	5.76	7.79	10.94	10.76	12.39	9.45	2.51	3.64	30.97	2.68	2.76	0.33	100
Nitrous oxides (NOx)	5.28	9.14	11.58	13.49	17.88	8.47	2.61	7.42	19.54	1.64	2.68	0.26	100
Non-methane volatile organic compounds (NMVOC)	4.93	12.25	15.25	18.95	22.68	7.87	0.73	11.70	4.11	0.39	1.06	0.07	100
Carbon monoxide (CO)	5.15	12.97	16.00	20.03	23.96	8.33	0.58	8.53	2.93	0.32	1.11	0.07	100
Nitrogen dioxide (N20)	4.64	11.55	14.19	18.18	22.50	9.63	7.17	1.27	7.61	0.69	2.38	0.20	100
Black smoke	6.43	8.93	11.50	12.26	16.03	7.31	2.70	4.80	24.16	2.04	3.49	0.34	100

Figure 7.7 Contribution Of Final Demand Sectors To The GWP Index For Jersey (1998) - Type I Attribution to Final Demand by Category (With All Final Demand Expenditures Determined Exogenously)

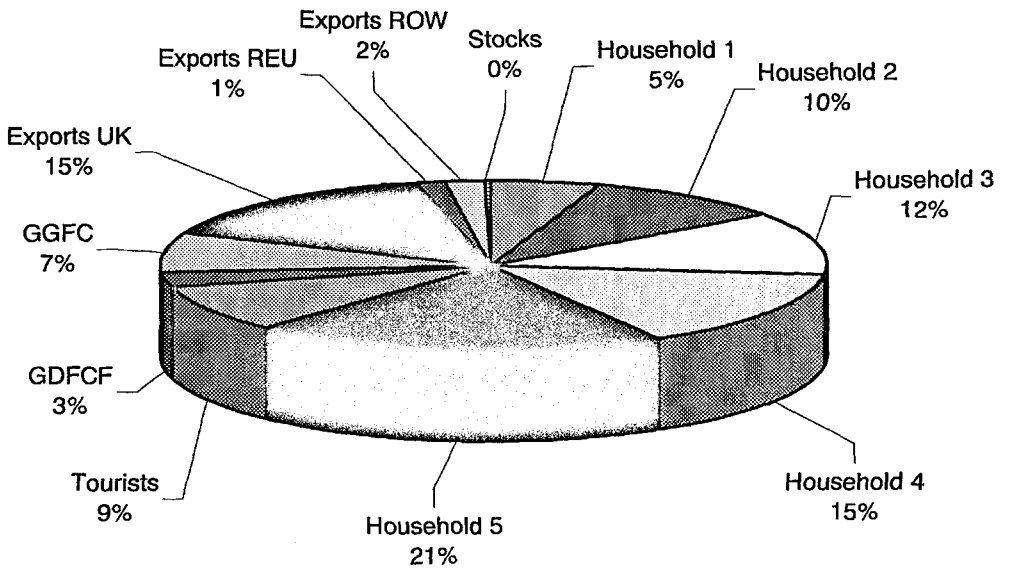
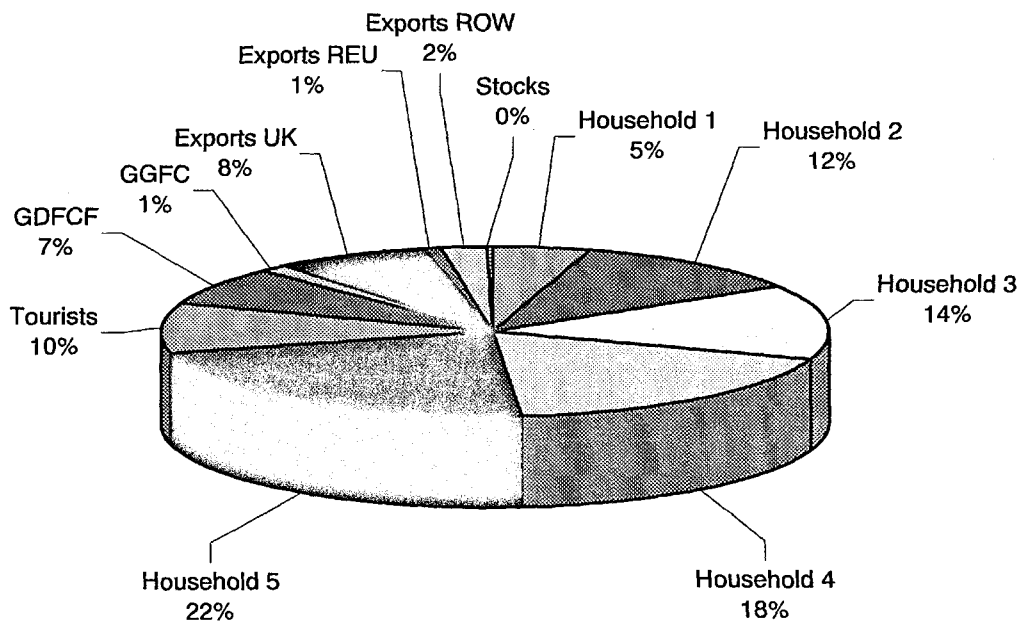


Figure 7.8 Contribution Of Final Demand Sectors To Total N2O Emissions Generated In Jersey (1998) - Type I Attribution to Final Demand by Category (With All Final Demand Expenditures Determined Exogenously)



However, the relatively high pollution intensity of household expenditure in general is important. In the case of most pollutants, I find that more than half of total emissions are attributable to local household expenditure even though only 20% of total local output is produced to meet final demand from households. For example, note the dominance of households in the case of N_2O (Figure 7.8): each household band, apart from the lowest income group, independently has a larger contribution to total emissions than any of the non-household final demand sectors. In the case of the GWP index (Figure 7.7) households are not quite as dominant. However in aggregate they still account for 63% of the total, with the highest share of emissions being attributable to the highest income band alone.

There are two main factors underlying these results. One is the importance of direct emissions by households. If I were only to consider production related emissions (and therefore indirect emissions by households) both the contribution of households and total emissions in the economy will be significantly lower across all pollutants. The other factor is the composition of the local output demanded by different final consumption groups. For example, the bulk of direct final demand for local outputs (48%) is for goods and services produced by the financial sectors ('Banks & Building Societies', 'Insurance Companies' and 'Investment Trusts & Fund Managers'). These are sectors with low direct and indirect pollution intensities and which are shown to make very small (not more than around 5% across all 3 sectors) contributions across all pollutants in the Type I attribution to intermediate demand. 95.5% of final demand for the outputs of the financial sectors is export demand, which equates to 77.8% of total export demand. On the other hand, financial sector outputs only account for 10% of direct household consumption of local goods.

3.4.2 Type II Attribution To Final Demand By Category

In the Type II attribution to final demand analysis, however, the picture changes significantly, because the bulk of household expenditure is treated as being endogenous to the system. This is because emissions attributable to households in the Type I analysis are reallocated to the production sectors whose wage payments to

households fund consumer expenditure. In Section 3.2 above I explain that when households are treated as being endogenous to the system this leads to sectors that are labour intensive and/or pay high wages having relatively large Type II output-pollution multiplier values (emissions per unit of final demand for sectoral outputs).

In the case of Jersey I find that the key result is huge increases in the emissions intensities of the finance sectors when induced (consumption and income) effects are taken into account (see Tables 7.3 and 7.5, and Figures 7.1 and 7.2). Given that the main final demand for finance sector outputs is export demand, the implication is that the Type II final demand multipliers for the export sectors will also increase. However note that, as with the Type II output-pollution multipliers for the finance sectors, the export sectors do not have the highest Type II final demand multipliers – see Table 7.13 and Figures 7.9 and 7.10 below. Tourist expenditure, government consumption (GGFC) and stock holding in fact become the most pollution intensive sources of final demand when induced effects are taken into account. However, in the same way as we saw the finance sectors becoming the dominant sources of pollution generation in the Type II attribution to intermediate demand in Section 3.3, the crucial factor here is the absolute size of the export sector, particularly demand for finance sector exports. Together with the increase in pollution intensities of the main export sectors this leads to the bulk of emissions generation being attributable to export demand in the Type II attribution to final demand.

In Tables 7.14 and 7.15 I report the results of the Type II attribution to final demand by categories in absolute (kilograms) and percentage terms respectively. I illustrate these results for the GWP index and N_2O in Figures 7.11 and 7.12. Note that small shares of total pollution generation remain attributable to households: this is the element of household expenditure that I assume to be non-wage related and therefore exogenously determined in the Type II case. The shares attributable to all other final demand sectors increase when wage-related expenditure by local households is considered endogenous, with the importance of induced effects depending on the labour intensity and/or level of wage payments in the sectors output is demanded from.

Table 7.13 Direct Plus Indirect Plus Induced Emissions Intensities (kg[1]) Per £1million Expenditure By Final Demand Sectors (Type II Final Demand Expenditure-Pollution Multipliers)

Final Demand Sector / Pollutant	Aggregate (Non-Wage Related) Household Consumption	Tourism Expenditure	GDFCF	Jersey GGFC	Exports UK	Exports REU	Exports ROW	Stocks
Global warming potential (GWP) composite	5437.099	201075.626	65983.734	287057.186	126013.825	71271.048	78754.543	178752.266
Carbon dioxide (CO2) as carbon	5294.868	190365.808	63948.489	281377.877	109727.921	66293.956	76426.431	170890.918
Methane (CH4)	6.041	489.586	87.636	251.148	765.853	230.378	102.651	356.486
Sulphur dioxide (SO2)	4.993	625.851	174.387	623.644	568.223	239.351	221.944	686.249
Nitrous oxides (NOx)	22.985	1349.217	429.027	1952.623	980.501	500.234	548.277	1398.823
Non-methane volatile organic compounds (NMVOC)	70.998	1570.952	451.987	2972.868	731.315	553.400	663.135	1162.674
Carbon monoxide (CO)	418.825	9167.046	2576.697	14709.088	4026.126	3182.253	3860.851	6739.794
Nitrogen dioxide (N20)	0.050	1.382	0.629	1.307	0.655	0.449	0.556	1.210
Black smoke	0.000	40.957	14.221	54.346	36.581	17.382	18.919	53.540

Notes:

1. The GWP (Global Warming Potential) Index is a weighted sum of CO2 (weight 1), methane (weight 21) and N_2O (weight 310): it therefore should not be read as 'kilograms' but simply as an index that is comparable across sectors within an economy and across different economies

Figure 7.9 Direct Plus Indirect Plus Induced GWP Intensities Of Final Demand Expenditures In Jersey (1998) - Type II Final Demand Expenditure-Pollution Multipliers

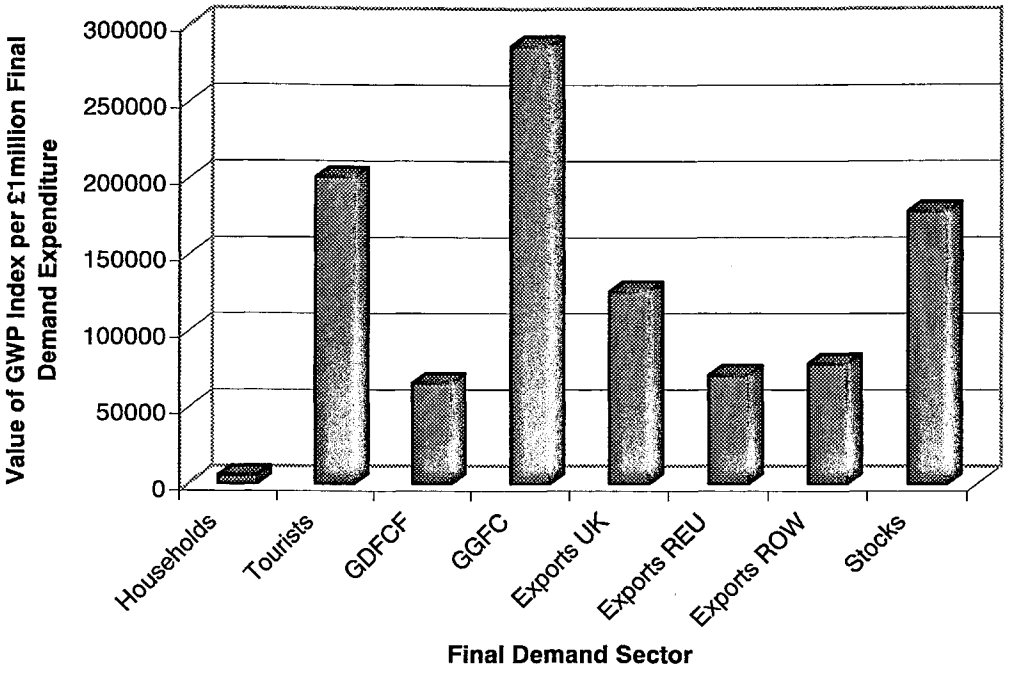


Figure 7.10 Direct Plus Indirect Plus Induced N2O Intensities Of Final Demand Expenditures In Jersey (1998) - Type II Final Demand Expenditure-Pollution Multipliers

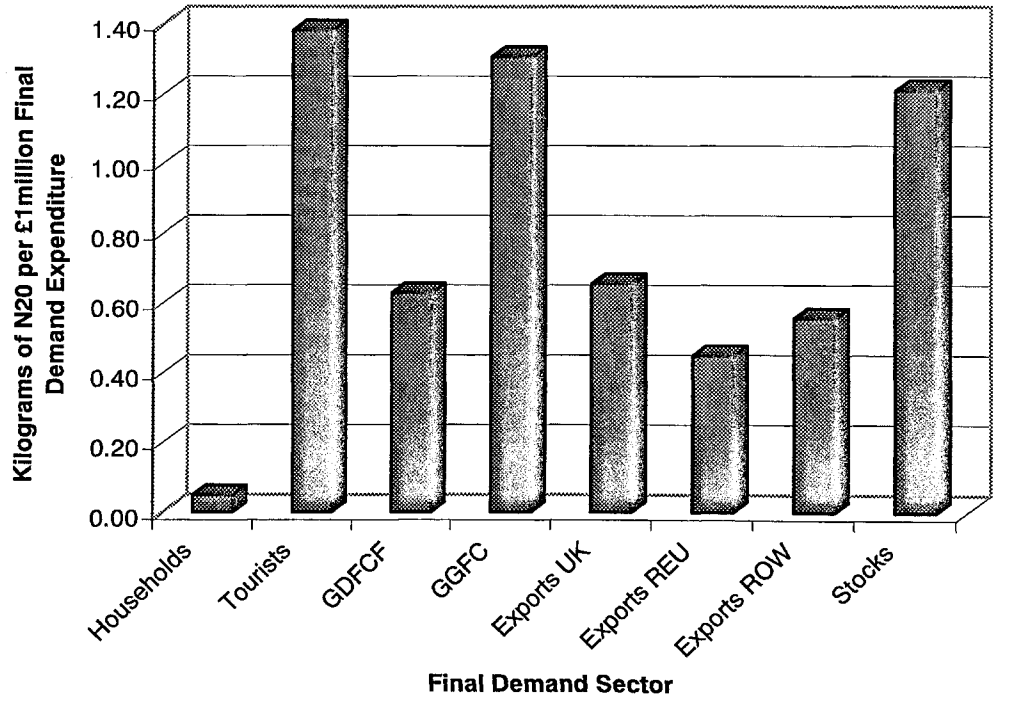


Table 7.14 Total Emissions (kg[1]) Generated In Jersey (1998) Attributable To Exogenous Final Demand Sectors - With Household Expenditure Funded By Local Wage Income Determined Endogenously

Final Demand Sector / Pollutant	Household Consumption	Tourism Expenditure	GDFCF	Jersey GGFC	Exports UK	Exports REU	Exports ROW	Stocks	Total Emissions (kg) Attributable to Exogenous Final Demand
Global warming potential (GWP) composite	5758987	48126914	29624600	55719984	101011986	21426905	48714112	1467476	311850966
Carbon dioxide (CO2) as carbon	5608336	45563548	28710840	54617587	87957296	19930594	47274044	1402938	291065182
Methane (CH4)	6399	117181	39346	48750	613904	69261	63496	2927	961262
Sulphur dioxide (SO2)	5289	149796	78294	121054	455484	71958	137285	5634	1024795
Nitrous oxides (NOx)	24346	322931	192619	379019	785964	150390	339140	11484	2205893
Non-methane volatile organic compounds (NMVOC)	75201	376003	202928	577056	586218	166374	410186	9545	2403511
Carbon monoxide (CO)	443620	2194108	1156855	2855146	3227320	956712	2388153	55331	13277245
Nitrogen dioxide (N20)	53	331	282	254	525	135	344	10	1933
Black smoke	0	9803	6385	10549	29323	5226	11702	440	73427

Notes:
1. The GWP (Global Warming Potential) Index is a weighted sum of CO2 (weight 1), methane (weight 21) and N_2O (weight 310): it therefore should not be read as 'kilograms' but simply as an index that is comparable across sectors within an economy and across

Table 7.15 Percentage Share In Total Emissions Generated In Jersey (1998) Attributable To Final Demand Sectors - Type II Attribution To Final Demand By Category

Final Demand Sector / Pollutant	Household Consumption	Tourism Expenditure	GDFCF	Jersey GGFC	Exports UK	Exports REU	Exports ROW	Stocks	Total
Global warming potential (GWP) composite	1.85	15.43	9.50	17.87	32.39	6.87	15.62	0.47	100
Carbon dioxide (CO2) as carbon	1.93	15.65	9.86	18.76	30.22	6.85	16.24	0.48	100
Methane (CH4)	0.67	12.19	4.09	5.07	63.86	7.21	6.61	0.30	100
Sulphur dioxide (SO2)	0.52	14.62	7.64	11.81	44.45	7.02	13.40	0.55	100
Nitrous oxides (NOx)	1.10	14.64	8.73	17.18	35.63	6.82	15.37	0.52	100
Non-methane volatile organic compounds (NMVOC)	3.13	15.64	8.44	24.01	24.39	6.92	17.07	0.40	100
Carbon monoxide (CO)	3.34	16.53	8.71	21.50	24.31	7.21	17.99	0.42	100
Nitrogen dioxide (N20)	2.72	17.11	14.60	13.12	27.15	6.98	17.80	0.51	100
Black smoke	0.00	13.35	8.70	14.37	39.93	7.12	15.94	0.60	100

Figure 7.11 Contribution Of Final Demand Sectors To The GWP Index For Jersey (1998) - Type II Attribution to Final Demand by Category (With Wage-Related Household Expenditure Determined Endogenously)

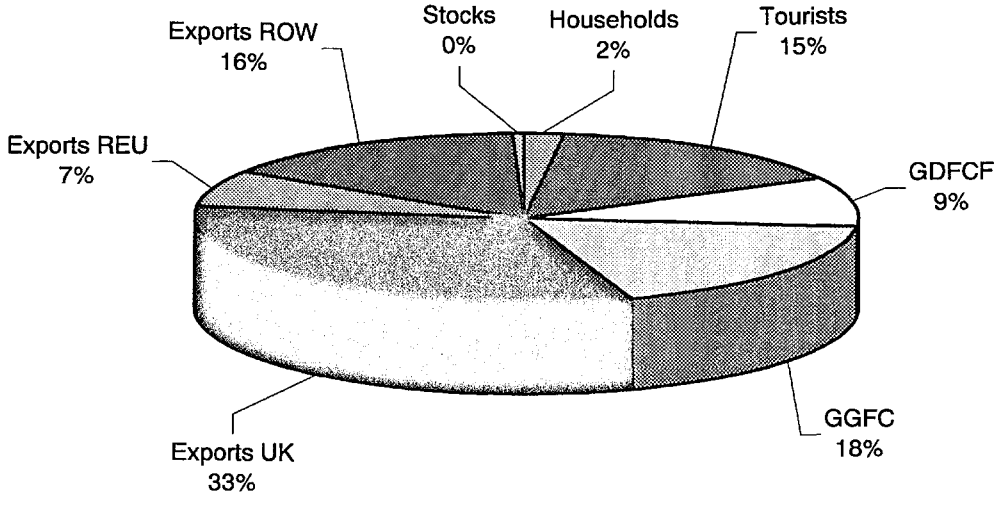
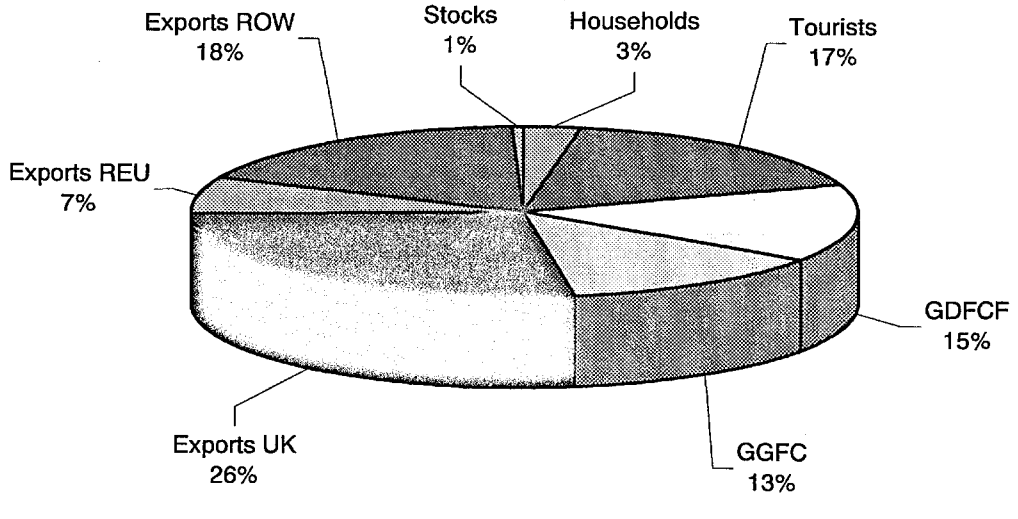


Figure 7.12 Contribution Of Final Demand Sectors To Total N2O Emissions Generated In Jersey (1998) - Type II Attribution to Final Demand by Category (With Wage-Related Household Expenditure Determined Endogenously)



I have already expressed concern over the inherent implication in Type II analysis that households are not held responsible for the bulk of their own pollution generation. It is possible to argue in favour of Type II analysis if it is considered that the population of an economy is endogenously determined by its production activities. In other words, it may be appropriate to use this type of attribution if there is concern about environmental damage in a particular place where many of the local inhabitants choose to live in order to be near their place of work. For example, suppose a large textile factory is located in a particular area and a town or village grows around it to accommodate the workers. Not only will the plant itself be directly polluting, but the workers will also generate emissions in the locality from burning fuels to heat their homes, operate their vehicles etc.

However, particularly with the decline in large scale manufacturing activities over recent years, it could be argued that the population of any given area is less likely to be endogenously driven by local production activities. Moreover, environmentalists would argue that while the level of consumer expenditure may be strongly linked to income from employment, the composition and pollution intensity of this expenditure is not. Therefore, in Section 3.3, where the results of the Type II attribution to final demand by commodities (production sectors) are reported, I raise the question as to whether it is appropriate to attribute direct and indirect emissions generation by households to the production sectors that employ household labour.

Moreover, another related question arises from the Type II attribution to final demand. In the case of Jersey the results of this analysis imply that the large majority (between 64% and 90%) of emissions of all pollutants can be attributed to foreign sources in the form of tourist and export demand. Again, this type of attribution may be considered appropriate if it is thought that the population of an area is endogenously driven by export-based production activities located in the local economy. For example, a number of areas in the north of Scotland attract migrants to work in oil industry activities.

However, generally, the attribution of responsibility for local emissions generation in the Type II (and Type I) analysis to external demand is contrary to the environmentalist's perspective that pollution problems are caused by local human consumption decisions. This is the issue of production vs consumption that I have raised above in Section 2.2.2. The point is that Type I and Type II attribution analysis are based on a Keynesian production-based perspective of how the economy operates. This is why the use of Type I and Type II attribution analyses for a single regional economy can also be criticised because they do not take account of any pollution embodied in imports that are consumed in that economy.

In recognition of the problem of the pollution content of imports, authors such as Atkinson *et al* (1997) and Pearce & Atkinson (1995) argue in favour of using an inter-regional accounting framework. However, I have argued, in Section 2.2.3 above, that the practical and conceptual problems inherent in the notion of a pollution attribution analysis including imports render this an unfeasible option in the present study. Instead I operationalise the notion introduced in Section 2.2.3 of a neo-classical consumption-based approach to attribution using the environmental IO system. I now report the results of adopting such an approach for Jersey.

3.5 Results From The Neo-Classical Linear Attribution System (NCLAS)

3.5.1 Direct Emissions Coefficients In NCLAS

In the neo-classical linear attribution system (NCLAS) the matrix of direct emissions intensities (output-pollution coefficients), $\mathbf{M_i}$ (Table 6.15), still applies for the 25 production sectors of the Jersey economy. However, in order to focus on local (private and public) consumption in the NCLAS system, I now endogenise investment (which is assumed to cover depreciation, and is allocated to sectors in line with shares in OVA) and exports (assumed to cover imports). As in the Type I case above, household expenditure is once again treated as being entirely exogenously determined, with the matrix of direct emissions intensities by final

demand sectors, $\mathbf{M}_z$, being the 9x6 version, with households disaggregated by income, as shown in Table 6.15.

In the matrix $\mathbf{M}_z$ for Jersey I also report direct emissions per unit of tourist expenditure (i.e. export consumption that actually takes place in Jersey) - where the final consumption sector, z, is tourism this vector is expressed as $\mathbf{m}_t$. However, in Section 2 I explain that all export demand is treated as endogenous in the neo-classical system, with exports being produced simply to finance imports. When a proportion of household demand is endogenised in the Type II analysis above, the household direct emissions coefficients are taken to reflect emissions per unit of income from employment rather than expenditure and added to the matrix of output-pollution coefficients for the production sector of the economy, $\mathbf{M}_{i(+h)}$. Similarly, to endogenise exports I must adjust the vector of coefficients that reflect direct emissions arising in Jersey per unit of expenditure by external agents to reflect emissions per unit of income earned in Jersey by the external sector. In an IO system income earned by the external sector in Jersey is the expenditure on imports by Jersey producers and final consumers. Therefore I require a (9x1) vector of coefficients, $\mathbf{m}_t^*$, that reflect direct emissions in kilograms generated in Jersey by export demand (tourist expenditure) per £1million of imports – i.e. direct emissions per £1million of trade.

I should point out that in 1998 Jersey ran a trade surplus, with the value of exports exceeding the value of imports. This implies that not all export revenue is used to fund imports. Therefore, strictly speaking, some adjustment should be made to reflect this factor by retaining a share of export demand as being exogenously determined, just as the excess of household expenditure over wage income is retained as an exogenous final demand in the Type II analysis above. However, given that the IO accounts do not give information on the uses of particular types of export revenues, I do not endeavour to make any such adjustment here. (As I explain in Section 3.2, with respect to the case of households, this would be better attempted in a SAM framework.) For now I assume that all revenues from exports to tourists are

used to fund imports, thereby allowing me to treat all direct and indirect emissions generation by tourists as being endogenous to the system.

I report the new vector of trade-pollution coefficients for Jersey below in Table 7.16. Vector $\mathbf{m_t^*}$ is then added as an additional column to the matrix of output-pollution coefficients for the production sector of the economy. Note that the other final demand sector that I endogenise in the NCLAS system, capital formation (stocks and GDFCF), is not responsible for any direct emissions generation. Therefore there will be a (kx1) vector, **o**, of zeros in the new combined matrix, $\mathbf{M_{i(+t)}}$, of direct emissions intensities for the production sector of the economy. $\mathbf{M_{i(+t)}}$ is a (kx(i+2) and takes the form:

(7.21) $\mathbf{M_{i(+t)} = [M_i \vdots m_t^* \vdots o]}$

3.5.2 Neo-Classical Output-Pollution Multipliers

I want to use the NCLAS system to determine the emissions intensity of producing different types of local outputs for local final consumption, relative to the emissions intensity of producing outputs for export to allow the consumption of imported goods and services, or for investment production. Also, just as in the Type I and Type II analysis above, I want to determine the contribution of different private and public final consumption sectors to total pollution generation.

Therefore, once again I require a matrix of output-pollution multipliers relating emissions generation to the production of output to meet final consumption (i.e. including indirect effects). However, here I endogenise trade and capital formation to get a matrix, **N**, of neo-classical output-pollution multipliers. To derive **N** I require a new (27x27) version of the **A** matrix, which I shall call $\mathbf{A^+}$. Relative to the standard (IxI) input coefficients matrix, $\mathbf{A^+}$ has two additional columns showing the input requirements of the trade and capital formation sectors from the Jersey economy. It also has two additional rows showing the input requirements of each of the production, trade and capital sectors from the trade sector (imports) and capital sector

(other value added). I then use Matrix $\mathbf{A^+}$ to create a new (27x27) inverse matrix, $\mathbf{[I-A^+]}$, which is shown below as the 'Neo-Classical Inverse Matrix' in Table 7.17.

Each element of the ith column of this new inverse matrix (across the first 25 columns) tells us how the input requirement from each of the (i+2) production sectors/activities is affected by one monetary unit (£1million) of *local* consumption demand for the output of sector i. The elements in the 'export' column tell us how much output is required from each of the (I+2) sectors/activities per £1million of trade. Finally, the elements in the 'capital formation' column tell us how the input requirement from each sector/activity is affected by £1million of investment demand. The column totals, therefore, give the 'neo-classical output multipliers': the column total for each local production sector, i, tell us how much total output in the economy is affected by £1million of *local* final consumption demand for the output of sector i. The multiplier for the trade sector tells us the economy-wide impact of £1million of import demand in terms of the direct and indirect output associated with the increase in exports required to finance the imports. Finally the capital formation multiplier gives the total impact of £1million of investment demand.

I multiply the neo-classical inverse by the adjusted matrix $\mathbf{M_{i(+t)}}$ of direct emissions intensities for the production sector of the economy to derive the (9x27) matrix, **N**, of neo-classical output-pollution multipliers:

$$\mathbf{(7.22)\quad N = M_{i(+t)}.[I-A^+]^{-1}}$$

I show the resulting matrix **N** below in Table 7.18. What the elements of the first 25 columns of this matrix tell us is the amount of pollution generated in the production of £1million of output to meet local private (household) or public (government) final demand for locally produced goods and services. The elements of the final column tell us the emissions intensity of producing exports in order to purchase £1million imports of foreign goods and services for local final consumption. The coefficients in the 'Trade' column are essentially a weighted average of the emissions intensities of the 25 standard production sectors; the weights are determined by how much output

each sector sends to the trade sector. I do not report the neo-classical output-pollution multipliers for the capital formation sector in Table 7.18 because no investment demand from the local final consumption sectors is recorded in the IO table (Table 5.3).

I graph the neo-classical output-pollution multipliers for the GWP index and N_2O below in Figures 7.13 and 7.14. These multipliers indicate how environmentally friendly local and imported consumption is for the States of Jersey (for the 1998 equilibrium dataset). Note that the emission multipliers for the consumption of commodities produced in local 'Agriculture & Fishing' are higher that those implied by the consumption of imports. For example, £1 million spent on imports generates, in Jersey, an implied 0.837kg of N_2O and adds 154108 points to the GWP index, compared to the 1.75kg of N_2O and 635887 GWP points that are produced by each £1 million expenditure on the consumption of local 'Agriculture & Fishing' outputs. (Thus implying that it would be more environmentally friendly for Jersey to import agricultural and fishing producing using revenue generated from the production of the composite export commodity.)

3.5.3 Attribution To Local (Exogenous) Private And Public Final Demand In NCLAS

Just as in the standard Leontief environmental IO analysis in Sections 3.2-3.4, I can use the neo-classical output-pollution multipliers to determine the contribution of different local final demand sectors to total emissions in the economy, and to determine the emissions intensities of each sector.

I calculate the vector **P** of total emissions in the NCLAS as

$$\textbf{(7.23)}\quad \mathbf{P} = \mathbf{P_i} + \mathbf{P_z} = \mathbf{M_{i(+t)}}.[\mathbf{I}-\mathbf{A^+}]^{-1}\mathbf{C_i} + \mathbf{M_z C^T} = \mathbf{NC_i} + \mathbf{M_z C^T}$$

Table 7.16 Export Consumption Direct Emissions Coefficients

Pollutants	Direct emissions (kg[1]) per £1million trade in Jersey, $(m_x)_t$
Global warming potential (GWP) composite	9514.860
Carbon dioxide (CO2) as carbon	9192.119
Methane (CH4)	13.657
Sulphur dioxide (SO2)	0.000
Nitrous oxides (NOx)	45.902
Non-methane volatile organic compounds (NMVOC)	160.390
Carbon monoxide (CO)	954.718
Nitrogen dioxide (N20)	0.116
Black smoke	0.000

Notes:

1. The GWP (Global Warming Potential) Index is a weighted sum of CO2 (weight 1), methane (weight 21) and N2O (weight 310): it therefore should not be read as 'kilograms' but simply as an index that is comparable across sectors within an economy and across different economies.

Table 7.17 Neo-Classical Inverse Matrix - Jersey 1998

Sectors	Agriculture & Fishing	Quarrying & Construction	Manufacturing	Electricity	Water	Gas, Oil & Fuel Dist.	Jersey Telecom.	Wholesale & Retail Trade	Hotels, Rest. & Catering	Land Transport	Sea & Air Trans. & Trans Supp	Jersey Post	Banks & Building Soc.	Insurance Companies	Inv. Trusts & Fund Mgrs	Computer Services	Legal Activities	Accountancy	Other Bus. Activities	Other Service Activities	Recreation, Culture & Sport	Education	Health, Social Work & Housing	Public Services	Public Admin. & Defence	Exports	Capital Formation
Agriculture & Fishing	1.02584	0.01632	0.14013	0.02963	0.01778	0.00756	0.02466	0.01576	0.04539	0.01685	0.01969	0.01171	0.01537	0.01244	0.01716	0.02091	0.01025	0.01052	0.00663	0.00965	0.03953	0.01261	0.01412	0.02008	0.01516	0.08132	0.01501
Quarrying & Construction	0.10681	1.14132	0.12259	0.12841	0.14045	0.09343	0.15947	0.10264	0.11621	0.10111	0.13662	0.08096	0.12840	0.07979	0.10792	0.10918	0.06743	0.06362	0.06472	0.07080	0.14598	0.10674	0.10068	0.23790	0.07090	0.24034	0.14782
Manufacturing	0.03128	0.03126	1.05879	0.04734	0.03175	0.02189	0.05547	0.02832	0.03628	0.03564	0.03039	0.03166	0.02469	0.02752	0.04114	0.03876	0.02774	0.02182	0.02249	0.02072	0.03942	0.02008	0.02877	0.03466	0.02320	0.12138	0.02314
Electricity	0.03130	0.00852	0.03589	1.00907	0.05036	0.00640	0.01772	0.02098	0.02595	0.01042	0.04026	0.01034	0.00536	0.00727	0.00756	0.01209	0.00696	0.00648	0.00671	0.00976	0.02995	0.01428	0.01926	0.04289	0.00947	0.02260	0.00516
Water	0.00765	0.00261	0.00881	0.00817	1.00289	0.00119	0.00324	0.00290	0.00695	0.00300	0.00520	0.00200	0.00307	0.00218	0.00287	0.00293	0.00231	0.00196	0.00187	0.00234	0.00694	0.00511	0.00745	0.01662	0.00345	0.00734	0.00345
Gas, oil & fuel distribution	0.01200	0.00275	0.00628	0.00239	0.00204	1.00270	0.00212	0.00245	0.00752	0.00431	0.00274	0.00157	0.00112	0.00105	0.00143	0.00211	0.00104	0.00085	0.00117	0.00364	0.00965	0.00587	0.00658	0.02136	0.00376	0.00509	0.00112
Jersey Telecommunications	0.01065	0.00934	0.01150	0.01025	0.00967	0.01175	1.00645	0.01326	0.01118	0.00960	0.00528	0.00657	0.00437	0.01735	0.00962	0.01711	0.01212	0.01389	0.01346	0.00502	0.01370	0.00898	0.01202	0.02067	0.00481	0.01503	0.00341
Wholesale & Retail Trade	0.11144	0.09777	0.13554	0.12303	0.10345	0.03040	0.22042	1.07349	0.07472	0.07314	0.06844	0.04879	0.07984	0.05456	0.07429	0.06957	0.04926	0.05142	0.04104	0.04818	0.09365	0.09449	0.10546	0.10606	0.06186	0.30757	0.06450
Hotels, Restaurants & Catering	0.05102	0.05337	0.09797	0.10106	0.05794	0.02116	0.07563	0.04738	1.04548	0.05364	0.06677	0.03712	0.05099	0.03912	0.05195	0.06836	0.02665	0.03368	0.02534	0.02982	0.06671	0.04331	0.04307	0.06780	0.05208	0.26064	0.04963
Land Transport	0.00602	0.00622	0.01102	0.00990	0.00575	0.00215	0.00771	0.00483	0.00562	1.00521	0.00657	0.00348	0.00503	0.00453	0.00564	0.00671	0.00302	0.00541	0.00250	0.00296	0.00696	0.00580	0.00595	0.02867	0.00523	0.02737	0.00493
Sea & Air Transport & Transport Support	0.01503	0.01523	0.03755	0.02984	0.01684	0.00673	0.02377	0.01942	0.01887	0.01871	1.01879	0.05194	0.01449	0.01244	0.01735	0.02172	0.00939	0.01014	0.00767	0.01682	0.02056	0.01298	0.01379	0.01992	0.01455	0.07735	0.01388
Jersey Post	0.01026	0.00682	0.01192	0.01004	0.01448	0.01510	0.01280	0.01563	0.00732	0.07432	0.00502	1.00634	0.00520	0.02849	0.01025	0.00752	0.00810	0.00499	0.01228	0.00548	0.01279	0.00753	0.00844	0.01708	0.00467	0.01802	0.00392
Banks & Building Societies	0.36325	0.34303	0.62401	0.83423	0.49741	0.13839	0.47369	0.30320	0.36112	0.33753	0.41759	0.20805	1.31765	0.24242	0.33234	0.42677	0.18328	0.20456	0.15728	0.19849	0.41473	0.26500	0.24991	0.42167	0.32476	1.75402	0.31069
Insurance Companies	0.01426	0.00703	0.01016	0.00602	0.01372	0.00191	0.00662	0.00646	0.00817	0.00857	0.00494	0.00291	0.00315	1.00385	0.00524	0.00891	0.00912	0.00336	0.01205	0.00779	0.00871	0.00557	0.00452	0.00891	0.00291	0.01473	0.00314
Investment Trusts & Fund Managers	0.08877	0.09097	0.17854	0.17690	0.10091	0.03679	0.13177	0.08267	0.07704	0.09156	0.11648	0.05754	0.08852	0.06623	1.06911	0.11906	0.05028	0.05676	0.04258	0.05180	0.11344	0.07260	0.06818	0.11656	0.09073	0.49177	0.08652
Computer Services	0.00739	0.00788	0.01106	0.00945	0.00739	0.00970	0.01920	0.00912	0.00747	0.00997	0.00666	0.00630	0.00602	0.00620	0.00918	1.00716	0.00555	0.00512	0.01065	0.00376	0.00936	0.00816	0.00791	0.00717	0.00529	0.02431	0.00579
Legal Activities	0.03978	0.01960	0.04309	0.03151	0.02520	0.01252	0.02788	0.04440	0.04352	0.04434	0.01669	0.01491	0.01644	0.05751	0.04315	0.04191	1.03936	0.01703	0.04369	0.01347	0.04900	0.01256	0.02737	0.02300	0.01371	0.06515	0.01312
Accountancy	0.03043	0.02906	0.05089	0.04929	0.03140	0.01170	0.03751	0.02856	0.02889	0.03179	0.03234	0.01669	0.02514	0.03233	0.02719	0.03596	0.01764	1.01657	0.02150	0.02243	0.03422	0.02178	0.02090	0.03318	0.02505	0.13396	0.02441
Other Business Activities	0.17538	0.04394	0.08925	0.04192	0.16396	0.03671	0.04970	0.07748	0.04590	0.06457	0.02922	0.07743	0.02268	0.06714	0.04491	0.05860	0.03636	0.06322	1.06450	0.02405	0.06903	0.03175	0.04539	0.05469	0.02136	0.09599	0.02143
Other Services Activities	0.03258	0.00784	0.01467	0.00390	0.00520	0.01474	0.00633	0.01109	0.00663	0.01656	0.00507	0.00404	0.00253	0.00283	0.00276	0.00478	0.00221	0.00203	0.00299	1.00255	0.00945	0.00443	0.00371	0.01107	0.00343	0.00966	0.00255
Recreation, Culture & Sport	0.00346	0.00355	0.00658	0.00691	0.00394	0.00143	0.00514	0.00322	0.00300	0.00357	0.00455	0.00224	0.00345	0.00258	0.00347	0.00465	0.00196	0.00221	0.00167	0.00202	1.00649	0.00283	0.00267	0.00455	0.00506	0.01920	0.00336
Education	0.00045	0.00046	0.00066	0.00090	0.00051	0.00019	0.00067	0.00042	0.00039	0.00048	0.00059	0.00029	0.00045	0.00034	0.00045	0.00060	0.00025	0.00029	0.00022	0.00026	0.00058	1.00037	0.00035	0.00059	0.00046	0.00250	0.00044
Health, Social Work & Housing	0.00013	0.00013	0.00024	0.00025	0.00015	0.00005	0.00019	0.00012	0.00011	0.00013	0.00017	0.00008	0.00013	0.00010	0.00013	0.00017	0.00007	0.00008	0.00006	0.00007	0.00016	0.00010	1.00010	0.00017	0.00013	0.00071	0.00012
Public Services	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	1.00000	0.00000	0.00000	0.00000
Public Administration & Defence	0.00484	0.00056	0.00253	0.00273	0.00568	0.00209	0.00147	0.00226	0.00128	0.00198	0.00111	0.00034	0.00048	0.00120	0.00070	0.00167	0.00160	0.00093	0.00031	0.00051	0.00325	0.00122	0.00631	0.00333	1.00048	0.00185	0.00041
Imports	0.29276	0.30110	0.55826	0.58591	0.33407	0.12182	0.43581	0.27295	0.25434	0.30295	0.38582	0.19013	0.29316	0.21910	0.29469	0.39422	0.16615	0.18782	0.14172	0.17139	0.37545	0.24040	0.22549	0.38596	0.30054	1.62907	0.28656
Other Value Added	0.75584	0.92181	0.96148	1.16489	0.97074	0.31408	1.04333	0.87974	0.90091	0.91649	1.03350	0.57714	1.24842	0.80942	1.00300	0.99427	0.76924	0.74867	0.80590	0.87965	0.89909	0.46530	0.85448	0.67342	0.42812	2.20435	1.45143
Total - Neo-classical output multipliers	3.2486	3.1661	4.2278	4.2242	3.8337	1.9226	3.8488	3.0717	3.1600	3.2364	3.4808	2.4525	3.3840	2.5078	3.2035	3.4937	2.5316	2.6009	2.3135	2.4017	3.4768	2.4678	2.8849	3.3782	2.4909	7.8513	2.5660

Table 7.18 Emissions Intensities (kg[1]) Of Production To Meet Local Final Consumption And Export Demand, With Endogenised Trade And Capital Formation, In Jersey (1998) - Neo-Classical Output-Pollution Multipliers

Sector / Pollutant	Agriculture & Fishing	Quarrying & Construction	Manufacturing	Electricity	Water	Gas, Oil & Fuel Dist.	Jersey Telecom.	Wholesale & Retail Trade	Hotels, Rest. & Catering	Land Transport	Sea & Air Trans. & Trans Supp	Jersey Post	Banks & Building Soc.	Insurance Companies
Global warming potential (GWP) composite	635887.243	71948.241	218881.860	1370651.766	112113.216	85996.508	73151.220	80988.587	123194.966	108656.357	364723.957	59716.662	33744.616	34400.889
Carbon dioxide (CO2) as carbon	333377.858	66703.309	177033.729	1361415.899	106510.091	83051.909	65544.455	75930.059	109554.548	102864.750	358199.287	56040.482	29040.639	30557.698
Methane (CH4)	14379.376	235.562	1977.319	432.006	258.392	117.992	354.801	231.044	643.136	254.182	303.452	168.960	220.643	179.745
Sulphur dioxide (SO2)	5916.111	225.078	1840.280	9808.830	616.282	133.942	366.840	339.133	670.408	259.721	791.788	230.460	166.977	168.151
Nitrous oxides (NOx)	3015.739	443.390	1591.679	17802.023	1147.683	656.242	623.112	734.243	932.108	786.505	6024.802	572.297	268.654	287.500
Non-methane volatile organic compounds (NMVOC)	421.932	170.273	388.683	447.139	247.094	395.069	214.902	295.440	207.118	572.065	1582.584	157.476	111.515	136.201
Carbon monoxide (CO)	1975.454	768.828	1985.726	2019.362	1336.031	2126.231	1113.547	1626.713	1074.292	3246.207	4974.737	641.326	571.325	753.230
Nitrogen dioxide (N20)	1.750	0.962	1.047	0.528	0.571	1.506	0.503	0.666	0.434	1.464	0.491	0.413	0.227	0.221
Black smoke	40.307	14.086	51.895	1172.352	62.802	9.269	27.090	29.633	35.209	17.250	331.223	26.448	10.232	11.859

Sector / Pollutant	Inv. Trusts & Fund Mgrs	Computer Services	Legal Activities	Accountancy	Other Bus. Activities	Other Service Activities	Recreation, Culture & Sport	Education	Health, Social Work & Housing	Public Services	Public Admin. & Defence	Trade (Exports/Imports)
Global warming potential (GWP) composite	42923.998	65118.458	33303.371	31383.880	35308.439	106574.600	124071.299	63056.255	74752.920	668435.873	43231.625	154108.136
Carbon dioxide (CO2) as carbon	37646.545	58557.902	30135.958	28143.312	32553.868	103003.511	112088.828	59159.773	70411.987	659528.802	38600.673	129330.497
Methane (CH4)	247.322	305.503	147.608	151.578	125.866	149.907	562.596	181.547	202.667	417.276	217.752	1167.538
Sulphur dioxide (SO2)	212.182	275.530	169.467	163.204	135.112	893.214	619.111	278.672	329.732	597.388	205.678	812.420
Nitrous oxides (NOx)	349.613	521.213	285.484	277.652	254.792	658.976	949.333	485.852	589.669	4580.807	350.632	1258.260
Non-methane volatile organic compounds (NMVOC)	167.260	346.760	99.061	99.376	139.854	498.078	223.976	112.987	120.150	10580.254	111.779	556.786
Carbon monoxide (CO)	911.852	2015.854	527.907	533.162	777.104	2847.805	1139.017	552.813	578.756	42753.533	565.780	2890.476
Nitrogen dioxide (N20)	0.270	0.468	0.218	0.185	0.359	1.365	0.542	0.271	0.274	0.465	0.188	0.837
Black smoke	13.571	20.021	12.963	12.620	9.887	15.959	40.293	20.104	26.073	55.041	14.988	47.689

Notes:

1. The GWP (Global Warming Potential) index is a weighted sum of CO2 (weight 1), methane (weight 21) and N_2O (weight 310): it therefore should not be read as 'kilograms' but simply as an index that is comparable across sectors within an economy and across different economies

Figure 7.13 GWP Intensity Of Production To Meet Local Final Consumption And Export Demand, With Endogenised Trade And Capital Formation, In Jersey (1998) - Neo-Classical Output-Pollution Multipliers

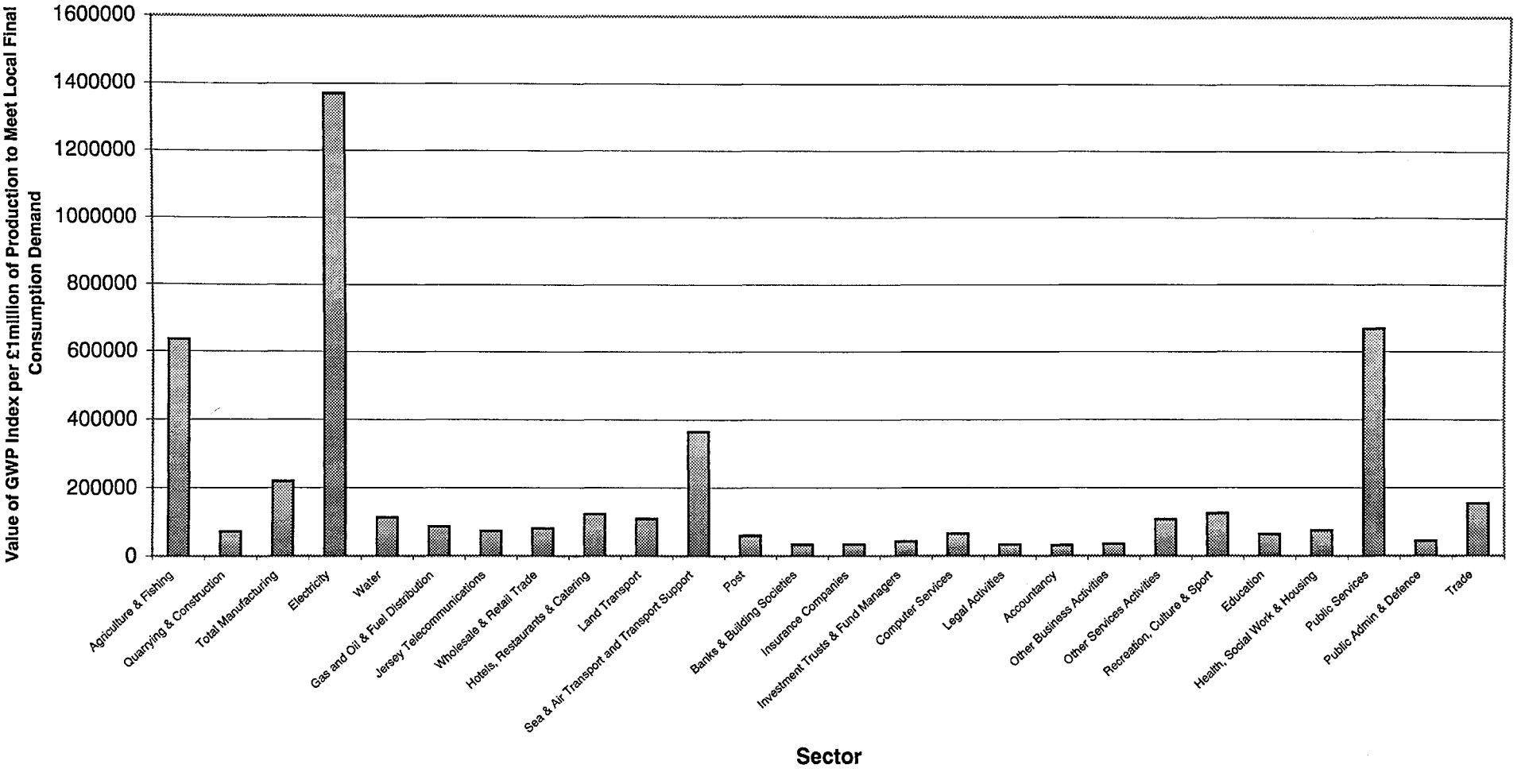
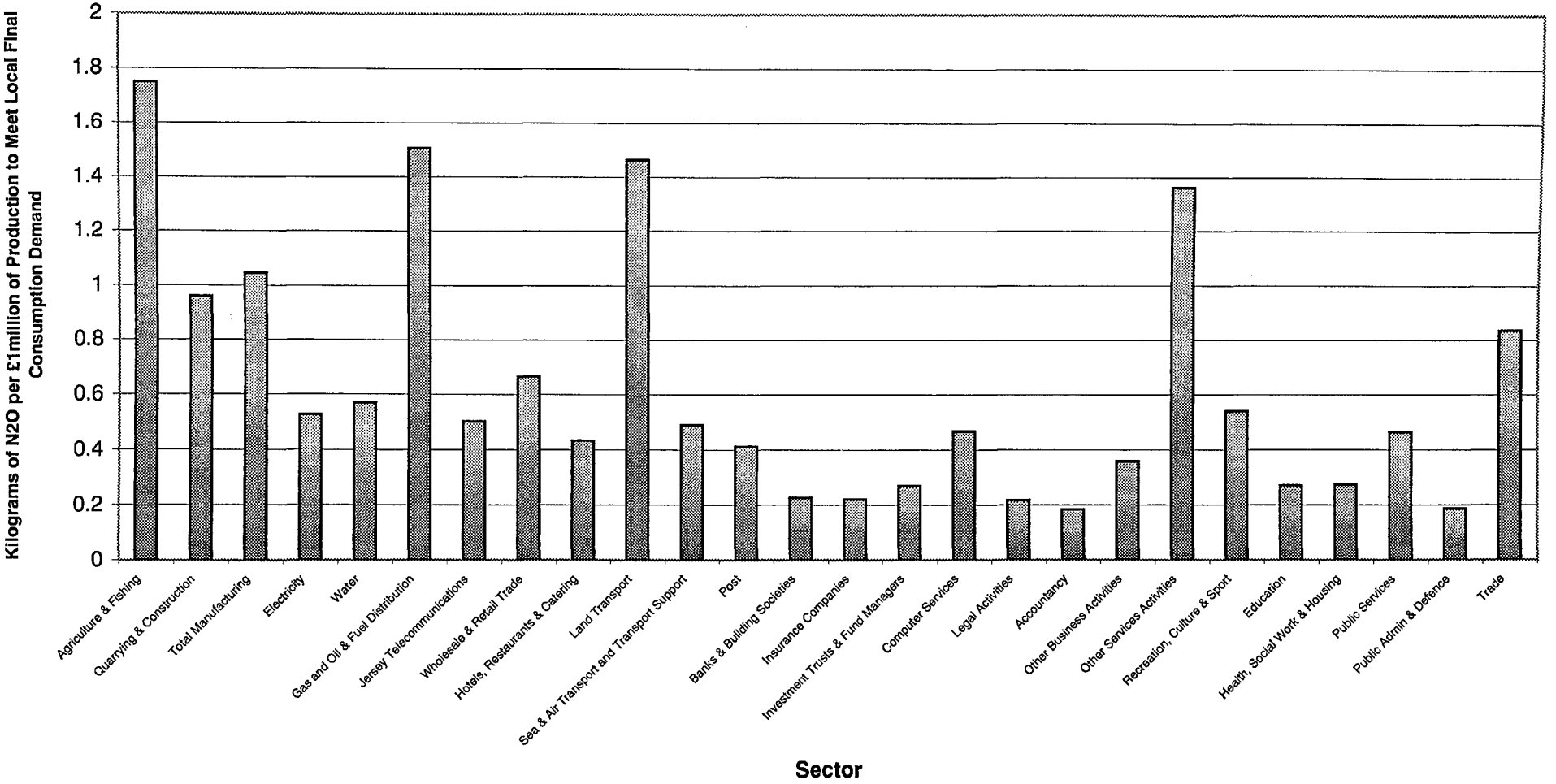


Figure 7.14 N2O Intensity Of Production To Meet Local Final Consumption And Export Demand, With Endogenised Trade And Capital Formation, In Jersey (1998) - Neo-Classical Output-Pollution Multipliers



Note that in the NCLAS analysis I have z = 6 local final demand sectors: five household groups and government final consumption (GGFC). I determine the (kx1) vector $\mathbf{p}_{zN}$ of total emissions attributable to each by calculating (7.23) for each local final demand sector, z, i.e.

(7.24) $\mathbf{p}_{zN} = \mathbf{N}(\mathbf{C}_i)_z + \mathbf{m}_z\mathbf{C}_z$

Because government final consumption (GGFC) is not responsible for any direct emissions generation (in the Jersey IO table the public sector only consumes directly polluting inputs during production activities) the second element on the right-hand side of (7.23) drops out for public consumption.

I calculate the neo-classical final demand pollution multipliers in the same way as described in Section 3.4 for the Leontief ones: that is, the share of emissions attributable to each sector, z, divided by total direct final demand expenditure by that sector ($\mathbf{p}_{zN}/\mathbf{C}_z$). I report the neo-classical pollution multipliers below in Table 7.19.

Next, I report the results of the NCLAS attribution to local (exogenous) final consumption demand in absolute terms (kilograms) in Table 7.20 and in percentage terms in Table 7.21. I also illustrate the results for the GWP index and N_2O graphically in Figures 7.15 and 7.17, with the corresponding final demand multipliers shown in Figures 7.16 and 7.18, respectively. The key point is that now I have all emissions in the Jersey economy attributed to local (public and private) final demand groups, over whose consumption choices Jersey has some influence.

Note that in both cases (and this is true across all the pollutants identified here) that most emissions generation is attributable to private final (household) consumption (the minimum share to households is 87% in the case of NMVOC). Moreover, private consumption is without exception more pollution intensive than public consumption. It is also the case that the share attributable to each household group rises with income, while the opposite is generally true of the emissions intensity of one unit of household expenditure.

Table 7.19 Emissions Intensities (kg[1]) Per £1million Local Final Consumption Expenditure in Jersey (1998), With Endogenised Trade and Capital Formation - Neo-Classical Final Demand Expenditure-Pollution Multipliers

Final Demand Sector / Pollutant	Household Consumption 1	Household Consumption 2	Household Consumption 3	Household Consumption 4	Household Consumption 5	Jersey GGFC
Global warming potential (GWP) composite	294269.975	308966.181	281264.739	254576.006	248818.409	146511.737
Carbon dioxide (CO2) as carbon	271642.099	288002.845	261802.793	236986.761	231418.957	141412.088
Methane (CH4)	1053.487	967.276	898.592	811.276	804.793	238.658
Sulphur dioxide (SO2)	1216.451	1047.180	1036.752	844.261	767.825	331.104
Nitrous oxides (NOx)	2197.969	2180.038	2032.867	1787.288	1712.456	1060.963
Non-methane volatile organic compounds (NMVOC)	1808.960	2424.972	2214.386	2006.960	1731.186	1544.245
Carbon monoxide (CO)	10243.363	13968.817	12640.913	11523.817	9910.059	6329.205
Nitrogen dioxide (N20)	1.628	2.099	1.908	1.782	1.609	0.283
Black smoke	87.175	74.884	70.595	59.154	56.516	26.378

Notes:

1. The GWP (Global Warming Potential) Index is a weighted sum of CO2 (weight 1), methane (weight 21) and N_2O (weight 310): it therefore should not be read as 'kilograms' but simply as an index that is comparable across sectors within an economy and across different economies.

Table 7.20 Total Emissions (kg[1]) Attributable To Local Final Consumption Demand In Jersey (1998)

(In The NCLAS System, With Endogenous Trade And Capital Formation)

Final Demand Sector / Pollutant	Household Consumption 1	Household Consumption 2	Household Consumption 3	Household Consumption 4	Household Consumption 5	Jersey GGFC	Total Emissions (kg) Attributable to Local Final Consumption
Global warming potential (GWP) composite	23531240	43385252	54186717	67715006	94593707	28439043	311850966
Carbon dioxide (CO2) as carbon	21721806	40441565	50437300	63036420	87978928	27449163	291065182
Methane (CH4)	84242	135826	173117	215792	305959	46325	961262
Sulphur dioxide (SO2)	97273	147046	199734	224566	291905	64270	1024795
Nitrous oxides (NOx)	175760	306122	391640	475403	651027	205941	2205893
Non-methane volatile organic compounds (NMVOC)	144653	340516	426610	533834	658148	299750	2403511
Carbon monoxide (CO)	819109	1961511	2435320	3065235	3767524	1228547	13277245
Nitrogen dioxide (N20)	130	295	368	474	612	55	1933
Black smoke	6971	10515	13600	15735	21486	5120	73427

Notes:

1. The GWP (Global Warming Potential) index is a weighted sum of CO2 (weight 1), methane (weight 21) and N_2O (weight 310): it therefore should not be read as 'kilograms' but simply as an index that is comparable across sectors within an economy and across different economies.

Table 7.21 Percentage Share Of Total Emissions Attributable to Local Final Consumption Demand In Jersey (1998)

(In The NCLAS System, With Endogenous Trade And Capital Formation)

Final Demand Sector / Pollutant	Household Consumption 1	Household Consumption 2	Household Consumption 3	Household Consumption 4	Household Consumption 5	Jersey GGFC	Total
Global warming potential (GWP) composite	7.55	13.91	17.38	21.71	30.33	9.12	100
Carbon dioxide (CO2) as carbon	7.46	13.89	17.33	21.66	30.23	9.43	100
Methane (CH4)	8.76	14.13	18.01	22.45	31.83	4.82	100
Sulphur dioxide (SO2)	9.49	14.35	19.49	21.91	28.48	6.27	100
Nitrous oxides (NOx)	7.97	13.88	17.75	21.55	29.51	9.34	100
Non-methane volatile organic compounds (NMVOC)	6.02	14.17	17.75	22.21	27.38	12.47	100
Carbon monoxide (CO)	6.17	14.77	18.34	23.09	28.38	9.25	100
Nitrogen dioxide (N20)	6.73	15.24	19.02	24.52	31.64	2.84	100
Black smoke	9.49	14.32	18.52	21.43	29.26	6.97	100

Figure 7.15 Attribution of The GWP Index For Jersey (1998) To Local Final Consumption Demand In The Neo-Classical Linear Attribution System (With Endogenous Trade and Capital Formation)

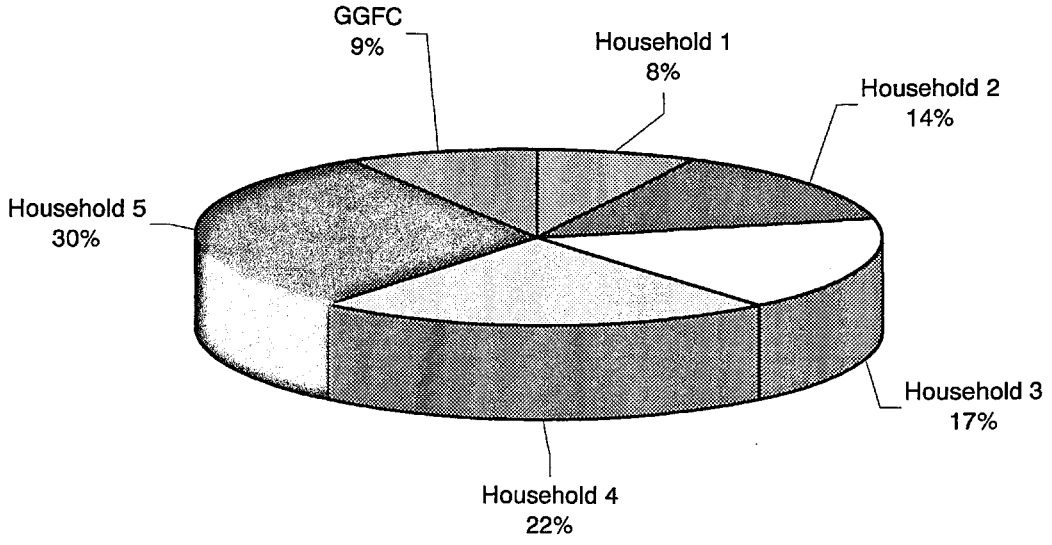


Figure 7.16 GWP Intensities Of Jersey Local Final Consumption (1998), With Endogenised Trade and Capital Formation - Neo-Classical Final Demand Expenditure-Pollution Multipliers

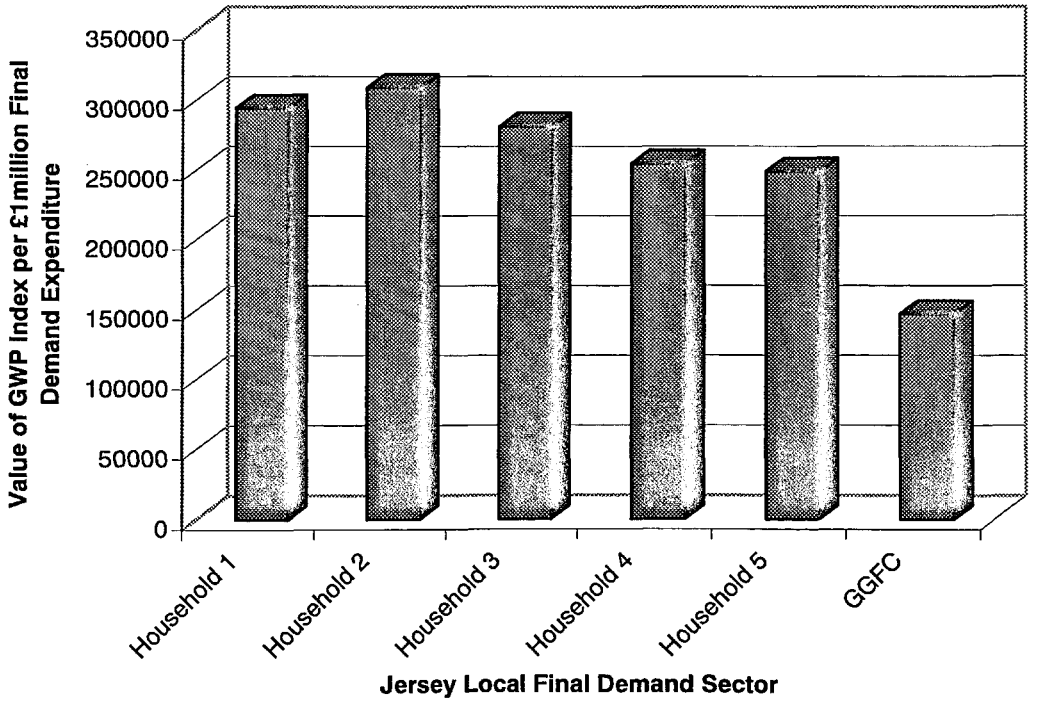


Figure 7.17 Attribution Of Total N2O Emissions Generated In Jersey (1998) To Local Final Consumption Demand In The Neo-Classical Linear Attribution System (With Endogenous Trade and Capital Formation)

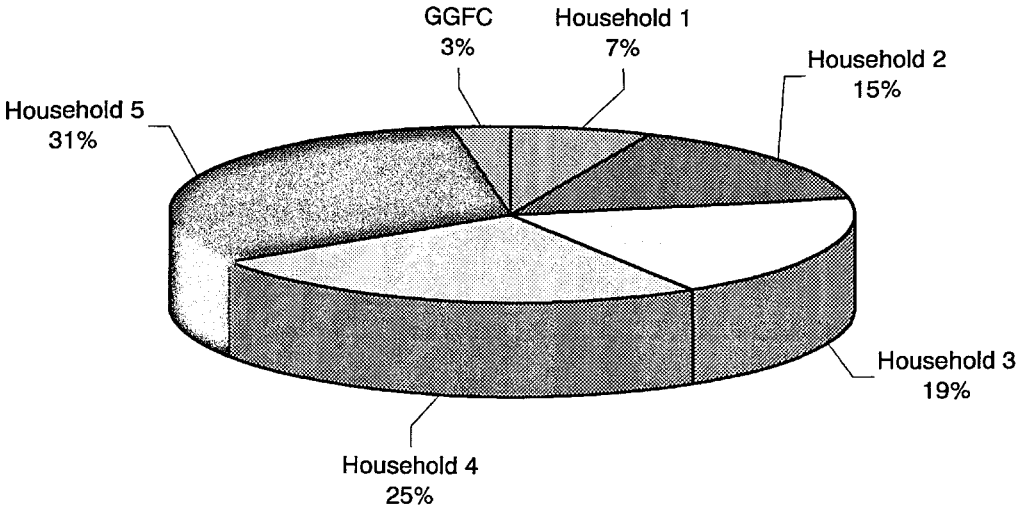
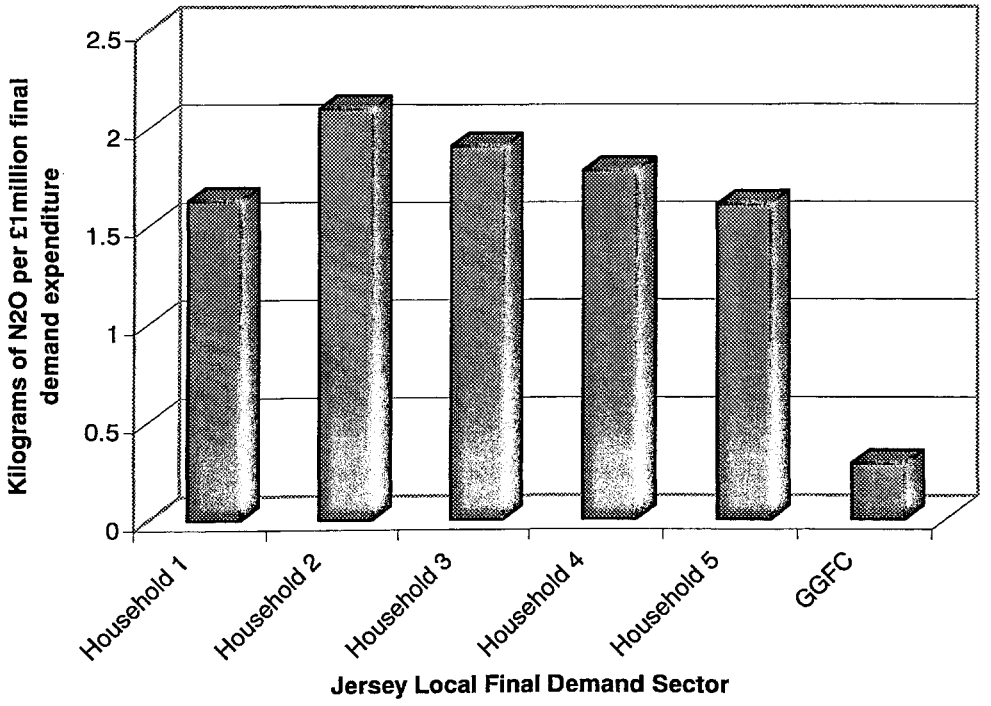


Figure 7.18 N2O Intensities Of Jersey Local Final Consumption (1998), With Endogenised Trade and Capital Formation - Neo-Classical Final Demand Expenditure-Pollution Multipliers



For example, in the case of the GWP index, 91% of emissions are attributable to household consumption, and the shares attributable to the individual household sectors rises with income. Note also that over 50% of total GWP emissions are attributable to the top two household income bands. (Indeed, across all pollutants it is the case that over 50% of total emissions and total household emissions are attributable to households in the top 40% income bracket.) This is despite the fact that, as shown in Figure 7.16, the GWP-intensity of household expenditure tends to be higher in the low-income bands. This is due to the point made in Section 3.4.1 about the importance of the *scale* of total expenditure in the high relative to the low income bands.

I report a similar picture for the individual pollutant N_2O in Figure 7.17. In the Jersey environmental IO accounting system constructed here emissions of N_2O are solely related to automotive fuel use. Almost all emissions, 97%, of this pollutant are attributable to households, the bulk of this (63%) being direct emissions from households' own automotive fuel use. Again, I find that the contribution of households rises with income, with the top two income groups being responsible for 58% of household emissions and 56% of total emissions. However, in Figure 7.18 we can see that the N_2O intensity of household expenditure tends to fall with income, although the picture is slightly different here with the lowest income band sharing a relatively low N_2O intensity with the highest income band. This is the same pattern as is observed in the case of the direct emissions intensities (Table 6.15) and the Type I final demand multipliers (Table 7.10 and Figure 7.6) and is fairly similar to what is found for carbon monoxide (CO). The point is that both N_2O and CO are mainly related to automotive fuel use, which tends to account for a lower share of each unit of household expenditure in the lowest and highest income bands.

Generally however, the neo-classical final demand multipliers in Table 7.19 show that the emissions intensity of household expenditure in Jersey is negatively related to income. This is consistent with the fact that energy use, particularly for heating and lighting purposes (heating oils and electricity use), per unit of expenditure tends to fall as income rises. However, given that total energy use tends to rise with income

in Jersey (see Table 6.1 of Chapter 6), this would suggest that anything like a tax on energy use intended to reduce emissions generation is likely to be regressive. However, it is important to note that this is only suggestive of the likely *direct* impact of an energy tax. General equilibrium analysis would be necessary to determine the full impact of any kind of energy tax on different types of household. In Chapter 4 (Section 6.3) I discuss the findings of three CGE studies of the distributional impacts of energy taxation - Boyd & Uri (1991), Stephan *et al* (1992) and Naqvi (1998). These studies found that, while the direct impact of energy taxes may be regressive, this is not necessarily the case in terms of the total impact. Weise *et al* (1995) report that a crucial factor in determining the distributional impact of energy taxation is how the resulting revenues are redistributed/spent by government.

4. Chapter Summary And Conclusions

In this chapter I present results generated using the environmental IO accounts constructed in Chapters 5 and 6 for the Jersey economy in 1998. My analysis combines detailed economic and environmental information to explore the size and nature of environmental problems in a small open economy. The results in this chapter illustrate the power of IO as a data source and as a flexible and rigorous organisational framework for environmental accounting. In terms of the specific empirical example presented here, as far as I am aware, my analysis is unique in the UK in that both the IO table and the pollution coefficients are constructed from up-to-date, region-specific data.

Moreover, the results of the accounting work that I present in this chapter are innovative in that I do not rely on the standard Keynesian theoretical underpinning normally associated with IO. That is to say, I propose that this form of pollution attribution is consistent with the existence of resource constraints and production non-linearity. Furthermore, I make an attempt to place local public and private consumption centre stage through the development of a neo-classical (trade-endogenous) attribution system. I do, however, highlight the fact that significant value-added might well be gained by extending this environmental accounting work

in a SAM context. This would permit a more sophisticated endogenisation of final demand sectors. It would also allow an empirical investigation of the attribution concepts, Gross National Pollution and Gross Domestic Pollution, that I suggest in Section 2.2.2 of this chapter.

However, it is important to stress that no matter how sophisticated attribution accounts are made, average attribution should not be confusion with marginal attribution or accounting confused with modelling. For example, it is appropriate to use the IO environmental accounts to say that in 1998 on average £100 million of Jersey consumption generated x tonnes of CO_2. However, it would be inappropriate to use the accounts to speculate about the additional pollution that would be generated in Jersey by additional consumption, unless very restrictive, and unrealistic, assumptions are made about the nature of the Jersey economy. Moreover, simply because a sector is a major polluter does not mean that it would be most cost-effective target for pollution reduction: any policy initiative is likely to result in endogenous price changes that cannot be predicted in an accounting framework. These issues require modelling, not accounting.

At the start of this chapter I discuss the possibility of using the environmental IO system for modelling applications. However, as I note above, this would involve making very restrictive and unrealistic assumptions about the nature of the Jersey economy. One problem is the presence of supply constraints, particularly in the Jersey labour market. In Appendix 7A I do make an attempt to limit the repercussions of having to make the assumption of infinitely elastic supply in an IO modelling application by looking at a combination of demand shocks where it is possible to impose a labour supply constraint. I do this by introducing two demand disturbances, where one is designed to offset the total employment effect of the other. However this is at best an *ad hoc* adjustment. A second problem is that in the IO framework quantities are modelled independently of prices, with the implication that the effects of any endogenous changes in prices in response to a given disturbance are ignored.

Therefore, the argument motivating the rest of my thesis is that a more flexible general equilibrium framework allows incorporation of more realistic supply- and demand-side behaviour. Fortunately, the environmental I-O accounts as I have developed them here serve as an ideal database for constructing such a model, and it is to this that I now turn my attention. In Chapter 8 I discuss the construction of a more flexible economy-environment CGE modelling framework of the Jersey economy. Then in Chapter 9 some illustrative simulations using this framework are presented.

Chapter 8. A Multi-Sectoral Economic-Environmental CGE Modelling Framework for Jersey (JEMENVI)

1. Introduction

In Chapters 6 and 7 I construct an environmental IO system for Jersey, using the basic Leontief methodology adopted by most of the environmental IO models reviewed in Chapter 3. Such a method involves my generalising the standard IO economic framework to take account of physical energy use and pollution generation that accompanies the production or consumption of economic commodities. In constructing the Jersey environmental IO system I focus on identifying Jersey-specific environmental coefficients, including direct emissions intensities for eight individual and one composite pollutants and physical energy use intensities for eight individual fuel types. The other main development of Chapter 7 is the inclusion of environmental coefficients for the two final demand groups that are responsible for direct energy use and pollution generation in Jersey, households and tourists, with households disaggregated by income band. I further develop the Jersey environmental IO system through the introduction of the neo-classical linear attribution system (NCLAS), which identifies local consumption as the driver of all pollution generation in the system.

However, I argue that environmental IO analysis for Jersey should be limited to the type of base year accounting application presented in Chapter 7. This is because of the problems associated with using conventional IO *modelling* techniques in conditions where the supply-side response of the economy is likely to be important. In the case of Jersey, where the labour market is known to be subject to supply constraints, these problems will be particularly relevant. I first introduce the problems associated with conventional IO modelling at the end of Chapter 3. Consequently, in Chapter 4 I go on to look at applications of more flexible computable general equilibrium (CGE) approaches to economic-environmental modelling. A CGE approach allows construction of a richer, more theory-consistent

model, while retaining the multi-sectoral, data-driven focus that has made IO such a popular choice for economic-environmental analysis.

The current chapter leads on from the discussion of economic-environmental CGE applications in Chapter 4, with a discussion of the CGE modelling framework that I apply to the Jersey economy in Chapter 9. My work on developing an economic-environmental framework for Jersey is part of a wider modelling project at the Fraser of Allander Institute. Over the last decade the Fraser of Allander Institute has developed the AMOS CGE modelling framework. This framework has usually been parameterised on Scottish data but it is suitable for application to other small open regional economies. The wider Jersey modelling project centres on applying the AMOS framework to the case of Jersey. My objective is to adapt the AMOS framework in such a way as to allow development of an economic-environmental model of Jersey that fully exploits the unique local database that is developed in Chapters 5 and 6 of this dissertation. In particular, I develop the existing environmental component of a multi-sectoral variant of AMOS to incorporate the environmental (energy use and pollution generation) coefficients that I derive from the Jersey economic-environmental accounts in Chapter 6 (Section 4).

Therefore, my objective in this chapter is to explain how the generic AMOS CGE modelling framework is developed to incorporate endogenous environmental variables, and how this framework is applied to the Jersey case to construct an economic-environmental model for Jersey (JEMENVI). The general approach is illustrated by a condensed version of the generic AMOS framework, set out in Table 8.1. Note that in this condensed version of the model structure intermediate demands, taxes, income transfers and the participation rate have been suppressed for pedagogic reasons (see notes to Table 8.1). However, these simplifications are limited to the listing in Table 8.1 and do not apply to the model itself.

In the text I expand on Table 8.1 (see below – Section 2.1) in a more detailed discussion of the generic model structure. In Section 2 I outline the basic AMOS framework. Then, in Section 3, I introduce the *n*-sector variant of AMOS that is most

suitable for environmental applications, and explain the application of this framework to the case of Jersey, with the introduction of the JEMENVI. Finally, I provide chapter summary and conclusions in Section 4.

2. AMOS (A Macro-Micro Model Of Scotland)

2.1 Model Structure

The AMOS framework is introduced in Harrigan *et al* (1991). AMOS was initially parameterised on 1989 data for the Scottish economy[1]. Harrigan *et al* (1991, p.424) explain that AMOS is regarded as a modelling *framework* "because it encompasses a range of behavioural assumptions, reflected in equations which can be activated and configured in many different ways". Therefore it transcends any single perspective of the operation of markets in the economy. AMOS incorporates a wide range of behavioural options, allowing the modeller to choose from a variety of model closure and key parameter values as appropriate for particular applications. Thus, it is also a framework that can be applied to any small open regional economy for which corresponding data are available. The essential data requirements for application of the AMOS framework are:

1. A set of structural parameters, generally given by the social accounting matrix (SAM) for the target economy in the chosen base year – e.g. the capital intensity of production in individual sectors.
2. A set of behavioural parameters based on econometric estimates or informed judgement – e.g. the elasticities of substitution among inputs to production
3. A final set of model parameters that are calibrated on the initial equilibrium conditions –e.g. the constant in the migration function (equation (8.24) below in Section 2.1.3).

[1] As part of the more general work undertaken alongside the present study, I have been responsible for updating the SAM database for Scottish applications of the AMOS framework. One result of this is a 1994 version of the basic 3-sector variant of AMOS.

Table 8.1. A Condensed Version Of The Generic AMOS CGE Model

Economic Equations	Short-run
(8.1) Commodity price	$p_i = p_i(w_n, w_{ki})$
(8.2) Wage setting	$w_n = w_n\,(N/L, cpi)$
(8.3) Labour force	$L = \bar{L}$
(8.4) Consumer price index	$\mathbf{cpi} = \sum_i \theta_i\ \mathbf{p_i} + \sum_i \theta_i^{RUK-RUK}\ \mathbf{p_i} + \sum_i \theta_i^{ROW-ROW}\ \mathbf{p_i}$
(8.5) Capital supply	$K_i^S = \bar{K}_i^S$
(8.6) Capital price index	$\mathbf{kpi} = \sum_i \gamma_i\ \mathbf{p_i} + \sum_i \gamma_i^{RUK-RUK}\ \mathbf{p_i} + \sum_i \gamma_i^{ROW-ROW}\ \mathbf{p_i}$
(8.7) Labour demand	$N_i^d = N_i^d(Q_i, w_n, w_{ki})$
(8.8) Capital demand	$K_i^d = K_i^d(Q_i, w_n, w_{ki})$
(8.9) Total labour demand	$\sum_i N_i^d = N$
(8.10) Capital market clearing	$K_i^S = K_i^d$
(8.11) Household income	$Y = \Psi_n N w_n + \Psi_k \sum_i K_i w_{ki}$
(8.12) Commodity demand	$Q_i = C_i + I_i + G_I + X_I$
(8.13) Consumption demand	$C_i = C_i(p_i, \bar{p}_i^{RUK}, \bar{p}_i^{ROW}, Y, cpi)$
(8.14) User cost of capital	$uck = uck(kpi)$

Economic equations (cont..)	
(8.15) Desired capital stock	$K_I^* = K_i^d(Q_I, w_n, uck)$
(8.16) Investment demand	$I_i = I_i(p_i, \bar{p}_i^{RUK}, \bar{p}_i^{ROW}, \sum_i b_{ij} I_j^d)$ $I_j^d = \lambda_j(K_j^* - K_j)$
(8.17) Government demand	$G_I = \bar{G}_I$
(8.18) Export demand	$X_i = X_i(p_i, \bar{p}_i^{RUK}, \bar{p}_i^{ROW}, \bar{D}^{RUK}, \bar{D}^{ROW})$
Multi-period model	**Stock up-dating equations**
(8.19) Labour force	$L_t = L_{t-1} + nmg_{t-1}$
(8.20) Migration	$\frac{nmg}{L} = nmg\ (w_n/cpi, w_n^{RUK}/cpi^{RUK}, N/L, N^{RUK}/L^{RUK})$
(8.21) Capital stock	$K_{it} = (1 - d_i)\ K_{it-1} + I_{it-1}^d$

Environmental equations	**Short-run**
(8.22) Pollutants	$POL_k = \sum_i m_{ik} Q_i + \sum_i m_{zk} C_z$
(8.23) Physical energy use	$FUEL_l = \sum_l \varepsilon_{il} Q_i + \sum_i \varepsilon_{zl} C_z$

NOTATION

Activity-Commodities

i, j are activity/commodity subscripts. (There are twenty-five of each in JEMENVI: see Appendix 8A.)

Transactors

RUK = Rest of the UK, ROW = Rest of World

Functions

nmg(.)	net migration function
p (.)	cost function
uck(.)	user cost of capital formulation
w(.)	wage-setting equations
$K^d(.)$, $N^d(.)$	factor demand functions
C(.), I(.), X(.)	Armington consumption, investment and export demand functions, homogenous of degree zero in prices and one in quantities

Variables

C	consumption
D	exogenous export demand
G	government demand for local goods
I	investment demand for local goods
I^d	investment demand by activity
K^d, K^S, K	capital demand, capital supply and capital employment
L	labour force
N^d, N	labour demand, and total employment
Q	commodity/activity output
X	exports
Y	household nominal income
b	elements of capital matrix
cpi, kpi	consumer and capital price indices
d	physical depreciation

nmg	net migration
p	price of commodity/activity output
uck	user cost of capital
w_n, w_k	wage, capital rental
Ψ	share of factor income retained in region
θ	consumption weights
γ	capital weights
λ	capital stock adjustment parameter
$\mathbf{POL_k}$	quantity of pollutant k
$\mathbf{m_{ik}}$	output-pollution coefficients
$\mathbf{m_{zk}}$	(final demand) expenditure-pollution coefficients
$\mathbf{FUEL_l}$	quantitity of energy/fuel type l
ε_{il}	output-energy use coefficients
ε_{zl}	(final demand) expenditure-energy use coefficients

Note (*): To report this condensed version of JEMENVI, I make two main simplifications:

1. Intermediate demand is suppressed throughout (e.g. only primary factor demands are noted in price determination in equation (1) and final demands in the determination of commodity demand in equation (12).
2. Income transfers are generally suppressed.
3. Taxes are ignored.
4. The participation rate is ignored.
5. The wage setting function (8.2) and the migration function (8.20) are expressed in terms of the employment rate rather than the unemployment rate.

All of these simplifications are limited to the model listing – i.e. they do not apply to the model itself.

The initial (Harrigan *et al* 1991) version of the AMOS is a single region static modelling framework[2]. The single time period can be interpreted as applying to different conceptual time periods (short, medium and long run) depending on what assumptions are made about the capital and labour markets. However, an important additional feature is introduced in applications such as McGregor and Swales (1994), McGregor *et al* (1996), where the process of adjustment to long-run equilibrium is analysed using a multi-period recursive dynamic approach. This means that the path of adjustment of the economy in response to any disturbance can be tracked through a series of short-run equilibria. A full description of the initial (static) AMOS framework and listing of the model equations is given in Harrigan *et al* (1991). Here I give a brief summary of the key features of the basic framework, including the multi-period variant.

2.1.1 Overview

The initial AMOS framework incorporates:

- 3 transactor groups – households, firms and government[3]
- 3 commodities and activities – manufacturing (M), non-manufacturing traded (NMT), and non-traded/sheltered (NT)[4]
- 2 exogenous external transactors – for the case of Scotland (or any UK region), these are the rest of the UK (RUK) and the rest of the world (ROW)

There are four main components of final demand (represented by equation (8.12) in the condensed version of the model in Table 8.1):

[2] A two–region variant of the AMOS framework has also been developed, calibrated on Scottish and UK data. See Gillespie *et al*, (2000a, 2001).
[3] AMOS does not distinguish between central and local government in the UK (i.e. there is only one consolidated government sector).

1. (Household) consumption, which is a linear homogenous function of real disposable income (Equation (8.13)).

2. Investment is treated in various ways, dependent upon the particular model closure that is chosen. In the short- and medium-run the capital stock and its sectoral composition are fixed so that, even where investment is endogenous, capital stocks are not updated[5]. In long-run equilibrium investment for each sector is endogenous and equal to depreciation with sectoral capital stocks set at their desired, cost-minimising levels. (Equation (8.15) (In the multi-period variant of the model, investment in each period is equal to depreciation plus some fraction of the gap between actual and desired capital stock – see Section 2.1.3 below.)

3. Government expenditure, which is taken to be exogenous (Equation (8.17)).

4. Exports, where exports and imports are determined via an Armington link, making them relative price sensitive (equation (8.18)). The Armington trade substitution elasticity determined by the model user (or informed by econometric work).

Harrigan *et al* (1991, p.425) explain that the primary motivation in developing the AMOS framework "was to extend the range of market processes and spatial economic interaction commonly admitted by regional economic models". This is reflected in the option to model commodity markets as being either perfectly competitive (where price is equated to marginal cost) or imperfectly competitive (where prices are marked up over marginal cost in a multi-sectoral generalisation of a Layard and Nickell (1986) type model[6]).

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[4] In the initial (Harrigan *et al*, 1989) 3-sector model, the non-traded sector incorporates (mainly public sector, construction and utility) activities where trade is treated as being fixed. In later versions of the model this sector is treated as 'sheltered' where trade is not fixed, but is small relative to other sectors.
[5] There is also an option that keeps the total capital stock constant but allows sectoral mobility.
[6] This variant of the AMOS framework also admits increasing returns technology, subject to second order conditions being satisfied for profit maximisation.

As I explain below, a range of labour market options are also encompassed in the AMOS framework, with continuous market clearing at one extreme, but with various forms of non-market clearing captured in the alternative labour market closures.

In terms of spatial economic interaction, while the (initial) AMOS is a single region modelling framework, in which all extra-regional variables are exogenous, it nevertheless offers a variety of views of the operation of the spatial economy. Firstly, the local labour market is linked to other UK regions through a migration relationship (see equation (8.20) and Section 2.1.3 below). Secondly, the commodity market options allow close international and interregional trade, giving a good approximation to the standard 'small open economy' assumption of international trade theory. However, at the other extreme, an appropriate choice of functional form and/or parameter values will result in a model in which regional goods prices are effectively determined independently of international prices. In addition, AMOS also provides the opportunity to impose constraints on the regional balance of payments and on public sector net transfers to the region.

2.1.2 Production Structure

In all model configurations cost-minimisation in production is imposed, with multi-level production functions, generally of constant elasticity of substitution (CES) form, so there can be input substitution in response to relative price changes, but with Leontief and Cobb-Douglas (CD) available as special cases. In the CES functions, elasticities of substitution, σ, as with all parameter values, can be set for individual applications according to econometric or 'best guess' estimates. The production inputs are labour (L), capital (K) and intermediates (J), with a choice between locally produced intermediate commodities and imports from RUK or ROW.

Intermediate purchases of locally produced goods and services in the base year (long-run) equilibrium are determined by the industry-by-industry block of the IO table (the upper left quadrant of Table 5.3 in Chapter 5) and are substitutable for

imported commodities via an Armington link. The composite input then combines with value-added (capital and labour) in the production of each sector's gross output.

Figure 8.1 – Production Structure In The Basic (3-sector) AMOS Framework

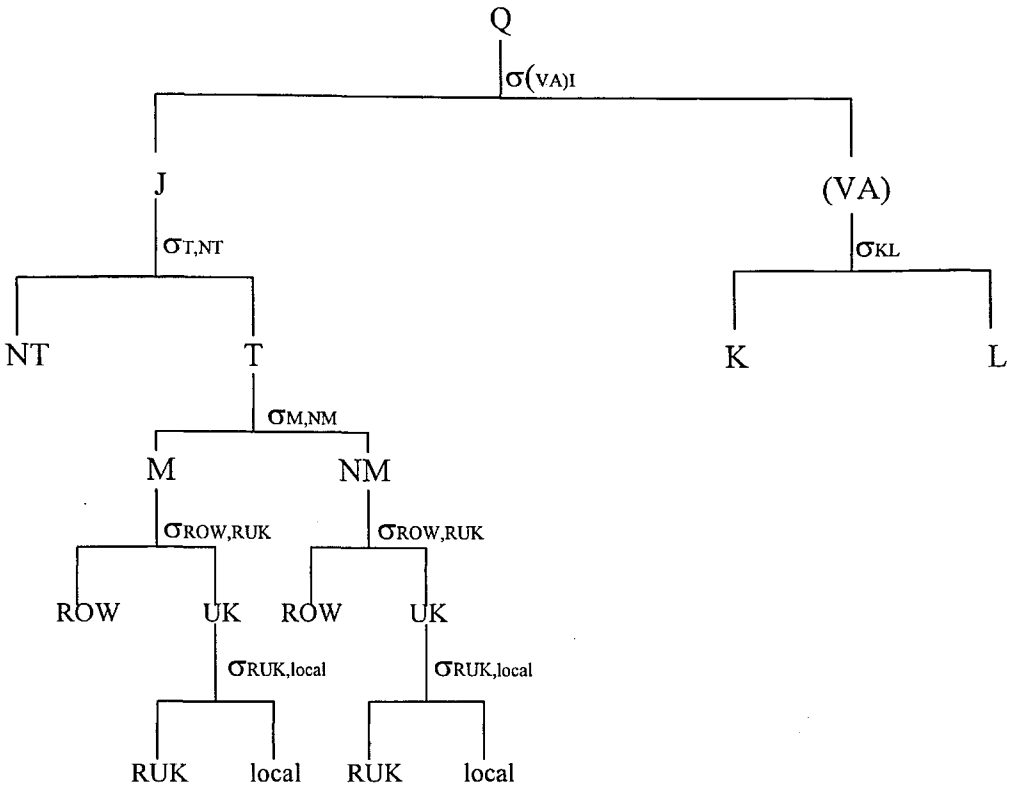


Figure 8.1 gives the output structure and corresponding basis for prices. However, note that in the condensed version of the model in Table 8.1 only value-added and value-added prices are treated explicitly. However, the prices of the intermediate goods that make up the intermediate composite are required. All local input prices are endogenous to the system, while all import prices are exogenous. The precise nature of the intermediate composite, J, depends on relative prices and the possibilities for substitution between different sources and types of intermediate input at each level. The dual of the production relationships in Figure 8.1 are cost functions. For example the price of value-added is determined by the rental rates of capital and labour (equation (8.1)). Gross output and the intermediate composite prices are determined in the same way, though this is suppressed in the condensed version of the model presented in Table 8.1.

The precise form of the wage equation (equation (8.2)) depends on what type of labour market regime is assumed to exist. One of the key features of the AMOS framework is that it incorporates five alternative labour market closures. The specification of the wage equation in each is fairly standard:

1. Neo-classical/continuous market clearing. Here the wage adjusts so as to equate labour demand and labour supply.
2. Keynesian. The nominal wage is exogenously determined at the regional level. The motivation for this would generally be a national bargaining regime. The aggregate labour supply function is suspended up to full employment.
3. Real wage resistance. The real wage is fixed - i.e. the nominal wage is a mark up on the consumer price index.
4. Regional Phillips curve. Nominal wages are related to consumer price index and responsive to unemployment (the AMOS default values for this closure are informed by econometric work on Scottish data).
5. Exogenous labour supply. A fixed proportional relationship exists between employment and working population (this is often taken to be the closure for national CGE models, and, as I explain in Section 4.1 below, is what I assume for the default configuration of the Jersey model).
6. Regional wage bargaining (also referred to as the bargained real wage, BRW, closure). The regional consumption wage is directly related to workers' bargaining power and inversely related to the regional unemployment rate via a bargained real wage function. Note that this closure does imply that local wages are flexible in that they respond to the local excess demand for labour.

Option (6), the regional wage bargaining option was not available in the initial (Harrigan *et al* 1991) version of AMOS. However, in recent years empirical support has grown for the notion of regional wages being determined in this way. In the AMOS framework the specification of the bargaining function is based on the (UK) regional econometric work reported by Layard, Nickell and Jackman (LNJ 1991).

This option is commonly selected for applications of the AMOS framework to the Scottish economy (see, for example, Gillespie *et al* (2000b)).

2.1.3 Capital Stocks And Population Adjustment

Under all closures, the labour market is characterised by perfect sectoral labour mobility and the labour force adjusts through migration. In the static version of the model there is no migration in the short run, with population, like the capital stock being fixed (equations (8.3) and (8.5)). In the medium to long run migration is possible (equation (8.20)). In the medium run there is full adjustment of the population so that the zero net migration condition is reinstated. However, the capital stock remains fixed. In the long run both the population and the capital stock are fully adjusted so that the system exhibits zero net migration and capital stocks are at their desired levels (equation (8.15)).

The adjustment process to long-run equilibrium is captured in the multi-period variant of the model. There are various options in the model for how migration occurs in the AMOS framework. The most commonly applied option uses the net migration flows in any period to update population stocks at the beginning of the next period (equations (8.19) and (8.20)). The regional economy is initially assumed to have zero net migration (as in the short-run in the static model), and ultimately, net migration flows re-establish this (long-run) population equilibrium. Net in-migration in any one period is taken to be positively related to the regional real wage differential in the target region relative to the national economy and negatively related to the regional unemployment rate differential in accordance with the econometrically estimated model reported in LNJ (1991).

(8.24) $\mathbf{m = \beta - 0.08(u_s - u_r) + 0.06(w_s - w_r)}$

where:

m = the net in-migration rate (as a proportion of the indigenous population)

w_x and u_x = the natural logarithms of the real consumption wage and unemployment rates in Scotland (s) and RUK (r)

β = a calibrated parameter (i.e. the value of β is determined when the model is calibrated to the base year dataset to meet the requirement of zero net migration in long-run equilibrium)

This migration model is based on that in Harris and Todaro (1970), and is commonly employed in studies of US migration (e.g. Greenwood *et al*, 1991; Treyz *et al*, 1993).

The process of adjustment of the capital stock is also captured in the multi-period variant of the model. Within each period, both the total capital stock and its sectoral composition are fixed, and commodity markets clear continuously. Each sector's capital stock is updated between periods via a simple capital stock adjustment procedure, according to which investment equals depreciation plus some fraction of the gap between the desired level of the capital stock and its actual level (equations (8.15) and (8.21)). This process of capital accumulation is compatible with a simple theory of optimal firm behaviour given the assumption of quadratic adjustment costs. Desired capital stocks are determined on cost-minimisation criteria and actual stocks reflect last period's stocks, adjusted for depreciation and gross investment. The economy is assumed initially to be in long-run equilibrium, where desired and actual capital stocks are equal, so that investment is simply equal to depreciation.

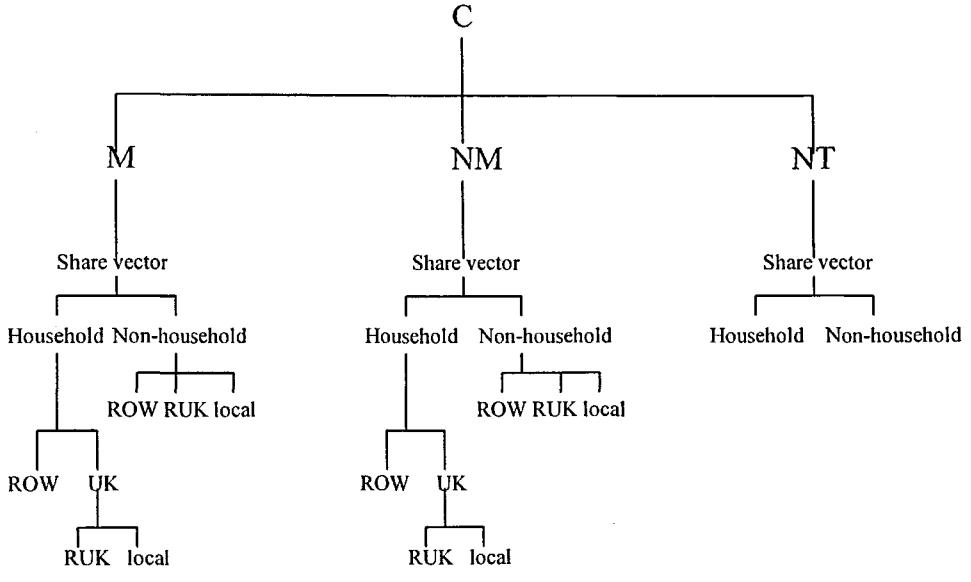
This treatment of capital stock adjustment is wholly consistent with sectoral investment being determined by the relationship between the capital rental rate and the user cost of capital. The capital rental rate is the rental that would have to be paid in a competitive market for the (sector specific) physical capital: the user cost is the total cost to the firm of employing a unit of capital. Given that the interest, capital depreciation and tax rates are taken to be to be exogenous, the capital price index (equation (8.6)) is the only endogenous component of the user cost. If the rental rate exceeds the user cost, desired capital stock is greater than the actual capital stock and there is therefore an incentive to increase capital stock. The resultant capital accumulation puts downward pressure on rental rates and so tends to restore

equilibrium. In the long run, the capital rental rate equals the user cost in each sector, and the risk-adjusted rate of return is equalised between sectors.

2.1.4 Final Consumption Demand

As with cost minimisation in production, in all model configurations cost minimisation in consumption is imposed.

Figure 8.2 – Structure Of Consumption Demand In The Basic (3-Sector) AMOS Framework



Final consumption demand for each sector's output (equations (8.13), and (8.16) to (8.18)) is allocated between the household and non-household sectors using a share vector that is based on the corresponding shares in final consumption for that sector's output in the base year. Household consumption of the commodities produced by the (two) traded sectors is a composite made up of UK and ROW commodities, with the UK consumption commodity a composite of locally produced and RUK goods. An Armington assumption is adopted concerning the demand for traded commodities. That is to say, locally produced goods and imports are imperfect substitutes for one another, but combine to make a composite consumption good in the case of each traded commodity. In a manner similar to the case of production, the consumer

attempts to minimise the cost of a given consumption composite, and will, in general, substitute against commodities whose price has risen.

The choice of aggregation functions available in the AMOS framework is the same as with production: CES, CD and Leontief. If CES is selected, the substitutability between commodities is dictated by the modeller's choice of the elasticity of substitution. (If high values are chosen, the case of the law of one price will be approximated because locally produced commodities and imports become very close substitutes; at the other extreme, if Leontief functions are assumed locally produced commodities and imports become complements in consumption.)

In the small non-household sector, the composition of consumption demand between locally produced commodities and imports from RUK and ROW is simpler, being based on the share of base year expenditure going to locally produced, RUK and ROW traded commodities.

2.2 Application Of The 3-Sector AMOS Framework

McGregor *et al* (1995 and 1996) use the 3-sector AMOS model to explore the implications of moving from the IO approach to modelling the economy using a more flexible CGE framework by relaxing the Leontief assumptions of quantities being modelled independently of prices and no supply-side constraints. However, depending on the policy application that needs to be modelled, the basic 3-sector framework is often considered to be too limited. For example, Gillespie (1999) develops a four-sector variant of the AMOS framework, where the manufacturing (M) sector is disaggregated by ownership (UK and foreign owned) for the purpose of analysing the system-wide impact of foreign direct investment (FDI) in Scotland. This version of the model, AMOSFDI, is further developed in Gillespie *et al* (2000), where the manufacturing sector (M) sector is further disaggregated to identify different types of manufacturing and different types of FDI plant (developmental and non-developmental). This 25-sector variant of the AMOS framework is used to

analyse the impact of an expansion in developmental foreign direct investment in the Scottish electronics sector.

Similarly, the 3-sector AMOS framework is not suitable for applications that seek to analyse the impact of the economy on the environment. In Chapter 3 (Section 2) I argue that the first requirement of an economic-environmental modelling framework is that it should be multi-sectoral in nature because of the importance of the *composition* of economic activity in governing its environmental impact. From the literature review in Chapters 3 and 4 it is clear that this is a generally accepted requirement. Industries are known to differ radically in the extent to which they generate pollution of various kinds, and it is therefore clear that any practical model of the economy-environment nexus must reflect this. Accordingly, a framework that, for example, aggregates all manufacturing sectors is of limited usefulness where the focus of the analysis is on environmental impacts.

The *n*-sector variant of the AMOS framework used by Gillespie *et al* (2000) was developed to address issues that are likely to require a higher degree of sectoral disaggregation of the economy than can be represented in the 3-sector model. The production and consumption structures illustrated in Figures 8.1 and 8.2 generalise in a straightforward way to the *n*-sector case. As with the initial version of AMOS, the *n*-sector variant encompasses a full range of behavioural assumptions and alternative market closures, which means that there is a high degree of flexibility in terms of the type of applications it can be used for. As above, the core requirement is an appropriate SAM database.

3. Using The Generic *N*-sector Variant Of AMOS To Construct An Economic-Environmental Modelling Framework For Jersey (JEMENVI)

3.1 The Jersey Economic Model (JEM)

Not only can the AMOS framework be calibrated to different base years for the Scottish economy; it can also be used to model activity in different regional

economies. In Section 2.1 above I explain that the AMOS framework can be applied to any region for which an appropriate SAM database exists and where the range of available model configurations encompasses the type of market conditions that exist in the target economy. Thus an economic modelling framework for Jersey (JEM) can be constructed by applying the SAM database describing the structure of the Jersey economy in 1998 that was constructed in Chapter 5 and identifying possible model configurations and parameter values that are likely to apply in the Jersey case[7].

There is one point regarding the classification of the Jersey economy in the AMOS framework that I should draw attention to. Note that in the condensed version of the generic AMOS framework in Table 8.1, and in Figures 8.1 and 8.2, the superscript 'RUK' in all equations where external prices enter as independent variables will be 'UK' in the case of Jersey. Jersey is not part of the UK, with the implication that the term 'RUK' in the AMOS framework, which was originally specified for Scotland (as a region of the UK) becomes simply 'UK'. However, the close integration of the Jersey economy with that of the UK, particularly with respect to trade flows, means that the treatment of the UK in the Jersey model is effectively the same as for RUK in the Scottish applications of the AMOS framework.

The activities/commodities identified in JEMENVI are specific to the Jersey case - I list these in Appendix 8A (note that the 25 activities/commodities correspond to the sectors identified in the Jersey IO accounts in Table 5.3).

As in the general AMOS case, within the basic JEMENVI framework it is possible to choose from the range of options regarding how markets are assumed to function in Jersey. This is normally done when simulations are being set up (see Chapter 9, Section 2). However, I begin by identifying a default configuration for Jersey that can be varied if and when it is appropriate to do so.

[7] Note that in Chapter 5, Section 4.2 I explain how it is not possible to disaggregate households by income band in the Jersey SAM because data are not available on the share of income from employment in each sector going to each income group. Therefore, in contrast to the environmental IO model that I present in Chapter 7, in the current version of the Jersey CGE model it is only possible to model a single representative household group.

First of all, I assume that all goods markets are competitive and that there is no binding constraint on the balance of payments or government budget. However, the model tracks both the balance of payments and public spending deficit.

The choice of labour market closure is an important issue. This is particularly so in the case of an economy like Jersey, where labour market constraints are thought to be crucial to the performance of the economy. In future simulation scenarios using the Jersey model the choice of labour market closure is likely to be a key factor that will be singled out for sensitivity analysis. However, as a starting point, I take the default labour market closure to be the exogenous (fixed) labour supply option. That is to say, I assume that Jersey is characterised by a constant (but very small) unemployment rate, meaning that there is a fixed proportional relationship between employment and working population and a totally inelastic aggregate labour supply curve. This would seem a reasonable assumption for Jersey, particularly in the simulations that reported in Chapter 9, where I constrain the operation of the labour market by exogenously imposing population and labour force projections made independently for Jersey by the UK Government's Actuarial Department. However, as I note above, the choice of labour market closure is likely to be subject to investigation and variation in future simulations[8].

Another option in the JEMENVI framework concerns the choice of key behavioural parameter values. A number of parameter values are determined when the model is calibrated to recreate the base year dataset constructed in Chapter 5 (the Jersey SAM, augmented with additional labour market and investment data). However, key parameter values, such as the speed of adjustment of the capital stock (from actual to desired levels), the relative price sensitivity of import and export demand, and elasticities of substitution in production are generally pre-specified (thereby constraining the process of calibration). No historical economic data are available for

[8] In fact, while I do not report the results here, the Fraser of Allander Institute has conducted additional population simulations using the JEMENVI model. These are similar to those I report in Chapter 9, but adopt the alternative regional bargaining closure. We find that the simulation results do not appear to be very sensitive to this change of labour market closure, given the low elasticity of labour supply in the bargained real wage function.

econometric estimation of parameter values in the Jersey case. Therefore, I must determine non-calibrated values according to what is observed for comparable economies and informed judgement. In the first instance I have determined default settings for the following key behavioural parameter values through consultation with the States of Jersey and the States' economic consultants following a review of parameter values used in models of comparable economies:

- Speed of adjustment, actual to desired capital stock: 0.3
- Elasticities of substitution in production of (all activities)
  - Value added (capital and labour): 0.8 (CES)
  - Intermediates composite: 0.0 (Leontief)
  - Gross output (value added and intermediates composite): 0.0 (Leontief)
- Armington trade elasticities: imports 2.0, exports 5.0 (all activities, including final consumption)

The first is the default setting used in the AMOS framework. The initial JEMENVI default setting for the elasticity of substitution between capital and labour of 0.8 for all sectors has been determined following a literature review of models constructed for comparable economies and consultation with the States of Jersey's economic consultants[9]. The assumption of Leontief technology in the production of total intermediates and gross output is required because of data constraints. The intermediate production matrix for Jersey is so sparse that use of a multiplicative function, such as CES, is not possible - see the upper left hand quadrant in the IO table constructed in Chapter 5, Table 5.3[10]. Use of a multiplicative function should be possible in the combination of value-added and the intermediate composite in the production of gross output. However, at this time I adopt the AMOS default setting of Leontief technology for this relationship. The Armington import elasticity is also set to the AMOS default setting of 2.0 for all sectors. However, I select a higher

[9] Note that I conduct initial sensitivity analysis of simulation results to the value of this parameter in Chapter 9. However I hope that future research will involve further sensitivity analysis and identification of sector-specific values for this particular relationship.

[10] As I explain in Chapter 10, hopefully it will be possible to develop the modelling software for Jersey to allow some substitutability between key intermediate inputs, such as different types of energy.

value, 5.0, for the export elasticities because of the belief held by the States and their consultants that Jersey exports are relatively highly price sensitive[11].

4.2 Adding The Environmental Component (JEMENVI)

Where an economic-*environmental* model is required for Jersey, the *n*-sector framework is the most appropriate variant of AMOS. In Chapter 3 (Section 2) I explain that one generally agreed requirement for a model of economic-environmental interaction is that it be multi-sectoral in nature because patterns of resource-use and pollution generation are likely to differ significantly across different types of activity in the economy. The 25-sector breakdown of the economic-environmental database constructed in Chapters 5 and 6 has been determined on this basis. Therefore I require that the CGE modelling framework is capable of modelling each of these sectors separately.

The environmental component of the generic AMOS framework that I develop here is a block of equations relating the physical generation of pollutants to the production of sectoral outputs and the level of real household expenditure in the base year that the model is calibrated to. These take the form of equation (8.22) in Table 8.1, which I reproduce here:

$$\textbf{(8.22)}\quad POL_k = \sum_i m_{ik} Q_i + \sum_z m_{zk} C_z$$

Where POL_k is the total physical amount of pollutant k generated in the economy in the chosen time period, m_{ik} and m_{zk} are the output- and expenditure-pollution coefficients for each production sector i, and final demand sector, z, respectively. In Chapter 6, Section 4 I explain that the output- and expenditure-pollution coefficients

[11] My sensitivity analyses in Chapter 9 also focus on the value the Armington elasticity of export demand. However, this is another area I hope will be subject to more extensive sensitivity analysis and sector-specific investigation in subsequent research. Specifically, in the first instance, I intend to repeat the simulations in Chapter 9, focussing on the impact of imposing different values for the Armington elasticities of export demand in different parts of the Jersey Finance sector.

respectively reflect the physical amount of pollutant k generated for each monetary unit of sectoral output, Q_i, and final demand expenditure, C_z.

Specifically, I use the Jersey-specific matrices $\mathbf{M_i}$ and $\mathbf{M_z}$ in the JEMENVI model database to allow computation of equation (8.17). (Note that the appropriate version of $\mathbf{M_z}$ will be the 9x2 version where household pollution coefficients are given for aggregate households (see Chapter 6, Section 4) because it is not possible to model households disaggregated by income band in the current Jersey CGE framework.)

However, note that the Jersey matrix $\mathbf{M_z}$ includes a vector of expenditure-pollution coefficients for direct emissions generation by tourists. At this time, the AMOS software only allows inclusion of direct emissions generation by one final demand group. To explain, the AMOS software was developed to include an environmental component at a very early stage of the Jersey project, before my research on which final demand sectors are responsible for direct emissions generation in Jersey began. This development used Scottish data for 1989 in order to allow the model to be calibrated and tested. However, the environmental component of the Scottish 1989 database is based on McNicoll & Blackmore's environmental IO accounting work, where aggregate households are the only final demand sector attributed with any direct emissions generation[12]. Therefore the environmental development of the AMOS software is limited in that it only allows computation of direct emissions generation, or, more generally, any physical units - pollution or energy-use - per unit of total expenditure by one final demand sector, households.

Therefore I have to compute direct emissions generation by tourists in Jersey off-line. I do this by taking C_z, where z = tourists, from the results of computing simulation (and base-run) scenarios and applying this directly to the vector of tourist expenditure-pollution coefficients. Specifically, because all direct emissions are a result of tourist expenditure on automotive fuels, I apply the vector $\mathbf{m_t}$ to the change in tourist expenditure on the composite commodity of the 'Gas, Oil and Fuel

[12] The Scottish economic-environmental CGE modelling framework is referred to as AMOSENVI. As part of the work associated with my study, I have updated the AMOSENVI framework using an

Distribution' sector. (In Chapter 10 I recommend that the JEMENVI software be developed to extend the number (as well as the range) of sources of pollution generation that can be modelled endogenously.)

The other part of the environmental component that I introduce to the AMOS framework is a second block of equations relating the physical use of different types of energy to the production of sectoral outputs and the level of real household expenditure. These take the form of equation (8.23) in Table 8.1, which I reproduce here:

(8.23) $$FUEL_l = \sum_i \varepsilon_{il} Q_i + \sum_z \varepsilon_{zl} C_z$$

Where $FUEL_l$ is the total physical amount of fuel l used in the economy in the chosen time period, ε_{il} and ε_{zl} are the energy consumption coefficients for each production sector i, and final demand sector, z, respectively, as derived in Chapter 6, Section 5 (matrices $\mathbf{E}_i$ and $\mathbf{E}_z$). Note that, as with pollution in (8.22), direct fuel use by tourists must be calculated off-line.

I should point out that where it is possible to make developments to the environmental component of the existing AMOS framework by carrying out off-line computations I have done so. However, other potential developments, such as modelling input-pollution relationships, cannot be accomodated in this way.

For example, emissions factors are available to compute pollution generation using equations (6.1) and (6.2) from Chapter 6. (See Sections 2.2 and 4 – this is how I compute emissions-by-sector for construction of the pollution coefficients.) However, the current version of the economic model can only compute results for the aggregate 'Oil & Fuel Distribution' sector and not for the individual fuel uses required for computation of (6.1) and (6.2). Even if I were to disaggregate the 'Oil & Fuel Distribution' sector in order to identify each individual fuel type the results of

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economic-environmental database for 1994. An example of using the AMOSENVI 94 framework for economic policy analysis can be found in the co-authored paper, McGregor *et al* (2001b).

computing (6.1) and (6.2) for each pollutant would be quantitatively the same as what is found using equation (8.22). This is because the assumption of Leontief technology in the production of the intermediate composite in all sectors, and in determining the composite consumption good for all final demand sectors, means that the use of all fuels within each individual sector changes proportionately in response to any disturbance. In Section 4.1 above, I explain that the assumption of Leontief technology in the production of the intermediate composite is a necessary one given the sparcity of the inter-sectoral matrix of the IO and SAM database, which prevents use of a multiplicative functional form, such as CES. Thus there is no possibility of any change in the level of emissions arising from substitution among fuels with different pollution characteristics. As I discuss in more detail in Chapter 10, relaxing this restriction requires separating energy use from other intermediates to allow substitution between different types of fuel before energy is combined with other materials and value-added in the production and consumption structures of the model.

4. Chapter Summary And Conclusions

In this chapter I explain the application of a new region-specific database to an existing CGE modelling framework in order to generate an economic-environmental CGE model for Jersey. As with the existing *n*-sector variant of the generic AMOS system that I use as a template, the new JEMENVI model is a multi-sectoral modelling *framework*, which incorporates a wide range of possible model specifications. This is crucially important in the case of Jersey, where a lack of historical region-specific economic data means that having the facility for comprehensive sensitivity analysis of model specification is essential. (Initial sensitivity analyses are reported in Chapter 9, Section 4.)

The main developments here are found in the environmental component of the model. In Chapter 6, Section 5, I show how a significant degree of added precision is gained in accounting terms from the use of Jersey-specific environmental coefficients, relative to what can be achieved using coefficients derived from UK

data. This will also be true in modelling applications. Thus, I would argue that the availability of the region-specific *environmental* database for Jersey allows more accurate computation of environmental impacts than would be possible in a model where national average emissions intensities are used to proxy for region-specific estimates. The Jersey-specific environmental database has also allowed a more sophisticated specification of economic-environmental relationships than would be possible if the model relied on adjusted-UK environmental data. As I explain in Chapter 6, Section 5, this is because the Jersey-specific database is more comprehensive in terms of the range of emissions sources included – the inclusion of direct emissions generation by tourists – and the inclusion of physical energy use broken down by fuel type and activity.

The next stage in this study is to use the model that I have constructed in this chapter to conduct simulations of the economic and environmental impacts of disturbances to the system. This is the focus of the Chapter 9, where I use the new JEMENVI model to assess the impact of four population policy scenarios currently being considered by the States of Jersey. My study then concludes in Chapter 10, with a summary of the work presented in this dissertation and recommendations for future development of the JEMENVI framework.

Chapter 9. Illustrative Simulations in the JEMENVI CGE Framework: The Economic and Environmental Impacts of Population Policy in Jersey

1. Introduction

In Chapter 8 of this dissertation I explain the construction of an economic-environmental CGE model for Jersey, referred to as JEMENVI. The model is calibrated to the 1998 economic-environmental database developed in Chapters 5 and 6 (where the 1998 database is assumed to represent initial, long run equilibrium conditions in the Jersey economy). The CGE model for Jersey builds on the environmental IO model developed in Chapter 7 by incorporating both production and consumption behaviour (supply and demand), modelling both prices and quantities, and relaxing restrictions on technology to allow substitution among inputs/commodities.

The purpose of this chapter is to report on some initial simulation exercises using the JEMENVI model. In Chapter 1 I explain that the main objective of my thesis is the construction of a model with endogenous environmental variables in order to track and explain the movement of chosen environmental, or 'sustainability' indicators in response to policy changes and/or other disturbances to the economic system. To illustrate the fulfillment of this objective, here I report on a number of simulations that track and explain the impact on energy consumption and pollution indicators variables resulting from various projected disturbances to the Jersey economy.

In fact, the scenarios that I simulate here concentrate on policy options relating to the achievement of one of Jersey's key sustainability objectives. In Chapter 2, Section 3.2, I explain how Jersey's aims regarding the sustainable development of the economy focus on several core issues. The growth and development of the economy and the economic welfare of Jersey residents is the central objective. However, for economic development to be perceived as 'sustainable', the stated policy consensus

(see States of Jersey, 1995, 1998) is that this must be achieved under certain environmental and population constraints. Jersey's environmental objectives relate to both local and international concerns. For example the States' Environmental Charter, endorsed in 1996, includes a commitment to the principles agreed at the Earth Summit in Rio de Janeiro in 1992 regarding greenhouse gas emissions (States of Jersey, 1998). Local concerns relate specifically to issues like traffic-related energy-use and pollution generation, particularly with respect to air quality in the main urban area (St Helier) and constraints on the supply of natural resources, such as water.

However, the key sustainability concern identified by Jersey (see Chapter 2, Section 3.2 and States of Jersey, 1998) relates to the number of people living and working on the island. The States of Jersey's current population and immigration policy (adopted in November 1997) is aimed at limiting the size of the total permanent population in line with a pre-stated target of 85,000 by controlling in-migration to the island through employment and residency regulations. Jersey's population concerns are related to the environmental ones noted above, because increased population is associated with increased environmental pressures. The direct pressure from local household consumption is particularly important here – as found in the environmental accounting study in Chapters 6 and 7, local households are directly responsible for the generation of most pollutants in Jersey.

On the other hand, there are currently very real concerns in Jersey, particularly in the business community, that restricting population will have a big impact on output (especially in the high value-added finance sectors) and may lead to the external perception that Jersey is 'closed for business'. There is also a more secondary concern in terms of the fiscal implications of Jersey's ageing population. Therefore one policy proposal is to encourage economic growth by allowing the working-age population to expand via in-migration, thereby reducing tightness in the labour market.

However, as I note above, the problem that policymakers face is that, in addressing these concerns, the equally passionate views of local residents over the size of the population and its environmental impacts must be taken into account. That is to say, it is recognised that any economic benefits of relaxing constraints on in-migration (which is likely to lead to the aforementioned population target being violated) must be balanced against the environmental impacts of increased economic activity and population. In short, it would seem that policymakers in Jersey face certain trade-offs in pursuing their sustainability objectives.

Here I undertake some illustrative analysis to demonstrate how the JEMENVI model can be used to inform policymakers on the size and nature of these problems. Their importance is reflected in the fact that the simulations reported here actually constitute the first policy application of the JEMENVI system.

The simulation scenarios have been formulated in conjunction with staff at the States of Jersey in response to questions raised by the States' Policy and Resources Committee, and focus on assessing the implications for economic development in Jersey under the constraint of limited population growth. I also consider environmental objectives through the introduction of a number of resource use and pollution indicators. However, I do not introduce any environmental *constraints* in the form of target values for indicator variables[1].

2. Simulation Strategy

I conduct four separate population policy simulations using the economic-environmental model of the Jersey economy (JEMENVI). These comprise combinations of two different population change scenarios with two different assumptions about other economic conditions. The two population scenarios used are:

1. Nil net migration.

2. Limited net in-migration (200 people of working age per annum) over the period 2001 – 2011.

The UK Government's Actuarial Department (UKAD) have quantified the demographic impacts of these two population change scenarios for Jersey. Broadly, in the nil net migration scenario there are changes to the population powered by natural demographic forces. In fact the population is increasing but ageing, so that the projected working population is falling. In the limited net in-migration scenario 200 net in-migration per annum is permitted, with 200 additional people aged 25 or under adding to the working population under the same conditions of demographic change projected under the nil net migration hypothesis. I detail the changes in total and working population projected by the UKAD under the two scenarios in Tables 9.1 and 9.2 (below).

In the four simulations I combine each of the two population scenarios in turn with two economic scenarios regarding demand conditions:

(a) No exogenous demand changes to the economy, apart from an adjustment to government expenditure to maintain a fixed level of government expenditure per head, as discussed in more detail below.

(b) An increase in export demand of 50% for the outputs of the seven 'financial and other business services' sectors (which, for simplicity I refer to as the 'Finance' sector)[2]. That is to say, there is a 50% one-off permanent step increase that takes place in 2002 in total (UK and ROW) export demand to each of the following sectors (the 25 production sectors identified in JEMENVI are given in Appendix 8A):

[2] The composition of the 'financial and other business services' sector, and the hypothesis that this aggregate sector is the recipient of the demand shock in Simulations 3 and 4, were determined in conjunction with the States of Jersey (see Section 1). In some of the results reported here, I aggregate the 25 sectors modelled to seven sectors, detailed in Appendix 9A, for the purpose of clarity in time series graphs.

- Banks & Building Societies
- Insurance Companies
- Investment Trusts & Fund Managers
- Computer Services
- Legal Activities
- Accountancy
- Other Business Activities

In the first two simulations I model each of the migration scenarios in turn with no exogenous change in other economic circumstances. The results of Simulation 1, with nil net migration, demonstrate the economic and environmental impact of the projected changes in the labour force. I compare these simulation results to the base-year values. In Simulation 2 I model the impact of imposing 200 net in-migration per annum to Jersey, isolating the *additional* impacts of this in-migration by using the Simulation 1 results as the base case. In the next two simulations I take each of these population scenarios and apply a 50% export demand shock to the financial and other business services sector (a permanent 50% step increase in export demand to each of the sectors identified above that occurs in 2002). That is to say, in Simulations 3 and 4 I take the same population scenarios as I have done in simulations 1 and 2 respectively and add an export demand shock. Again, the results for Simulation 3 are compared to the base year values, and in Simulation 4 I report the additional impacts of in-migration by using the Simulation 3 results as the base case. I summarise the composition of each of the simulations in terms of the alternative economic and migration scenarios modelled in the table below:

	Nil net migration	**200 p.a. net in-migration**
No Finance demand shock	Simulation 1 (vs base)	Simulation 2 (vs Sim 1)
Finance demand shock	Simulation 3 (vs base)	Simulation 4 (vs Sim 3)

Table 9.1 Jersey Projected Population Changes For The Period 2001-2011 - Nil Net Migration Hypothesis

Year / Population	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Total population	87819	88029	88204	88357	88486	88592	88679	88750	88809	88859	88892
% change from 2001 base	0	0.24	0.44	0.61	0.76	0.88	0.98	1.06	1.13	1.18	1.22
Working age population (UKAD)	57576	57576	57562	57517	57478	57507	57475	57398	57362	57243	57151
% change from 2001 base (UKAD)	0	0.00	-0.02	-0.10	-0.17	-0.12	-0.18	-0.31	-0.37	-0.58	-0.74
Working age population (JEMENVI)	57583	57540	57498	57455	57413	57370	57328	57285	57243	57200	57158
% change from 2001 base (JEMENVI)	0	-0.07	-0.15	-0.22	-0.30	-0.37	-0.44	-0.52	-0.59	-0.66	-0.74

Table 9.2 Jersey Projected Population Changes For The Period 2001-2011 - Limited Net In-Migration (200 Per Annum) Hypothesis

Year / Population	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Total population	88022	88438	88824	89191	89538	89867	90187	90498	90804	91110	91408
% change from 2001 base	0	0.47	0.91	1.33	1.72	2.10	2.46	2.81	3.16	3.51	3.85
Working age population (UKAD)	57771	57971	58157	58312	58473	58701	58869	58991	59154	59234	59341
Net in-migration per annum (UKAD)	195	200	200	200	200	199	200	199	199	199	199
% change from 2001 base (UKAD)	0	0.35	0.67	0.94	1.21	1.61	1.90	2.11	2.39	2.53	2.72
Working age population (JEMENVI)	57782	57939	58096	58253	58410	58567	58724	58881	59038	59195	59354
net in-migration per annum (JEMENVI)	200	200	200	200	200	200	200	200	200	200	201
% change from 2001 base (JEMENVI)	0	0.27	0.54	0.82	1.09	1.36	1.63	1.90	2.17	2.45	2.72

As noted above, in all cases I make one further adjustment. In Section 1 above, I explain how one area of concern associated with population growth in Jersey is the impact on public sector spending. In the simulations conducted here I do not focus on any hypothesis regarding changes in government expenditure or funding. However, I take the *status quo* situation to be a constant level of government expenditure ***per head.*** Therefore, in each simulation, I exogenously adjust the level of total government expenditure in each period in proportion to the change in total population. On the revenue side, I assume that the tax structure and tax rates remain constant.

In reporting the results I assume the initial (base) period to be 2001 (based on the initial conditions represented by the 1998 database – no attempt is made to adjust for the 3-year period between 1998-2001). The proportional projected population and demand changes over the 11-year period 2001-2011 are applied to the actual base year data, which represent 1998 (see Chapter 5). The base-year period, 2001, is the period where the first population (demographic and/or migration) changes occur but the economic impact does not begin until 2002; thereafter population changes occur in every period up to and including 2011.

I assume that everything - apart from the population changes, the associated changes in government expenditure, and the 'financial and other business services' sector demand shocks, where relevant - remains constant. Specifically, I do not impose any other external demand shocks or supply-side disturbances, such as technical progress or productivity growth. This allows me to study the impact of the various population scenarios in isolation. Of course, it is important to note that the results are not *forecasts* of what will actually happen. It would be unrealistic to assume that there will be no other change in the economy over the projected time period. Rather, the simulations that I conduct here are designed to isolate population influences on the Jersey economy.

It is also important to note that the results I report here are limited to the time period agreed with the States of Jersey (2001 to 2011 inclusive). However, since population

changes occur in every period, there will be further adjustments beyond 2011 in response to all the scenarios being simulated before the economy returns to long-run equilibrium. While I do not do it here, the JEMENVI framework can be used to compute long-run results (with period-by-period results describing the adjustment process) - see Chapter 8.

For the four simulations reported in Section 3, I adopt the model configuration (specification and parameter values) as described for the default case in Chapter 8 (Section 3.1). There I explain that the default settings for the following key parameter values have been determined through consultation with the States of Jersey and the States' economic consultants following a review of parameter values used in models of comparable economies:

- Speed of adjustment, actual to desired capital stock: 0.3
- Elasticities of substitution in production of (all activities)
  - Value added (capital and labour): 0.8 (CES)
  - Intermediates composite: 0 (Leontief)
  - Gross output (value added and intermediates composite): 0 (Leontief)
- Armington trade elasticities: imports 2.0, exports 5.0 (all activities, including final consumption)

The labour market closure I choose for Jersey in the simulations reported here is the exogenous (fixed) labour supply option. That is to say, I assume that Jersey is characterised by a constant (but very small) unemployment rate, meaning that there is a fixed proportional relationship between employment and working population. While the simulations focus on the impact of different migration scenarios, the model's migration function is not activated – in these simulations the population and labour force are determined exogenously (and independently) using the projections quantified by the UK Actuarial Department. For all other markets I assume the default closure - all goods markets are competitive and that there is no binding constraint on the balance of payments or government budget.

In Section 4, following the reporting of results, I go on to explain that the next stage in the modelling process should be sensitivity analyses of the model specification adopted here. This stage in the process is particularly important given the absence of econometrically estimated parameter values for Jersey. Ideally, this analysis should focus on areas identified through interaction between modellers and policymakers following the initial presentation of results. In the first instance, within the confines of this dissertation (and in anticipation of feedback and interaction with policymakers in Jersey), I report limited sensitivity analyses in Section 4, where I focus on varying two of the key parameter values listed above. These are the Armington trade elasticities, which determine the sensitivity of export demand to changes in local output prices, and the elasticity of substitution between capital and labour in the CES production functions determining the composition of the primary input aggregate (value-added) in each sector. My motivation for focussing on these parameters is that I find the key factor determining the environmental impacts of the each of the scenarios simulated here to be the effect on the level of real household income and expenditure. Since the main force driving changes in household income and expenditure is changes in labour demand it seems appropriate to begin the sensitivity analysis of the results presented here by focussing on the key parameters determining the wage elasticity of the general equilibrium demand for labour. This governs the response of labour income, and therefore household expenditure, to changes in the labour demand.

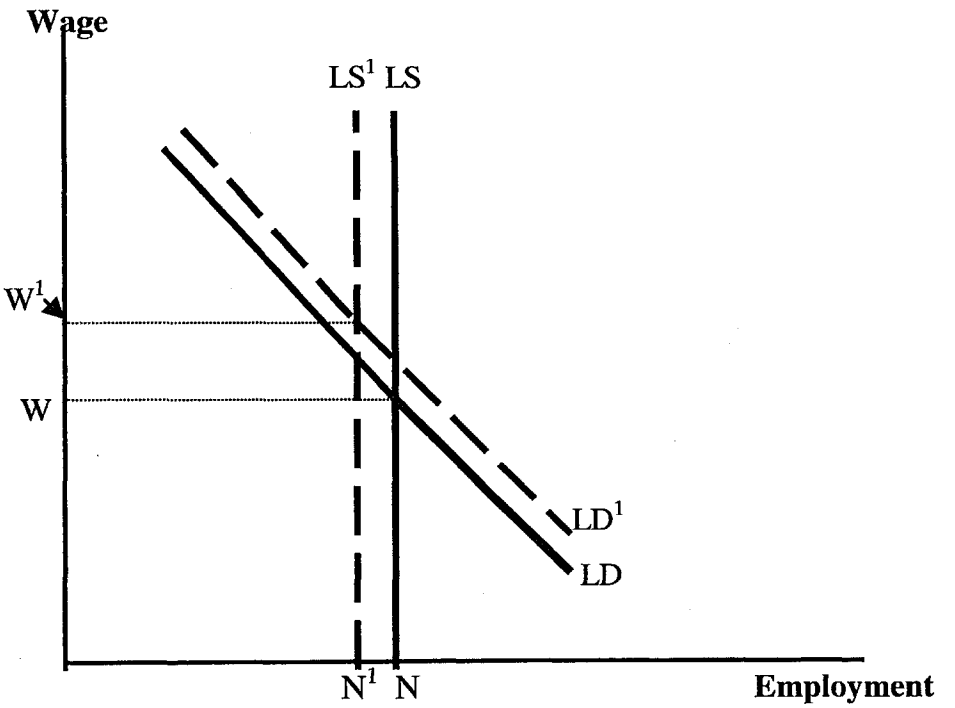
3. Simulation Results

3.1 Simulation 1: Nil Net Migration

In this simulation I examine the economic and environmental impacts in the Jersey economy of imposing the nil net migration scenario during the period 2001-2011. Under this scenario the UK Government Actuary's Department (UKAD) estimates a natural population growth of 1073 people between 2001 and 2011. However, a rapidly increasing retired population results in a fall in working population of 425 people during the same period. Therefore, the important aspect of this simulation is

that while the total population is rising Jersey has a falling number of people available for work. I detail these demographic changes in Figure 9.1.1, where I show the total and working population projections for Jersey in terms of percentage changes from the base year, 2001. Note that the model can accommodate projected changes in total population period-by-period, but has to approximate working population changes with a linear trend, which I show in Figure 9.1.1 (below) as the JEM[3] line. (I detail the actual population changes under the nil net migration hypothesis in Table 9.1.)

Figure 9.1 General Equilibrium Labour Supply And Demand Under The Nil Net Migration Scenario



Before discussing the actual simulation results, it is useful to provide a simplified theoretical account of the basic labour market impact of the population changes implied by the nil net migration scenario using the general equilibrium labour demand and supply curves in Figure 9.1. Note that the analysis in Figure 9.1

[3] JEM is a shortened version of the acronym JEMENVI, representing 'Jersey Economic Model'

corresponds to the new long-run equilibrium resulting from Simulation 1 (2001) – i.e. once all the population changes have occurred and the wage has fully adjusted. It is also important to note that the labour supply and demand curves in Figure 9.1 are the *general equilibrium* labour supply and demand curves, which take full account of *all* the effects of wage changes (including income effects) resulting from the hypothesised disturbance(s).

As I explain in Section 2, under the labour market closure I adopt in all the simulations reported here a constant unemployment rate is maintained. This means that there is a fixed proportional relationship between employment and the working population. This is represented by a vertical aggregate labour supply curve in Figure 9.1. The economy is initially in equilibrium where labour supply, curve LS, equals labour demand, LD, at wage level W and employment N. Under the nil net migration scenario working population falls. This is illustrated by an inward shift of the labour supply curve, from LS to LS^1. However, total population increases. This means that there will also be an upward shift in the general equilibrium labour demand curve, from LD to LD^1, reflecting the fact that public sector activity must increase to maintain a fixed level of government expenditure per head of population. Thus the main direct impact of the population changes implied by the nil net migration scenario is a lower labour supply, with employment N^1, and a higher general wage level, W^1.

3.1.1 Economic Impacts

Figure 9.1.2 illustrates the impact of the demographic changes implied by the nil net migration scenario on Jersey GDP, GDP per head and total employment. Under the assumption of a unified labour market characterised by a fixed labour supply, total employment falls in line with the reduction in the labour supply (working population). In Figure 9.1.2, GDP falls by 0.46% by 2011, implying that the economy has been negatively affected by nil net migration – i.e. the reduction in factor availability reduces the productive capacity of the economy.

(JEMENVI specifically identifies the environmental variant of the model).

Fig 9.1.1 Jersey Projected Total And Working Population Changes For The Period 2001-2011 - Nil Net Migration Case

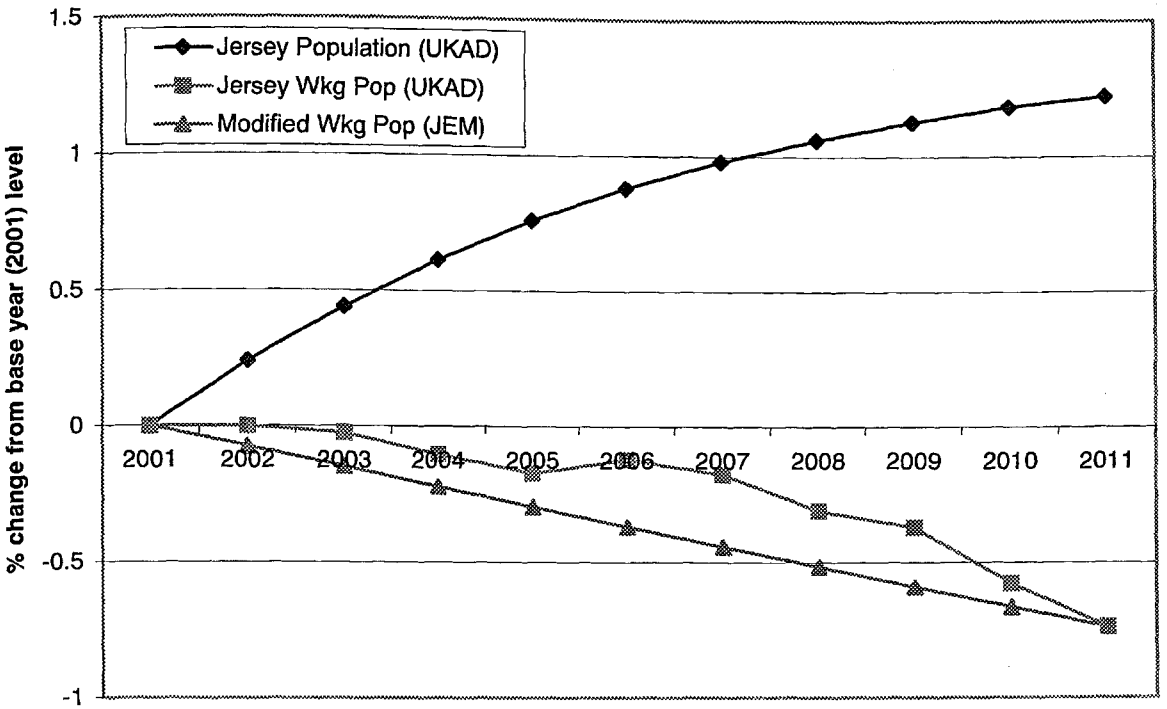
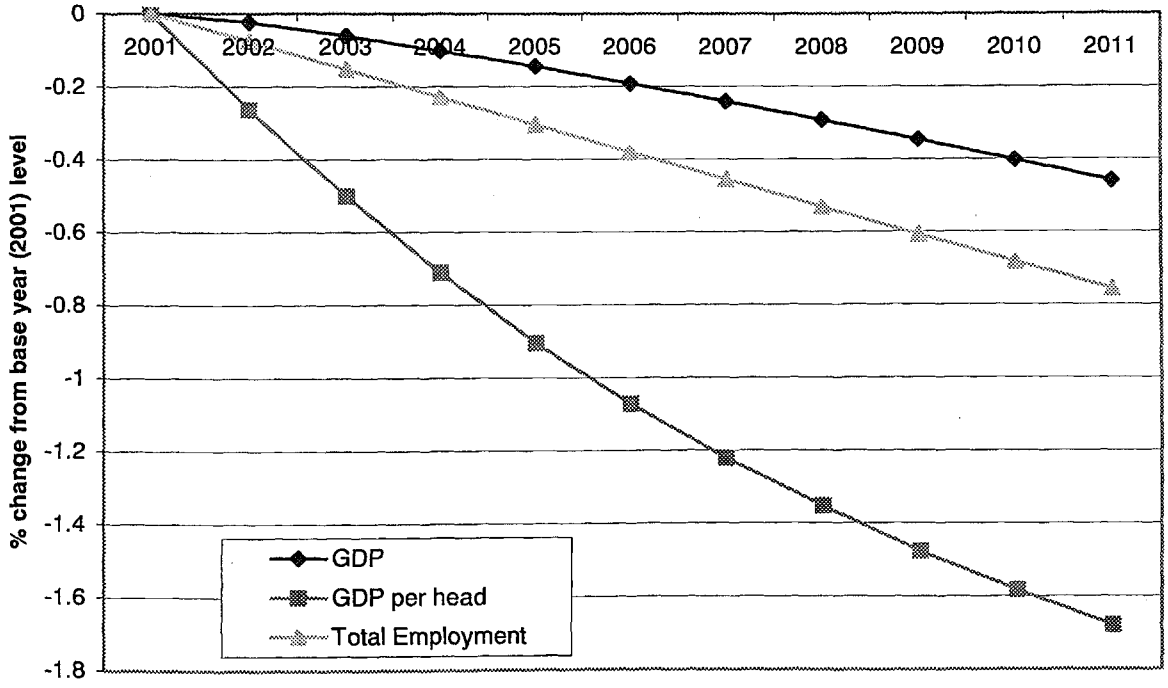


Fig 9.1.2 Impact Of Nil Net Migration On GDP, GDP Per Head And Total Employment In Jersey, 2001-2011



It is worth noting that the reduction in total employment is of a relatively small magnitude. The fall is caused by the reduction in the supply of labour as an input to production, but note that the fall in GDP is less than the fall in employment (-0.76% by 2011). This is partly because there is some stimulus to demand as government spending increases in line with population growth. Moreover, capital stocks do not fall by as much as employment for two reasons. Firstly, the increase in real wages causes firms to substitute capital for labour. Secondly, the downward adjustment of capital is subject to frictions due to capital fixity (i.e. in the short to medium-run it is easier for firms to reduce employment than capital).

These two factors combine to ensure GDP does not fall by as much as employment and, therefore, GDP *per employee* actually rises. However, because of the increasing population, GDP *per head* falls, and does so even more rapidly than GDP, although again by a relatively small amount: by the end of 2011 (year 10 of the simulation) GDP per head is 1.68% lower than the 2001 (base year) level. (Moreover, this implies that for *each* year the average decrease in GDP per capita is only 0.168%. In fact, the largest annual change occurs in the first year, with a fall of 0.264% in 2002; every year thereafter the magnitude of the fall in GDP per capita declines, with only a 0.01% drop between 2010 and 2011.)

The effects of this increased tightening of the labour market can be seen in Figure 9.1.3. Both the nominal and real-consumption wages increase and there is a rise in the Consumer Price Index (CPI). However, the scale of these increases is small – all change by less than 0.6% by 2011. Two points are important concerning the CPI. First, the CPI results only demonstrate step changes in Jersey prices and do not chart an inflationary process (just as the increases in the production of sectoral outputs do not represent a growth process). Second, the impact on the CPI is small, due to the fact that only local prices, not import prices, are rising (I assume that all external prices remain constant).

Fig 9.1.3 Impact Of Nil Net Migration On The CPI And On Before-Tax Real And Nominal Wages In Jersey, 2001-2011

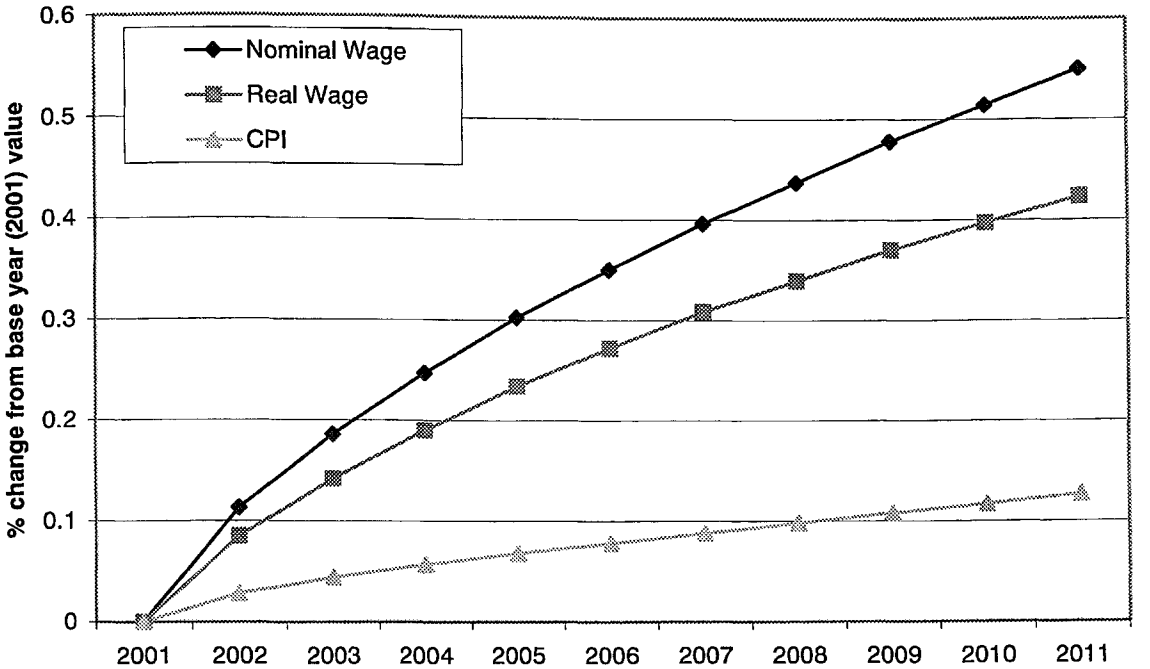


Fig 9.1.4 Impact Of Nil Net Migration On Competitiveness (Local Output Prices) In Jersey, 2001-2011

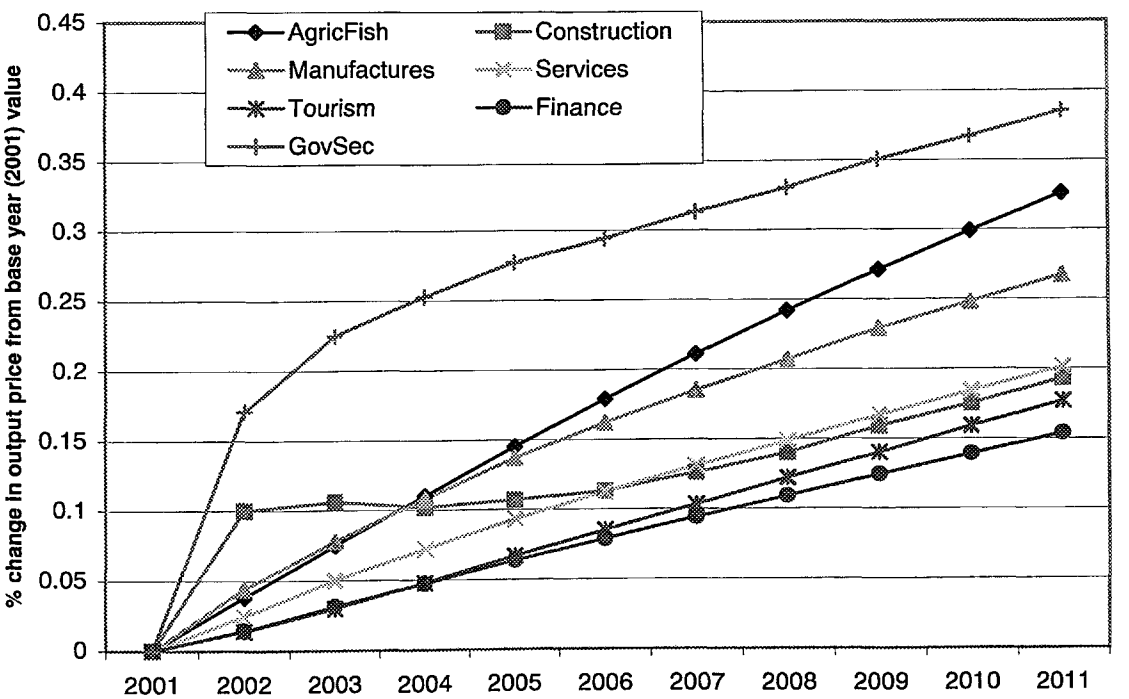
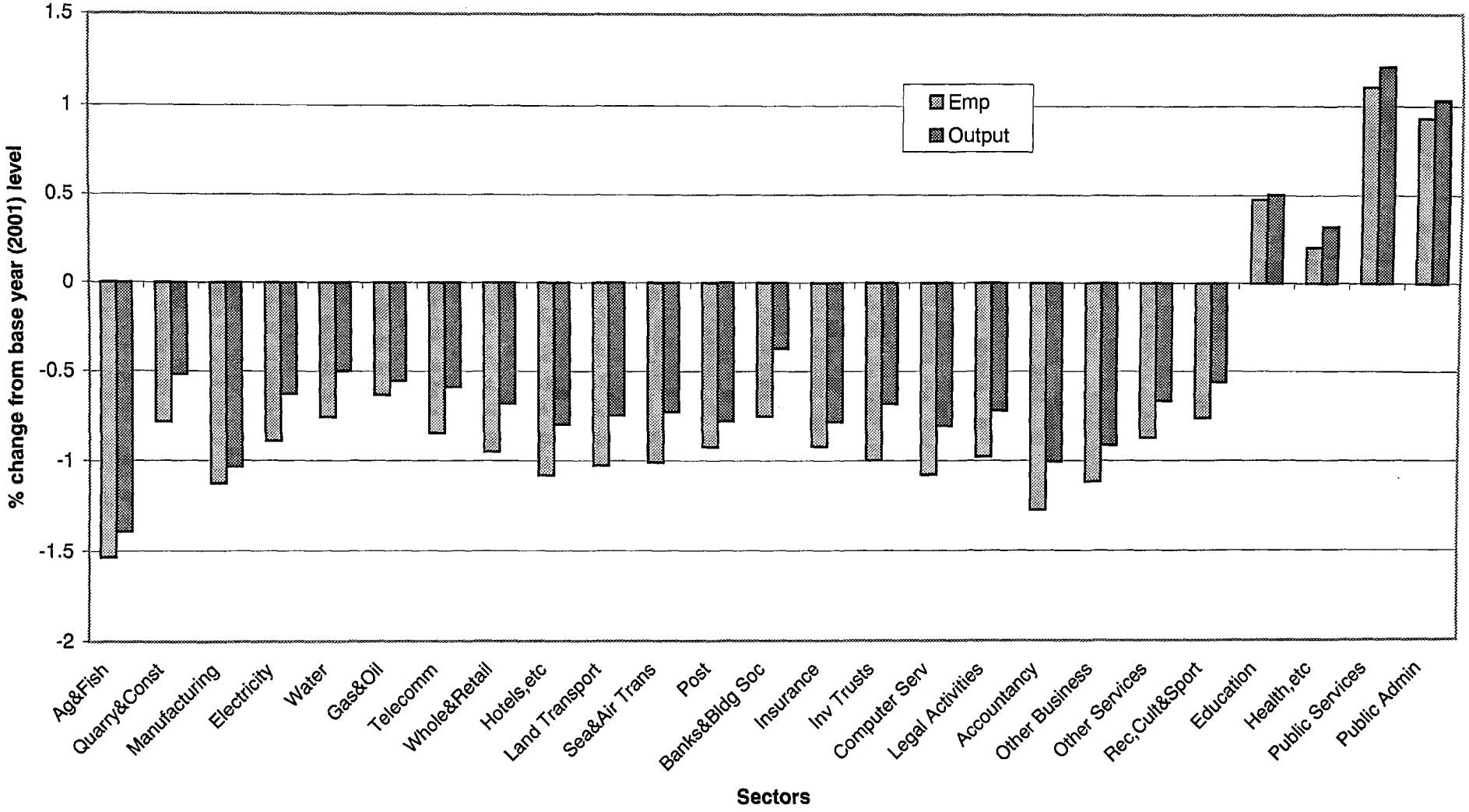


Fig 9.1.5 Impact By 2011 of Nil Net Migration On Sectoral Employment And Output In Jersey



In Figure 9.1.4 I report how these local input price increases alter competitiveness across sectors in the Jersey economy in terms of changes in the prices of locally produced goods as against the prices of goods produced elsewhere. For illustrative purposes, I aggregate the 25-sector results to the 7-sector breakdown detailed in Appendix 9A. In Figure 9.1.4 I interpret "competitiveness" as the price of Jersey goods relative to those traded on the international market. As the graph shows, the increases in wage and the CPI negatively affects Jersey competitiveness causing output prices in all sectors to rise. Most sectors exhibit a gradual increase in output prices as the reduction in labour supply and higher wage effects begin to impact, but one or two are notably different. Construction, for example, has a sharp increase in price in the short-run, which then levels off – this is caused by the initial increase in population and government spending which lead to an increase in investment demand.

The government sector shows the biggest increase in output price. There are three underlying reasons for this. Firstly, it is relatively labour intensive. However, it is also sheltered, which allows the price of output to rise. Finally there is a simultaneous increase in the demand for government sector output as population increases.

In Figure 9.1.5 I report the impact by 2011[4] of the increasing population and falling labour supply on output and employment across the 25 sectors identified in the JEMENVI model. Despite the fall in competitiveness, output and employment actually rise in each of the four government sectors. This is because, with the exception of 'Education', these sectors are *sheltered* from external competition, i.e. they only serve local demand and do not export their output. Consequently, the government sectors are less affected by the rise in the relative prices than other sectors of the economy. Further, these sectors experience a direct demand boost through the increase in government expenditure that is required to maintain spending per head constant. However all the other sectors exhibit negative output and employment effects, with the extent of the effect determined by two factors.

First, labour intensive sectors are hit hardest by the increased cost of labour. Secondly, sectors that are more open to international trade feel the negative competitiveness effects more strongly. Agriculture and Fishing suffers the most due to a combination of these two factors: it is very labour intensive and experiences the largest competitiveness effect of the private sectors. Hotels, Restaurants and Catering is hit relatively hard for the same reasons. On the other hand, Banks and Building Societies suffers the least, partly because it is the least labour intensive sector in the economy and partly because it uses relatively few locally produced inputs, and therefore experiences the lowest competitiveness effect. Employment falls by a greater proportion than output in almost every sector because as the price of labour rises, firms attempt to substitute capital for labour. Also, it takes more time to optimally adjust the capital stock.

In Figure 9.1.6 (below) I illustrate the impact of the nil net migration scenario on GDP and GNP.[5] The model does not, at present, routinely report GNP so I must produce results for this variable "off-line" using the information generated in the simulations together with the base-period data that I use to construct the Jersey Social Accounting Matrix (SAM) in Chapter 5.[6] Any large differences between GNP and GDP primarily reflect large changes in sectors with high levels of foreign ownership. For example, if a sector such as Banks and Building Societies were to suffer significant negative effects we would expect to see a more severe impact on GDP rather than GNP. This is because Jersey's Banks and Building Societies sector has a high level of foreign ownership and therefore contributes less to GNP than to GDP. In this case there is only a small difference between GDP and GNP, because the reduction in output is spread relatively evenly across those private sectors where

[4] Recall that 2011 is not the "long-run" solution, in that the capital stock in individual industries is not optimally adjusted at this point.

[5] GDP is the market value of all final goods and services produced within an economy in a given period. GNP is the total income earned by a nation's permanent residents (nationals) during the same period, and differs from GDP by including income that nationals earn abroad and excluding income that foreigners earn domestically.

[6] If the structure of the economy changes then the SAM alone does not contain enough information to calculate GNP: the database underlying the SAM must also be used to calculate the share of value added flowing out of each sector.

there is a high level of local ownership. The good performance of the public sector is likely to be the explanation underlying the slightly higher GNP figure.

In Figures 9.1.7 and 9.1.8 I show the year-on-year impacts on employment and output respectively amongst the seven aggregate sectors identified in Appendix 9A. These results confirm that only the public sector gains in the nil net migration scenario, while among the private sectors Construction suffers the least, partly because of the surge in demand in the early periods, its relatively low labour-intensity and negative-competitiveness effects. However, the seven-sector results mask the fact that, from 2006, the Banks & Building Societies sector actually becomes the one that suffers least. The performance of the aggregate Finance sector is pulled down by sectors like Other Business Activities and Other Service Activities which are fairly labour intensive and use more local produced inputs, and therefore suffer larger negative competitiveness effects. (The performance of the utility sectors is similarly masked by their inclusion in the aggregate Services sector.) Agriculture and Fishing is the sector shown to suffer most under the nil migration scenario in the 25-sector results shown in Figure 9.1.5. This is also the case in the 7-sector results because in more aggregate sectoral breakdown I also identify Agriculture & Fishing ('AgricFish' in Appendix 9A) as an individual sector.

I summarise the economic impacts of the nil net migration scenario by 2011 in Tables 9.1.1 and 9.1.2. Both tables isolate the impact of nil migration and its associated demographic changes. In Table 9.1.1 I present the changes in aggregate variables. These results show that the Jersey economy suffers under the nil net migration scenario in terms of reduced aggregate activity, though not to a great extent. GDP, GDP per head and total employment all fall, while the CPI and real wages rise. This is due entirely to the decrease in working population, although this effect is limited by the increase in government spending. I should emphasise that the magnitude of these results is in fact relatively small. For example GDP only falls by 0.46% by 2011.

Fig 9.1.6 Impact Of Nil Net Migration On GDP And GNP In Jersey, 2001-2011

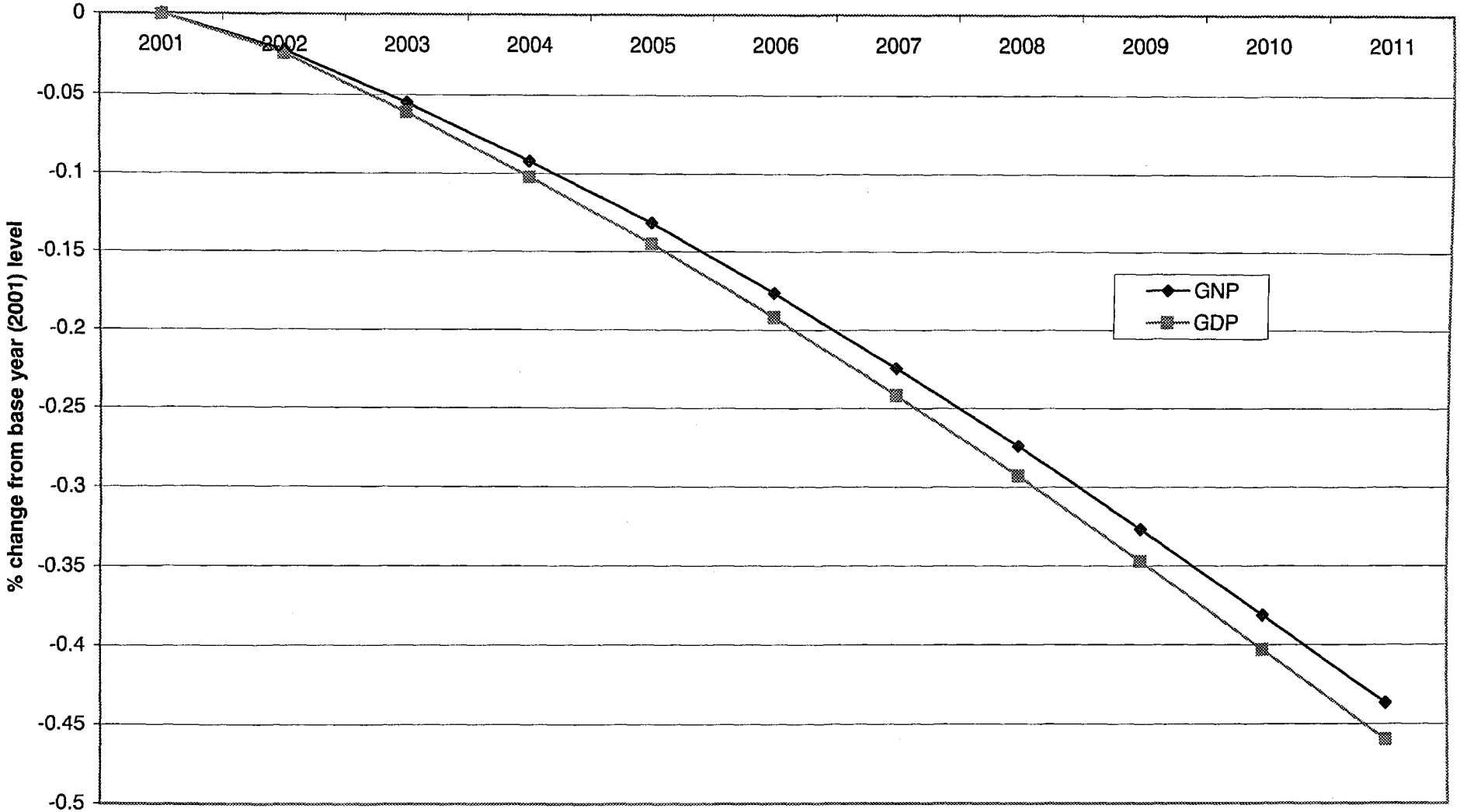


Fig 9.1.7 Impact Of Nil Net Migration On Sectoral Employment In Jersey, 2001-2011

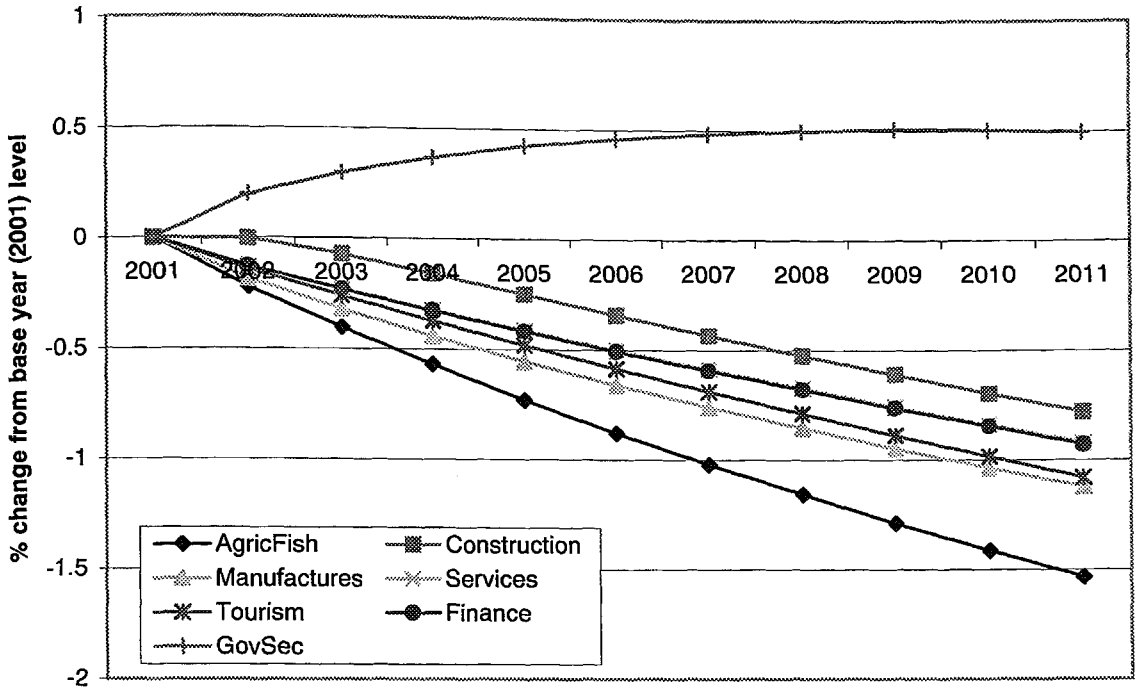
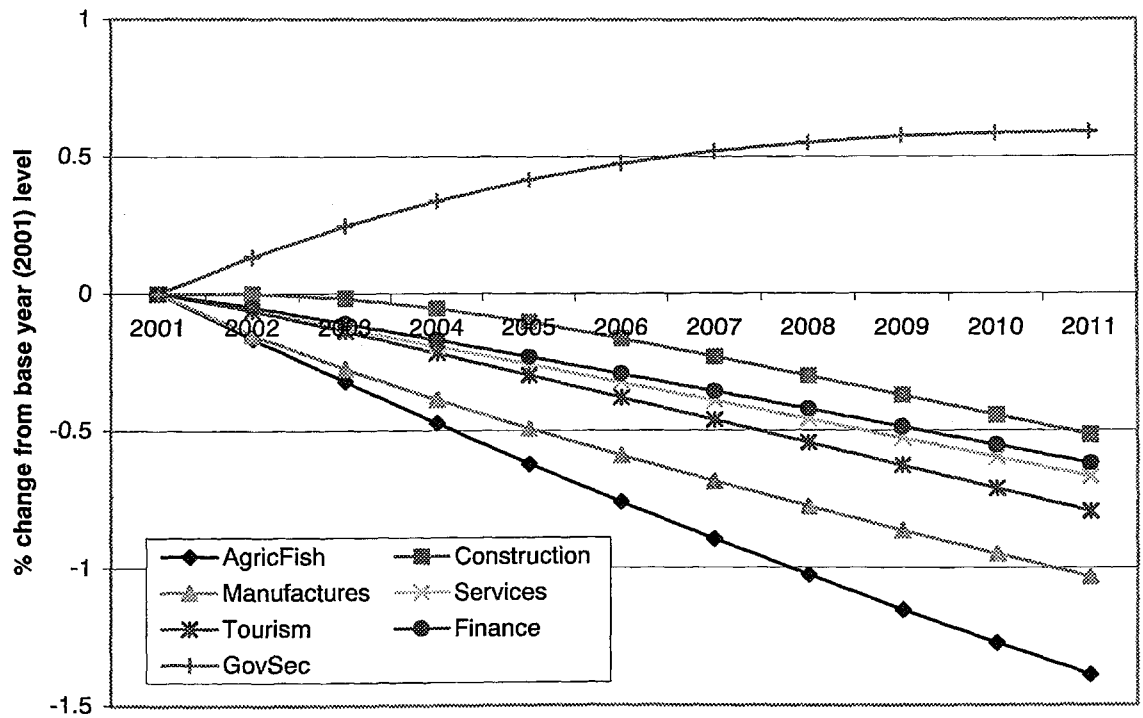


Fig 9.1.8 Impact Of Nil Net Migration On Sectoral Output In Jersey, 2001-2011



Summary of Results: Simulation 1 - Nil Net Migration Case

Table 9.1.1 - Impact By 2011 Of Nil Net Migration On Aggregate Economic Variables In Jersey

	% Change
GDP	-0.46
GDP per head	-1.68
Real Wage	0.423
Real HH Income & Expend.	-0.327
Total Employment	-0.758
CPI	0.127

Table 9.1.2 - Impact By 2011 Of Nil Net Migration On Sectoral Employment, Output And Price of Output In Jersey

	% Change			Absolute Change
	Employment	Output	Price of Output	Employment
AgricFish	-1.534	-1.390	0.326	-31
Construction	-0.781	-0.516	0.193	-37
Manufactures	-1.123	-1.034	0.267	-24
Services	-0.923	-0.668	0.201	-112
Tourism	-1.081	-0.795	0.177	-65
Finance	-0.929	-0.621	0.154	-122
GovSec	0.495	0.590	0.385	34

In Table 9.1.2 I summarise the sectorally disaggregated proportionate effects on employment, output and price of output for the 7-sector breakdown of the economy. Again, although the effects are almost uniformly negative in terms of activity and competitiveness (the only exception is the public sector), they are of a relatively small magnitude. I include the absolute change in employment in Table 9.1.2 because percentage changes may be misleading when sectors are of vastly different sizes. For example, the aggregate Finance sector experiences one of the smallest drops in employment in percentage terms, but the largest drop in absolute terms. This is because Finance, as defined in these simulations (see Appendix 9A), directly accounts for roughly 28% of total employment in Jersey.

3.1.2. Environmental Impacts

In Figure 9.1.9 I report the impact of the demographic and associated economic changes implied by the nil net migration hypothesis on physical energy consumption and water use in production and consumption activities in Jersey. In line with the decrease in aggregate economic activity, energy consumption generally falls, as does demand for water. Only one type of energy consumption, gas, shows any increase over the time period in question. This is explained by the expansion in activity in the government sectors, which are the heaviest gas users in the economy (in 1998, these four sectors combined accounted for 58.5% of total gas use). Public sector activities are also among the most gas-intensive, in terms of physical units used per £1million of production, in Jersey. Public Services and Health, Social Work and Housing respectively rank as the first and second most gas intensive sectors in the economy, and Education and Public Administration and Defence as the fifth and sixth, after Recreation, Culture & Sport and Hotels, Restaurants & Catering. However, the rise in gas use in the government sectors is increasingly offset by the decline in activity in other gas consuming sectors and in the household sector. This is reflected in Figure 9.1.9, which shows that the increase in gas consumption (over the base year level) peaks in 2005 and becomes negative by 2011.

Figure 9.1.9 Impact Of Nil Net Migration On Energy And Water Consumption In Jersey, 2001-2011

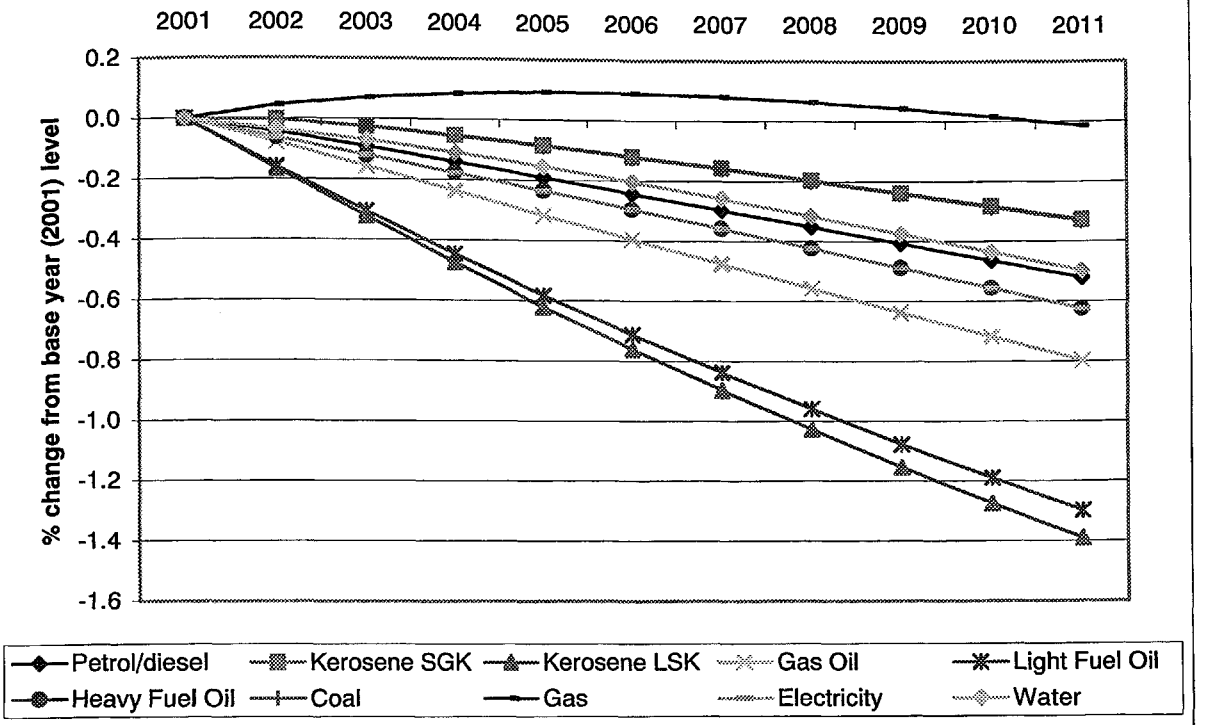
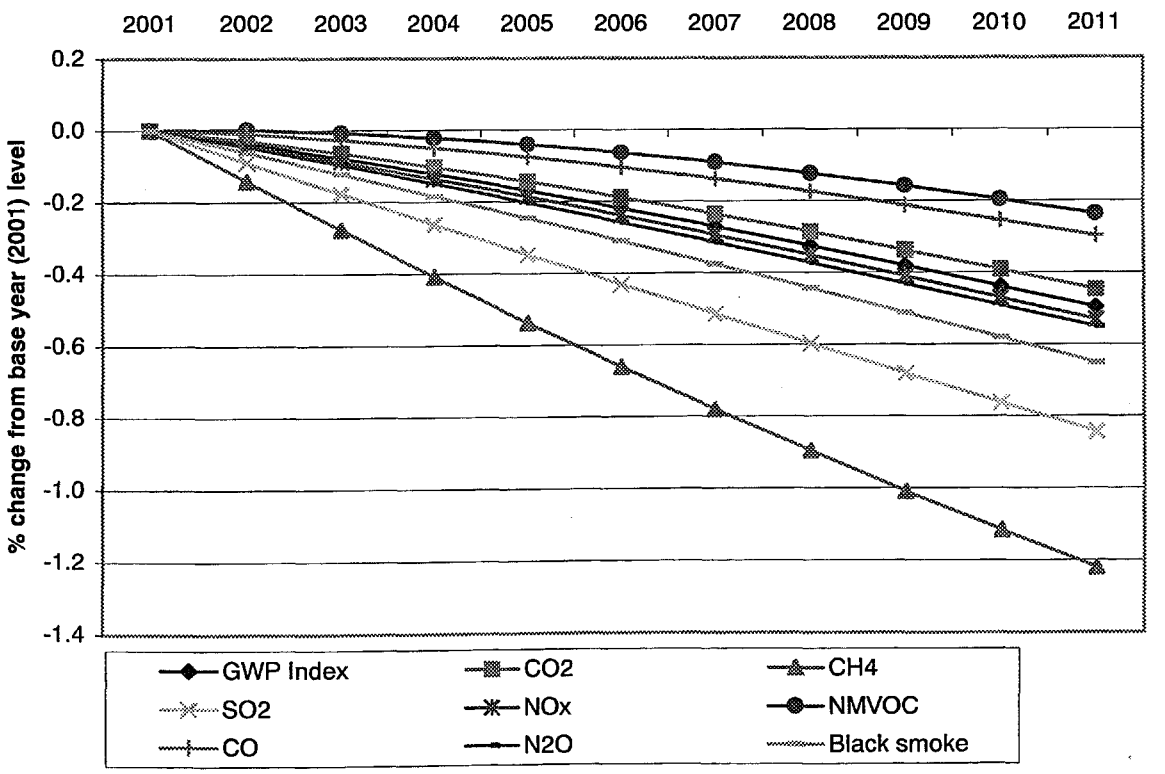


Figure 9.1.10 Impact Of Nil Net Migration On Emissions Of 8 Individual And 1 Composite Pollution Indicators In Jersey, 2001-2011



The demographic changes cause a fall in the consumption of all other types of energy consumption throughout the period of study in line with the general decline in activity. The largest negative impact is observed in the case of low sulphur kerosene (kerosene LSK). This fuel is exclusively used in Jersey by the Agriculture & Fishing sector (for CO_2 enrichment in greenhouses), and therefore shows a year-on-year decrease in use that is proportionate with the fall in Agriculture & Fishing output levels observed in Figure 9.1.8.

Note from Figure 9.1.9 that total consumption of electricity and heavy fuel oil fall by the same amount and at the same rate: this is because heavy fuel oil is exclusively used in Jersey for generating electricity on the Island. However the fact that I assume that technology is fixed throughout the period under study is crucially important in the case of electricity generation and consumption. Jersey imports part of its electricity supply from a nuclear power station located in France. If there were an increase in the share of electricity imported from this source, the use of heavy fuel oil (and gas oil) in the production of electricity would decline relative to total electricity use.

The consumption of two other energy types in Jersey is almost entirely exclusive to one area of activity: households account for 99% of coal use on the Island and are the only consumers of kerosene in heating oil form (kerosene SGK). Therefore, again the decline in consumption of these two fuel types is proportionate to the fall in real household income and expenditure observed in each year of the simulation (falling by 0.33% by 2011).

For all other fuel types, the composition of the change in activity driving the fall in energy consumption is more complex. In the case of light fuel oil, use is limited to the Agriculture & Fishing, Manufacturing and Other Service Activities sectors, with the decline in activity in the Agriculture & Fishing sector, as the heaviest user, dominating the effect shown in Figure 9.1.9. Eighteen of the 25 sectors use gas oil as an input to production so the decline in consumption of this fuel is a result of changes in activity in all these sectors. However, again, production in the Agriculture

& Fishing sector is significantly more gas oil intensive than in any other sector and, as we have already seen, this is the sector that shows the largest decline in output. Therefore a significant share of the impact on gas oil consumption is driven by the change in Agriculture & Fishing activity. Similarly all sectors use water and electricity, so the composition of the impacts on water and electricity use of the nil net migration scenario are complex and the total impact will be driven by changes in activity across the whole economy. However, again it is possible to identify sectors which experience more significant output effects, such as Public Services, Agriculture & Fishing and Manufacturing, where production is also relatively intensive in the use of electricity and water as inputs to production.

Every sector in the economy engages to some extent in transport activities and therefore uses automotive fuel as an input to production. However the activity that has the highest automotive fuel use intensity in the Jersey economy is household final consumption. Households are also the main users of automotive fuels on the Island (in 1998 70.5% of total automotive fuel was supplied directly to household final consumption). Therefore the bulk of the effect on automotive fuel use can be directly related to the decline in real household income and expenditure.

As well as physical energy consumption, in the JEMENVI model I identify the generation of 8 individual air pollutants and one composite pollutant, an Index of Global Warming Potential (GWP)[7]. I explain the construction of base year (1998) environmental accounts describing direct pollution generation in Jersey by the 25 production sectors and seven final demand groups from different sources in Chapter 6 of this dissertation. Drawing on an earlier study of sources of pollution generation in Jersey (see Coley, 1994), in Chapter 6 I identify emissions factors for different types of polluting activities that take place in Jersey. Firstly, there are fuel combustion factors, which state the physical amount of each individual pollutant that will be generated when one physical unit of each fuel type is combusted using a specific type of technology. Secondly, there are non-fuel combustion emissions factors for a range of activities in Jersey that generate pollution independently of fuel

[7] The GWP Index is introduced and defined in Chapter 6, Section 3.4.

use. These activities include waste incineration, emissions of non-methane volatile organic compounds (NMVOCs) from solvent use, or biological emissions of methane (CH_4) from livestock and human beings. As a result, in the base year (1998) environmental accounts for Jersey that I use to construct the JEMENVI model, pollution generation is broken down by source in terms of:

1. W*ho* pollutes - i.e. pollution generation by each production and final demand sector.
2. *How* pollution is generated - i.e. different types of fuel combustion and non-fuel combustion polluting activities that take place within each sector.

One of the key findings of the 1998 environmental accounting study that I carry out in Chapter 6 of this dissertation is that most pollution generated in Jersey is a result of fuel combustion. (This result is consistent with the findings of the earlier study of pollution generation in Jersey reported in Coley (1994).) Therefore, as energy use declines in the nil migration scenario, so do emissions of all the pollutants identified in Figure 9.1.10. (Gas use has relatively low pollution intensity, with the implication the positive emissions effects from the increase in gas consumption observed in Figure 9.1.9 are negated by the decline in other polluting activities).

However, in Chapter 6 I explain that non-fuel sources of pollution generation are also important in Jersey. For example, the waste incineration carried out by the Public Services sector is highly intensive in the production of NMVOCs relative to any other activity in the economy. This activity also has the second highest carbon monoxide (CO) intensity (after the Sea & Air Transport and Transport Support, SATTS, sector). I report above that activity in all four of the government sectors, including Public Services, increases in response to the demographic changes implied by the nil migration hypothesis. Therefore emissions from waste incineration also increase. The decline in all other activities is enough to negate the positive pollution effects of increase activity in the Public Services sector. However, note that emissions of the two pollutants that production in the Public Services sector is most

intensive in, NMVOC and CO, show the smallest level of decline throughout the period of study – see Figure 9.1.10.

Another non-fuel source of emissions is methane (CH_4) emissions from the livestock used in the Agriculture & Fishing sector. Indeed, this was the main source of methane emissions in Jersey in 1998, accounting for 82.7% of total methane generation. Figure 9.1.8 shows that Agriculture & Fishing suffers the largest negative output effect under the nil migration scenario; this dominates the impact on methane emissions throughout the period, which is the largest negative pollution effect. I find that the second largest negative pollution effect occurs in the case of sulphur dioxide (SO_2). This is also largely explained by the reduction in Agriculture & Fishing activity. As I note above, the heaviest user of light fuel oil (LFO) in Jersey, and the most LFO-intensive sector is the Agriculture & Fishing sector (which accounted for just under 80% of total LFO used in 1998). LFO has an extremely high SO_2-intensity relative to other fuels. Therefore the decline in Agriculture & Fishing activity causes a relatively large impact on SO_2 emissions, as I report in Figure 9.1.10.

I summarise the environmental impacts of simulating the nil net migration scenario by 2011 in Tables 9.1.3 and 9.1.4, where I isolate the energy use and pollution effects of nil migration and its associated demographic changes. In Table 9.1.3 I present the changes in mainly traffic-related variables. I find that total automotive fuel use declines, though not to a great extent. More significant is the composition of the change in (land) traffic-related energy use. Automotive fuel use in the aggregate Government sector increases by 0.48%. However the absolute amount of fuel involved is small relative to the decline in automotive fuel use in other parts of the economy. Total automotive fuel use in all other production sectors declines by 0.76%. This is a larger percentage change than is observed in the household sector, where there is a fall of 0.33%. However, given that the majority of automotive fuel use in Jersey is concentrated in the household sector (70.5% in 1998), this equates to a significantly bigger drop in the absolute amount of fuel consumed (just over 96 tonnes, which is 44.2% of the total decline).

Table 9.1.3 Impact By 2011 Of Nil Net Migration On Traffic-Related Energy Consumption And Emissions Generation In Jersey

	Absolute Change (kg)	% Change from base
Total automotive fuel (petrol/derv) use	-217120	-0.52
Government sector	674	0.48
Other production	-71135	-0.76
Households	-96061	-0.33
Tourists	-50598	-1.77
Emissions of:		
Non-methane volatile organic compounds (NMVOC)	-5912	-0.24
Carbon monoxide (CO)	-40696	-0.30
Nitrogen dioxide (N20)	-11	-0.55
Carbon dioxide (CO2)	-1325723	-0.45
Nitrous oxides (NOX)	-11908	-0.53

Table 9.1.4 Impact By 2011 On All Other Environmental Indicators In Jersey

	Absolute Change (kg)	% Change from base
Total energy use		
Kerosene SGK	-95780	-0.33
Kerosene LSK	-15694	-1.39
Gas Oil	-199737	-0.80
Light Fuel Oil	-106013	-1.30
Heavy Fuel Oil	-426057	-0.63
Coal	-18091	-0.33
Gas (Mains & Bottled Propane/Butane)	-1866	-0.01
Emissions		
Methane (CH_4)	-11743	-1.22
Sulphur dioxide (SO_2)	-8645	-0.84
Black smoke	-478	-0.65
Value of Global Warming Potential (GWP) Index for Jersey	-1575637	-0.50

The other major contributor to the decline in total automotive fuel use is tourists, whose only direct energy use during their stay in Jersey is combustion of automotive fuels in private or hire vehicles. This reduction reflects the negative competitiveness effects discussed above and illustrated in Figure 9.1.4, where the Gas, Oil & Fuel Distribution sector is shown as part of the aggregate Services sector. The negative competitiveness effects mean that in general Jersey becomes a relatively more expensive destination for tourists because the price of output produced in the Jersey sectors that tourists directly or indirectly consume has risen. The reduction in automotive fuel use reflects part of the general negative competitiveness effect that impacts on tourist demand: the general increase in the price of output in the Gas, Oil & Fuel Distribution sector causes the cost of recreational use of vehicles in Jersey to rise.

Emissions of three pollutants, NMVOC, CO and nitrogen dioxide (N_2O) are highly correlated with automotive fuel use in Jersey: traffic-related emissions of NMVOC, CO and N_2O account for respectively 81.6%, 87.5% and 100% of total emissions of these three pollutants in the base year environmental accounts[8]. Emissions of all three show a decline by 2011. However the smaller magnitude of the drop in NMVOC and CO emissions relative to what I find in the case of automotive fuel use and N_2O generation reflects the influence of other sources of these two pollutants (in particular the increased waste incineration discussed above).

Emissions of two other pollutants are significantly, but not so highly correlated with automotive fuel use: CO_2 and nitrous oxides (NO_X). In Table 9.1.3 I report proportionate declines in emissions of both these pollutants by 2011, which are of around the same magnitude as what I find for automotive fuels. However, it is important to recognise that more than half the total emissions of CO_2 and NO_X in 1998 came from sources other than automotive fuel use, mainly other types of fuel use, including electricity generation and aircraft movements. Therefore the CO_2 and NO_X effects shown in Figure 9.1.10 and Table 9.1.3 are driven by a number of

[8] In Chapter 6 (Section 5) I explain that another source of N_2O emissions in Jersey would be expected to be fertiliser use in the Agriculture & Fishing sector. However neither Coley (1994) or the present

factors, including significant positive effects from the increase in Public Services (waste incineration) activity.

In Table 9.1.4 I report the impacts by 2011 on all other types of fuel distributed by the Gas, Oil and Fuel Distribution sectors and emissions of the three remaining pollutants – methane (CH_4), sulphur dioxide (SO_2), and black smoke. Of these, only methane is traffic-related. However changes in automotive fuel use only account for a very small part of the total methane effect – as I explain above, the decline in methane emissions is mainly driven by the decline in activity in the Agriculture & Fishing sector. In Table 9.1.4 I also report the impact on the GWP index, the value of which falls in response to the general decline in activity, though, again, there is upward pressure from the increase in CO_2 generation in the Public Services sector.

Generally, then, I conclude that while the implications of the nil net migration scenario are negative in so much as the economy suffers through reduced levels of activity, there are also positive implications in terms of the environmental benefits of reduced energy use and pollution generation. However, it is important to note that all of the economic or environmental effects implied by the nil net migration (status quo) scenario are of relatively small magnitude.

3.2 Simulation 2: Additional Impact Of 200 Net In-Migration Per Annum

In this simulation I identify the additional economic and environmental impacts of allowing 200 in-migration per annum. The population projections (detailed in Figure 9.2.1, below, and Table 9.2) show that under this scenario the total population of Jersey grows ahead of the nil net migration scenario by an additional 2,313 people. Working population also increases, by an additional 1,995. The results that I present in this section are all *additional* to the nil net migration scenario results reported in Section 3.1, which is taken as the base case. Therefore, as everything else is held constant, the results isolate the economic and environmental impacts on Jersey of an

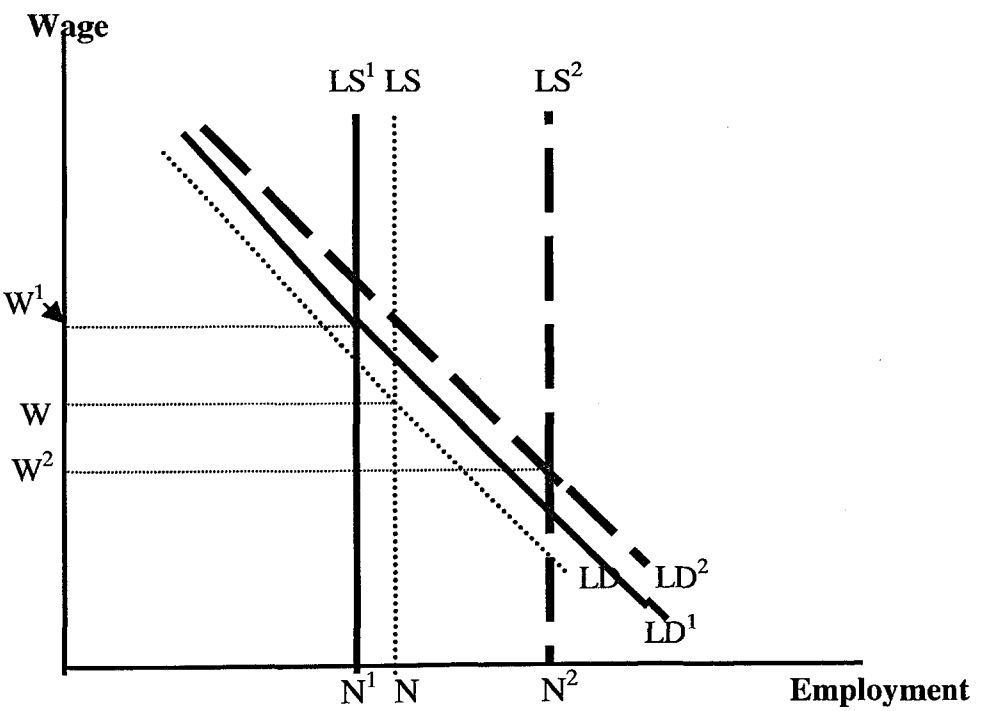
(1998) study has been successful in identifying appropriate emissions factors or physical fertiliser use data.

increased population and, crucially in this case, an increased labour supply (solely from the additional 200 net in-migration per annum).

In Figure 9.2.1 I graph the additional percentage changes in total and working population under the 200 in-migration scenario relative to the nil net migration scenario. Again, it is necessary to adjust the UK Actuarial Department population projections to get a linear trend for inputting to the model. However, in this case, the UKAD and JEM working population lines are so close that it is difficult to differentiate between them on the graph – see the actual changes in Table 9.2.

Again, I can illustrate the basic impact of relaxing the labour supply constraint in this way using the general equilibrium labour supply and demand framework.

Figure 9.2 General Equilibrium Labour Supply And Demand Under The 200 Net In-Migration Per Annum Scenario



The increase in the labour supply implied by the increase in working population under the 200 net in-migration per annum scenario is reflected in the outward shift of

the general equilibrium labour supply curve, from LS^1 to LS^2. Labour demand will also increase, LD^1 to LD^2, in as much as public sector activity must increase to maintain fixed government expenditure per capita as total population increases (additional to what is observed in the nil net migration case). However the net additional impact of relaxing the labour supply constraint in this way is to lower the real wage level in the economy, W^1 to W^2, as the total labour supply and employment rise from N^1 to N^2.

3.2.1 Economic Impacts

In Figure 9.2.2 I report the additional impact of 200 net in-migration per annum on GDP, GDP per head and total employment. I should stress the fact that these results are additional to the nil net migration scenario. For example, Figure 9.2.2 shows an increase in total employment of 3.58% by 2011, which is additional to the 0.758% fall reported in Figure 9.1.2. Therefore, the total effect of allowing 200 migration is to generate an expansion in employment which, by 2011, equals an increase of 2.822% [= 3.58% + (-0.758%)] on the base-period figure. It is clear, therefore, that the introduction of migrants to Jersey allows the economy to expand and has positive impacts in terms of employment and GDP, which more than outweigh the negative effects identified when migration is suppressed. However, allowing in-migration means GDP per head falls further than under nil net migration because the increase in GDP is not enough to make up for the larger increase in population.

I report the effects on the cost of labour in Figure 9.2.3. The introduction of new workers provides some slack in the market and, as a result, nominal wages, real wages and the CPI all fall (in fact by an amount that exceeds the increases from nil net migration). Again, however, I would point out that all the effects observed so far are relatively small: in-migration adds only 2.041% to GDP by the year 2011, while real wages fall by only 1.461% over the same time period.

Fig 9.2.1 Additional Projected Total And Working Population Changes For The Period 2001-2011 - With 200 Net In-Migration Per Annum

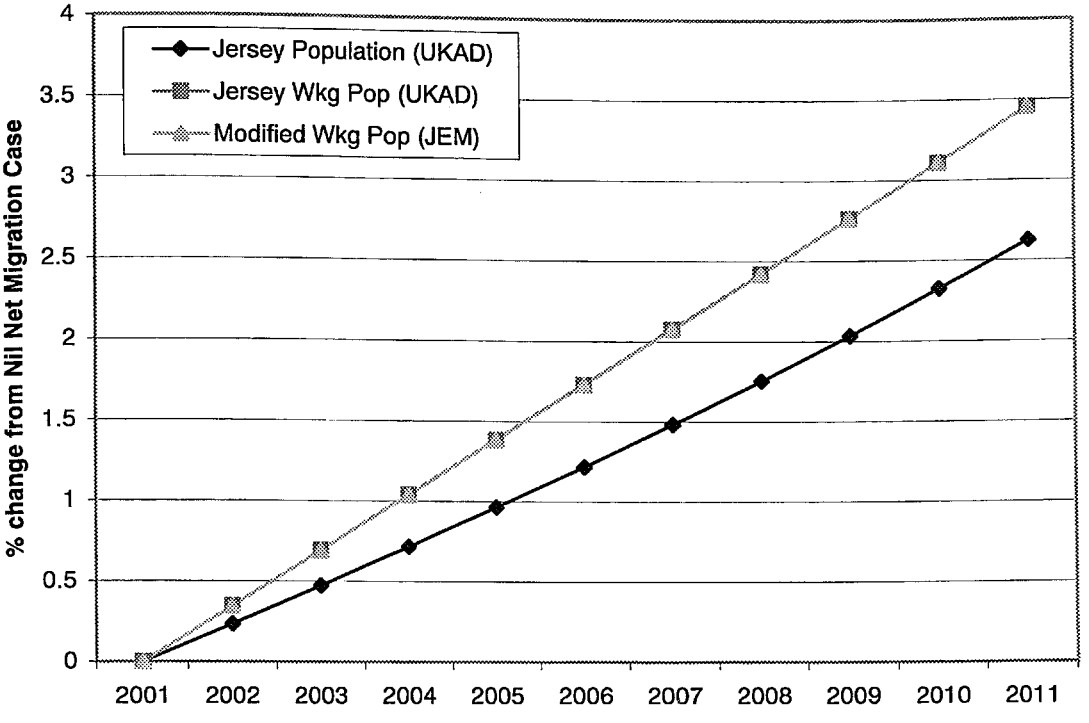


Fig 9.2.2 Additional Impact Of 200 Net In-Migration Per Annum On GDP, GDP Per Head And Total Employment In Jersey, 2001-2011

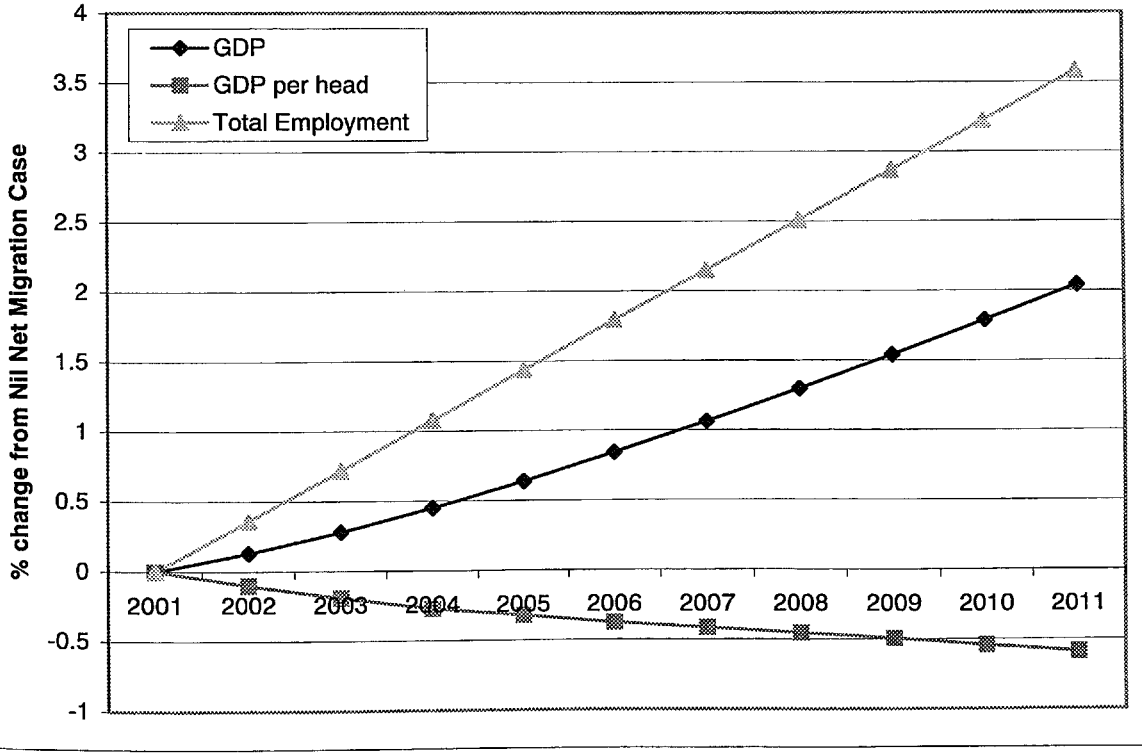


Fig 9.2.3 Additional Impact Of 200 Net In-Migration Per Annum On The CPI And On Before-Tax Real And Nominal Wages In Jersey, 2001-2011

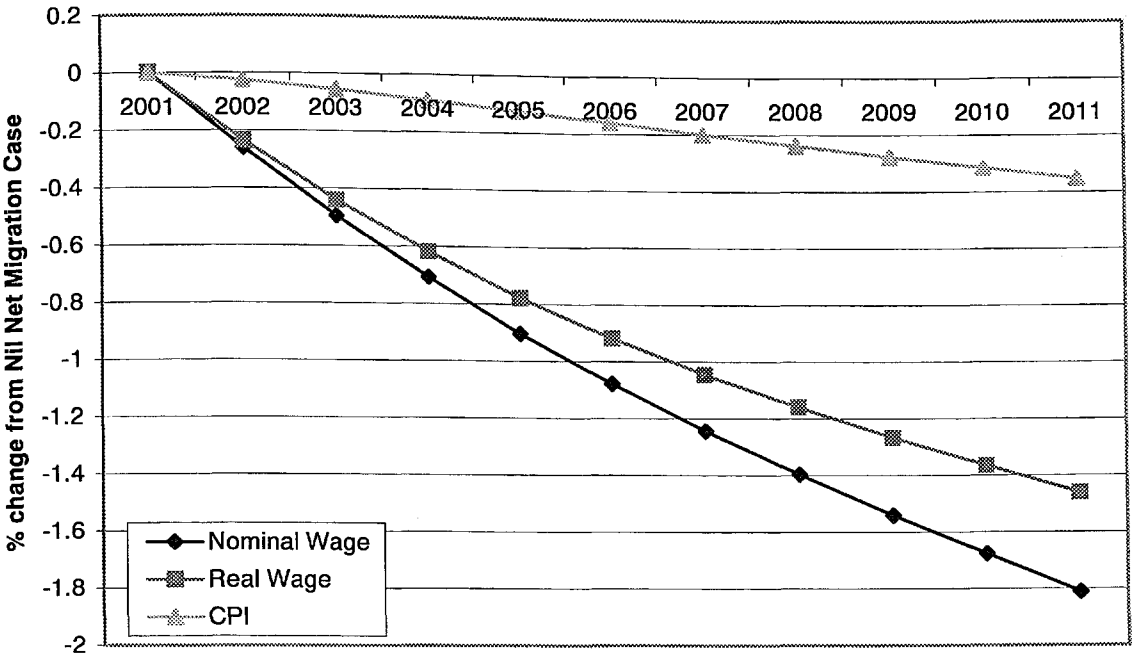


Fig 9.2.4 Additional Impact Of 200 Net In-Migration Per Annum On Competitiveness (Local Output Prices) In Jersey, 2001-2011

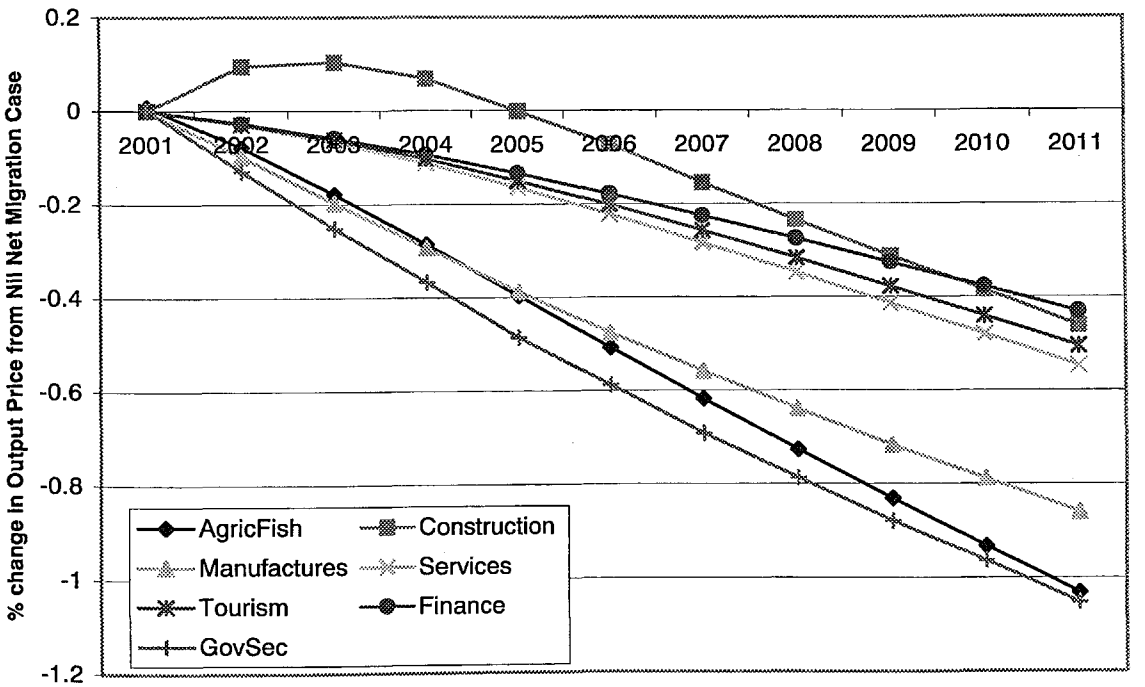


Fig 9.2.5 Additional Impact By 2011 Of 200 Net In-Migration Per Annum On Sectoral Employment And Output In Jersey

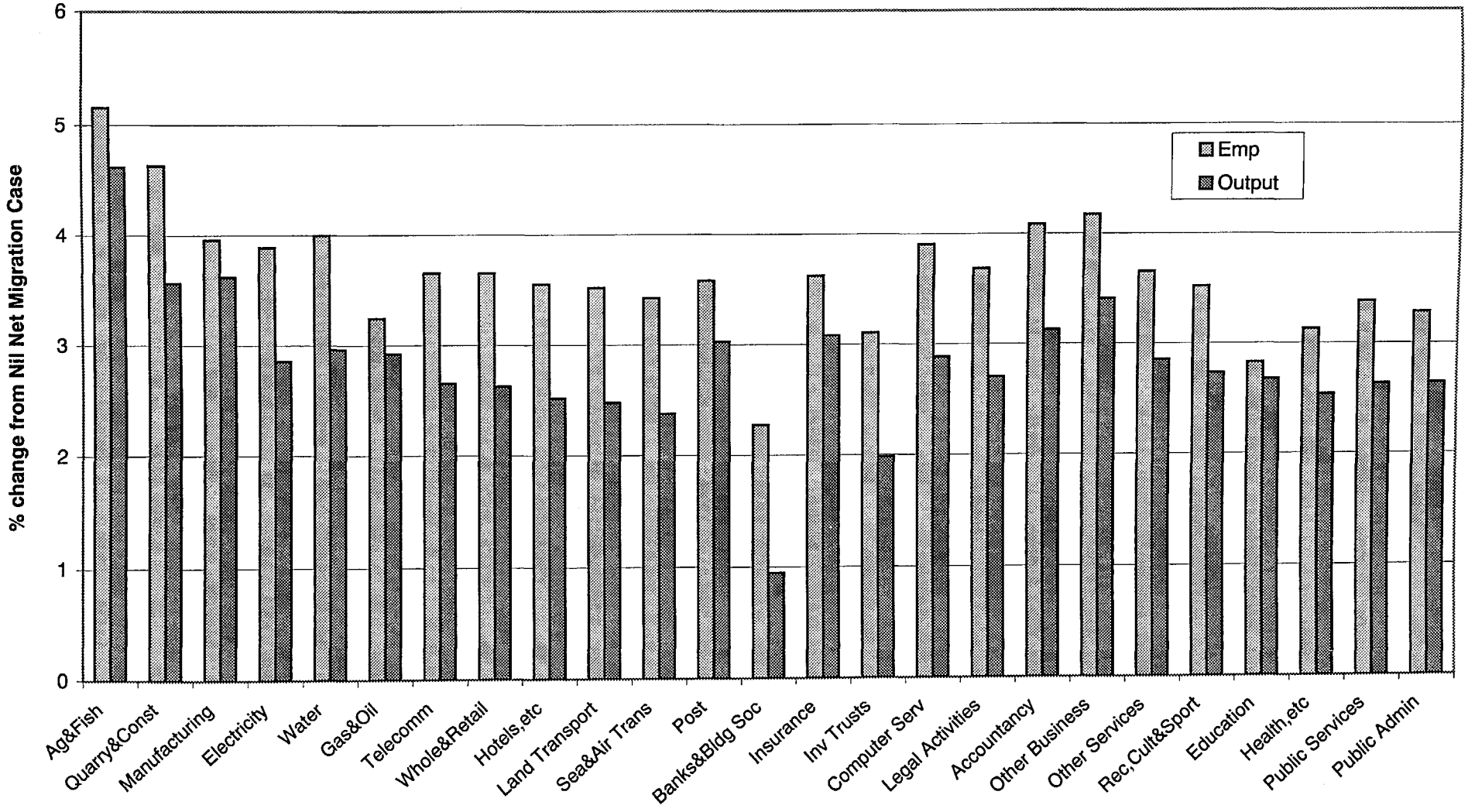


Fig 9.2.6 Additional Impact Of 200 Net Migration Per Annum On GDP And GNP in Jersey, 2001-2011

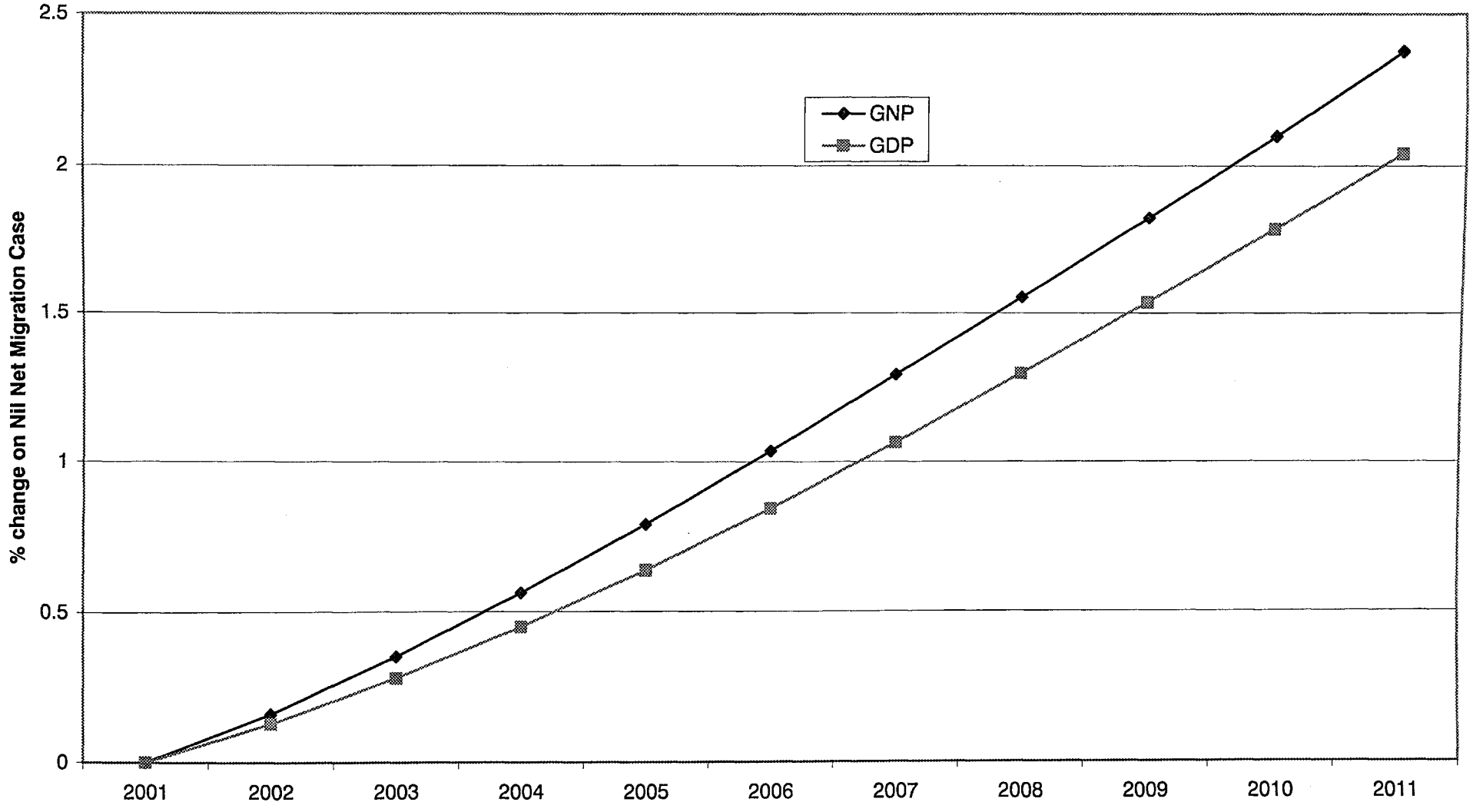


Fig 9.2.7 Additional Impact Of 200 Net Migration Per Annum On Sectoral Employment In Jersey, 2001-2011

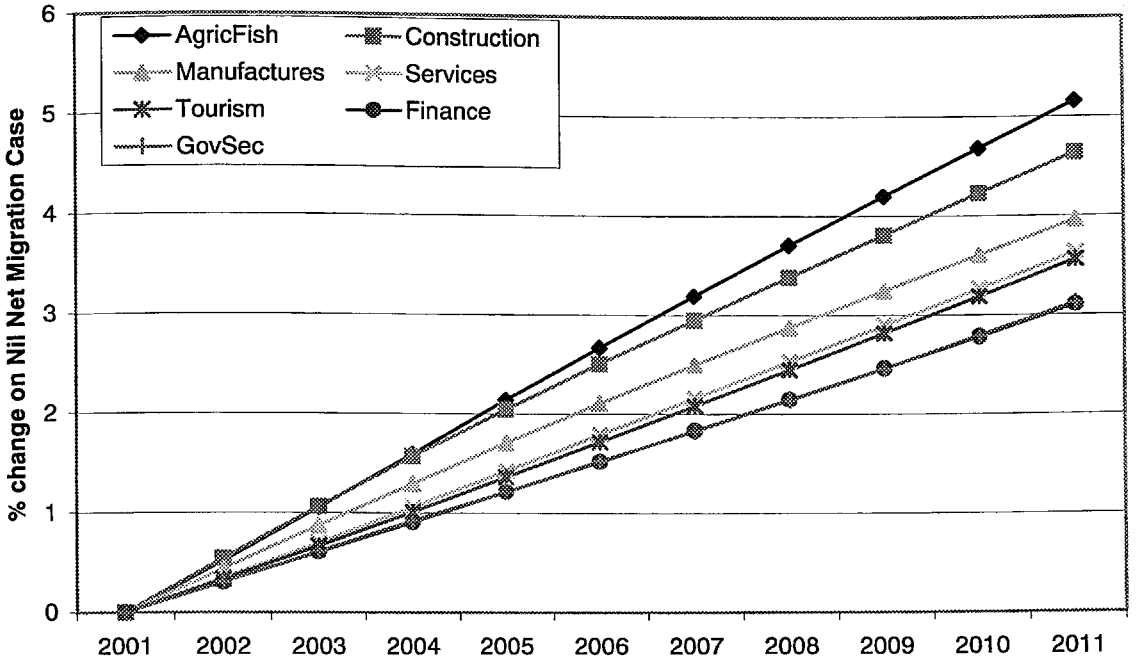
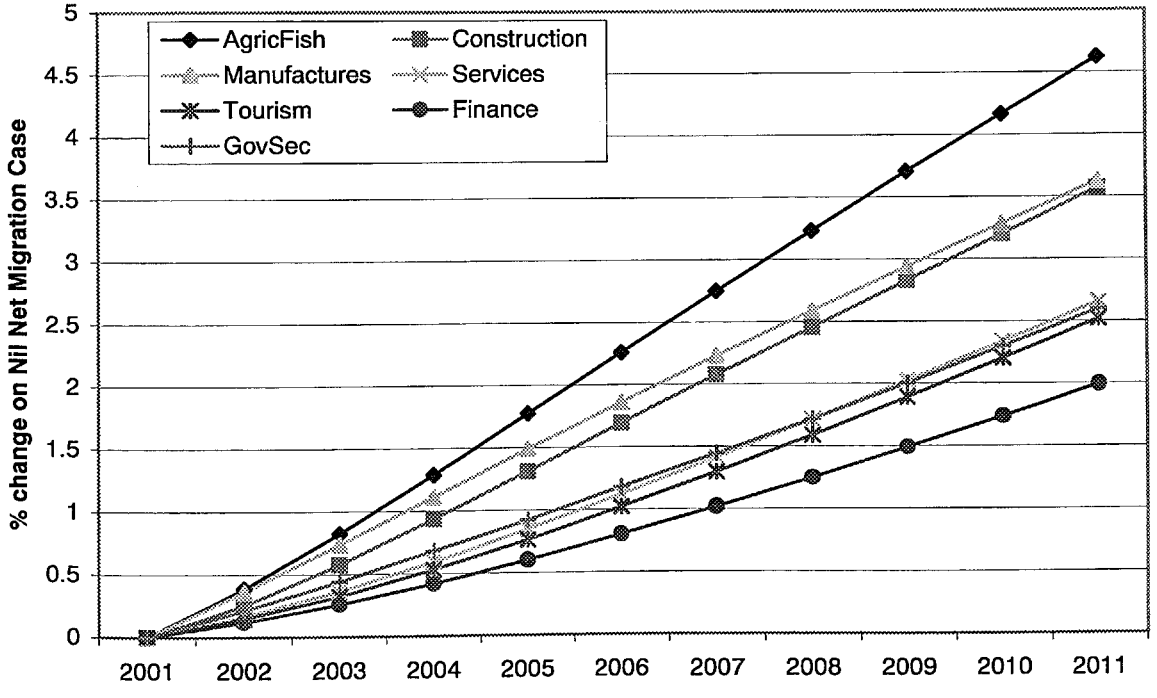


Fig 9.2.8 Additional Impact of 200 Net Migration Per Annum On Sectoral Output In Jersey, 2001-2011



Summary of Results: Simulation 2 - 200 Net In-Migration Case

Table 9.2.1 - Additional Impact By 2011 Of 200 Net In-Migration Per Annum On Aggregate Economic Variables In Jersey

	% Change
GDP	2.041
GDP per head	-0.589
Real Wage	-1.461
Real HH Income & Expend.	1.846
Total Employment	3.58
CPI	-0.353

Table 9.2.2 - Additional Impact By 2011 Of 200 Net In-Migration Per Annum On Sectoral Employment, Output And Price Of Output In Jersey

	% Change			Absolute Change
	Employment	Output	Price of Output	Employment
AgricFish	5.155	4.620	-1.032	105
Construction	4.633	3.566	-0.462	220
Manufactures	3.957	3.623	-0.860	84
Services	3.626	2.653	-0.547	440
Tourism	3.554	2.516	-0.505	214
Finance	3.100	1.994	-0.431	406
GovSec	3.119	2.595	-1.053	217

However, even small changes in input prices have knock-on effects on competitiveness. I report the impact on local output prices for the 7 aggregate sectors in Figure 9.2.4. Whereas the nil net migration scenario leads to conditions in the labour market becoming tighter, thereby reducing the competitiveness of Jersey goods on the international market, allowing 200 net in-migration per annum has the opposite effect. Only Construction experiences a negative competitiveness effect (increase in price), and this is only in the short-run when there is a surge in demand caused by the increase in total population. After four years all sectors exhibit positive competitiveness effects (which again are sufficient to outweigh the negative effects observed in the nil net migration scenario). Therefore, the additional impact on employment and output in all sectors by 2011 is uniformly positive, as shown in Figure 9.2.5. As in the nil net migration case the largest effects occur in those sectors that are labour intensive, and/or have strong backward linkages in the local economy, and/or are open to international trade. As such Agriculture and Fishing, which is labour intensive with relatively strong backward linkages in the local economy and is a very open sector exhibits the biggest increase in both output and employment. On the other hand, Banks & Building Societies exhibits the smallest increase because, although very open, it experiences the smallest competitiveness effect and does not use significant amounts of labour or locally produced goods.

In Figure 9.2.6 I report the impacts on GDP and GNP, which are again very close. This is because the benefits of migration are spread across the private sectors (GNP is slightly higher because sectors like Banks & Building Societies, which is a major source of GDP as against GNP, enjoy relatively little benefit from the in-migration). Figures 9.2.7 and 9.2.8 confirm that all seven aggregate sectors, but especially Agriculture & Fishing and least of all Finance, benefit from the introduction of migrants.

Finally, I summarise the *additional* economic impacts of 200 in-migration *per annum* by 2011 in Tables 9.2.1 and 9.2.2. Aggregate variables such as GDP and total employment increase, as does real household income and expenditure, while wages and prices fall. GDP per head falls further than under the nil net migration scenario

because population increases at a higher rate than GDP. Again, however, I would highlight the fact that these effects are relatively small. The sectoral results show that in percentage terms Agriculture & Fishing is the biggest gainer, but the absolute changes in employment are quite different – Agriculture & Fishing is the second smallest gainer while the aggregate Finance sector, with the smallest percentage change, has the second largest absolute increase in employment. These results reflect the original employment structure in the economy.

In summary, in terms of the economic impacts, allowing 200 in-migration benefits the Jersey economy by providing some slack in the labour market. This allows GDP and employment to increase and causes a fall in wages and the price of local goods, which in turn impacts on competitiveness and increases output and employment.

3.2.2 Environmental Impacts

In Figure 9.2.9 I report the additional environmental impact of 200 migration per annum on physical energy consumption and water use. Again, it is important to note that these results are *additional* to what is reported in Section 3.1 for the nil net migration scenario. For example Figure 9.2.9 shows an increase in water use of 2.96% by 2011. This is additional to the 0.5% fall shown in Figure 9.1.9. Thus, the total effect of allowing 200 migration per annum is to generate an expansion in water use which, by 2011, equals an increase of 2.46% [=2.96+(-0.5%)] on the base period figure.

The positive impact on activity in the Agriculture & Fishing industry is clearly reflected in Figure 9.2.9. In the nil net migration case, where Agriculture & Fishing suffer the largest proportionate decline in output, Figure 9.1.9 shows that the largest negative energy consumption effects are found in the case of the fuels that are exclusively used by Agriculture & Fishing sector (kerosene LSK and LFO). Here, with 200 net in-migration per annum, the effect is reversed, with the largest *positive* impacts found in the case of these two fuels. Moreover, these positive effects are more than sufficient to outweigh the negative ones in the nil net migration case.

Figure 9.2.9 Additional Impact Of 200 Net In-Migration Per Annum On Energy And Water Consumption In Jersey, 2001-2011

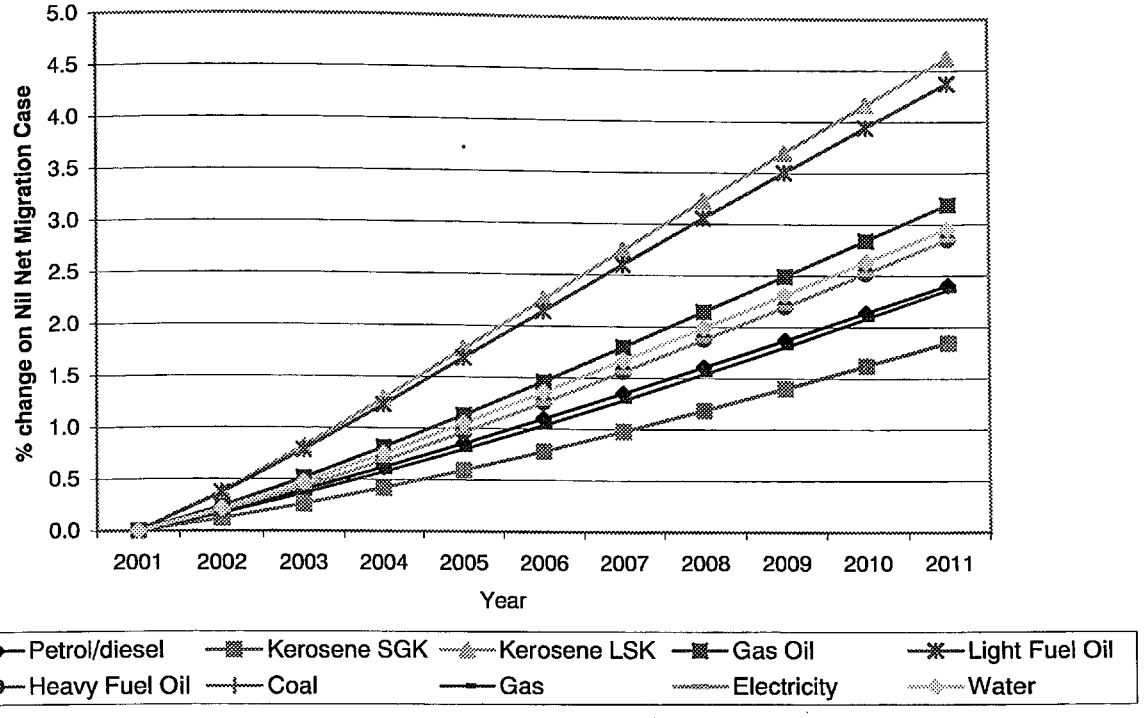
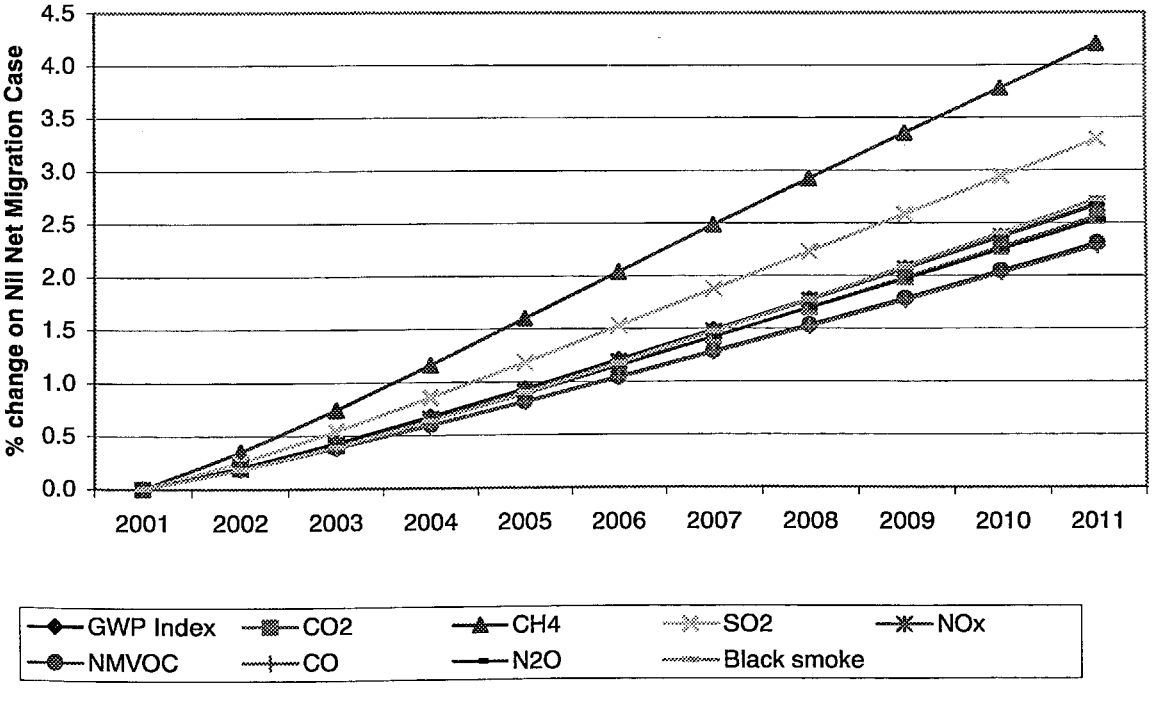


Figure 9.2.10 Additional Impact Of 200 Net In-Migration Per Annum On Emissions Of 8 Individual And 1 Composite Pollution Indicators In Jersey, 2001-2011



Additional Environmental Impact By 2011 Of 200 Net Migration Per Annum

Table 9.2.3 Additional Impact by 2011 Of 200 Net In-Migration per Annum on Traffic-Related Energy Consumption And Emissions Generation In Jersey

	Absolute Change (kg)	% Change from base
Total automotive fuel (petrol/derv) use	1003233	2.41
Government sector	3598	2.59
Other production	293537	3.15
Households	542292	1.85
Tourists	163806	5.71
Emissions of:		
Non-methane volatile organic compounds (NMVOC)	57695	2.31
Carbon monoxide (CO)	312026	2.28
Nitrogen dioxide (N20)	49	2.53
Carbon dioxide (CO2)	7592623	2.56
Nitrous oxides (NOX)	59964	2.68

Table 9.2.4 Additional Impact By 2011 On All Other Environmental Indicators In Jersey

	Absolute Change (kg)	% Change from base
Total energy use		
Kerosene SGK	540703	1.85
Kerosene LSK	52162	4.62
Gas Oil	801104	3.19
Light Fuel Oil	357427	4.37
Heavy Fuel Oil	1944866	2.85
Coal	101140	1.85
Gas (Mains & Bottled Propane/Butane)	305483	2.36
Emissions		
Methane (CH_4)	40422	4.20
Sulphur dioxide (SO_2)	33777	3.30
Black smoke	2002	2.73
Value of Global Warming Potential (GWP) Index for Jersey	8456646	2.67

The next largest impacts shown in Figure 9.2.9 are the increases in consumption of water, gas oil and electricity (along with the heavy fuel oil that is used, with gas oil, in electricity generation in Jersey). These three resources are used in most production activities in Jersey, so the positive impact on their use is driven by the general increase in activity across the economy. (However, as I explain in Section 3.1.2, the resource intensity and scale of resource use in the sectors that benefit most in terms of increased activity will drive the precise magnitude of the effect in each case.)

It is interesting to note that the smallest energy consumption effects are found where households are the heaviest and/or most intensive users. In particular, kerosene SGK, which is only used by households in Jersey (for domestic heating purposes), shows the smallest positive energy consumption effect, along with coal, which is almost exclusively used by households. The positive impact in the case of automotive fuel is also small relative to that observed across other energy/fuel types. This is because the main contributory factor to the impact on automotive fuel use is the rise in real income and expenditure in the household sector, which is more limited, in proportionate terms, than the general increase in productive activity in the economy. (while employment rises with the 200 net in-migration per annum, allowing productive activity to increase, real wages fall, limiting the positive impact on household activity.)

Correspondingly, Figure 9.2.10 shows that the smallest pollution impacts are observed for what I identify as the three main traffic-related pollutants – CO, NMVOC and N_2O. The largest impacts are again observed in the case of methane and SO_2 emissions, both of these effects being driven by the increase in activity in the Agriculture & Fishing sector.

I summarise the additional impacts on energy consumption and pollution generation of 200 net in-migration per annum by 2011 in Tables 9.2.3 and 9.2.4. All the environmental impacts are positive and outweigh those observed in the nil net migration case in Simulation 1, with the implication that the total effect of allowing

200 net in-migration per annum is an adverse one from an environmental perspective. Therefore I conclude that there is a trade-off between the positive economic impacts of relaxing the labour supply constraint in this way (summarised in Tables 9.2.1 and 9.2.2) and the detrimental environmental effects experienced as a result. However, again I would highlight the fact that all the effects (both economic and environmental) are relatively small in proportionate terms.

3.3 Simulation 3: Nil Net Migration With A 50% Export Demand Shock To The Financial And Other Business Services (Finance) Sector

In the first two simulations I report on how changing demographics and limited migration are likely to affect the economy in Jersey by isolating changes in population and working population. In the next two simulations I take each of the migration scenarios identified above and combine them with a 50% export demand shock to the 'financial and other business services' sector (hereafter referred to as Finance)[9].

While in Simulations 1 and 2 I assume no exogenous demand changes in the economy, in Simulations 3 and 4 I examine how population changes affect the economy when these are accompanied by external demand pressures. Under this disturbance I assume that the demand for Jersey finance and finance-related exports experience a permanent 50% step increase in 2002. This means that with constant prices relative to the rest of the world, Jersey's 'Financial and Other Business Services' sector exports will rise permanently by 50% - i.e. the export demand for each of the individual sectors I identify in Section 2 experiences a permanent, but one-off, increase of 50%. (However, note that Jersey Finance sector prices rise as a result of the demand stimulus, so that exports from these sectors never in fact increase by the full 50%.)

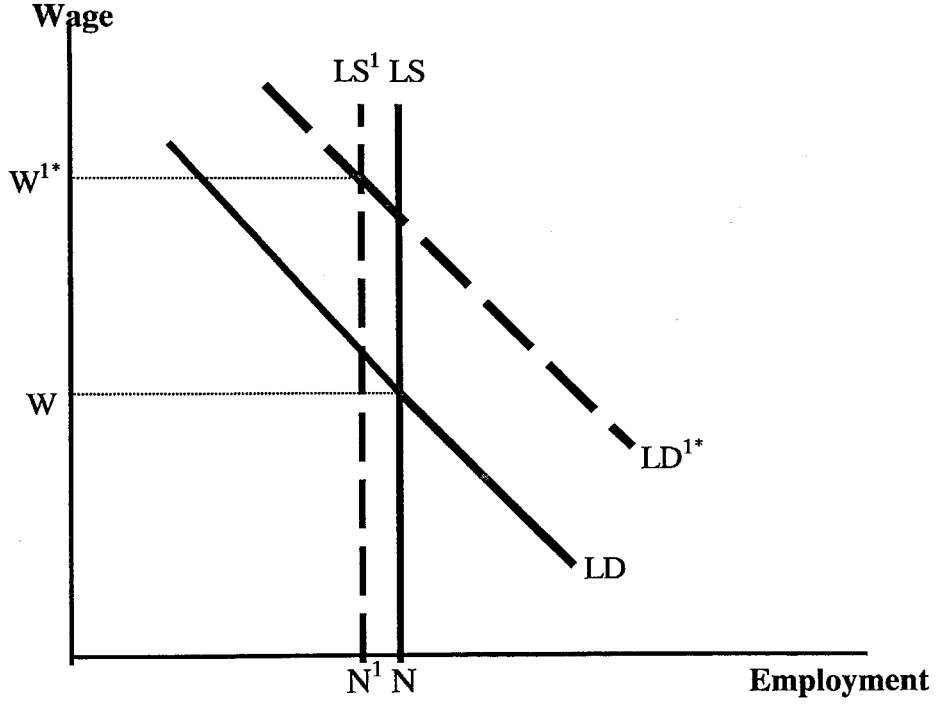
The demographic changes in this simulation are identical to those used in Simulation 1 (see Figure 9.1.1 and Table 9.1), with population increasing whilst the working

[9] See Section 2 and Appendix 9A for details on the composition of this sector.

population falls. Note also that, as with Simulation 1 in Section 3.1, the results of Simulation 3 are measured against the base year data (*not* the nil net migration, no finance shock case).

Again, before I discuss the actual simulation results, the basic analytical argument underlying the key direct impact of the nil net migration scenario combined with a 50% increase in export demand to the Finance sector can be explained using the general equilibrium labour supply and demand diagram in Figure 9.3.

Figure 9.3 General Equilibrium Labour Supply And Demand Under The Nil Net Migration Scenario Combined With A 50% Export Demand Shock To The Finance Sector



As in the case of nil net migration with no demand shock (Simulation 1) the projected fall in the working population causes the general equilibrium labour supply curve to shift inwards from LS to LS^1, with a fall in total employment from N to N^1.

Note that the change in the labour supply and total employment is exactly the same as in Simulation 1. However, in the presence of the export demand shock to the Finance sector the general equilibrium labour demand curve moves up further than it does when the only stimulus to demand is the need to maintain government expenditure per head of population constant with the increase in total population. That is to say, $LD^{1*}>LD^{1}$. As I illustrate in Figure 9.3 this means that conditions in the labour market are even tighter than in Simulation 1 as the real wage level moves up to W^{1*} ($W^{1*}>W^{1}$), where $LS^{1} = LD^{1*}$.

3.3.1 Economic Impacts

In Figure 9.3.1 (below) I report the impact on GDP and employment when the 50% export demand shock to Finance is combined with the zero migration demographic scenario. The first thing to note is that while the change in employment is exactly the same as for Simulation 1, the impact on GDP and GDP per head is very different. In contrast to the small but negative impacts apparent in Simulation 1, here I find that there is a dramatic increase in both GDP and GDP per head, with GDP achieving 9.11% growth by 2011. This is caused by the large increase in export demand in the financial sectors, all of which have high value added intensity. In addition, employment is pulled into these sectors away from low value added activities, all of which combines to push up Jersey GDP. Jersey GDP per head also shows dramatic improvement, but the percentage increase remains slightly below GDP because of the rising population.

I report how the combination of the nil net migration scenario and an export shock affects the price of labour and locally produced goods in Figure 9.3.2. Predictably, the shortage of labour and increase in export demand combine to push up wages. Note the large increase in both real and nominal wages compared with Simulation 1. For example, by 2011 real wages increase by 5.227% compared with only 0.423% in Simulation 1. In the first period to receive the export shock, 2002, the CPI rises by just less than 2% but this level subsequently remains relatively constant, with only a small upward drift to the year 2011. Figure 9.3.3, which reflects competitiveness

effects through changes in output prices, illustrates why the CPI suffers this initial dramatic increase and the subsequent very gradual rise. In 2002, the period of the shock, prices in Finance, Construction and the Government Sector rise markedly, due to the direct impacts of the combined export demand and demographic shocks and the associated increase in demand for investment. As investment continues, however, prices in these sectors start to fall into line with the price rises in the other sectors. In general, the competitiveness of Jersey sectors on the international market suffers as prices rise in all markets.

I provide a more sectorally disaggregated summary in Figure 9.3.4, where I report changes in employment and output by 2011. In the previous simulations (with no exogenous demand shock to the Finance sector) employment or output in every private sector moved in the same direction. This is clearly not the case here, with some sectors showing increases and others falls. There are several reasons for this. Starting with the Finance sectors, most exhibit large increases in employment and output, which can be directly attributed to the export shock. The relative size of the impact in each of the finance sectors depends on two factors: firstly the proportion of total output exported, and secondly the size of the competitiveness effect and its impact on exports. By 2011 none of the sectors actually experience a full 50% increase in exports because increases in the price of sectoral outputs – i.e. decreases in competitiveness - ensure that this amount is never actually achieved. For example, Other Business Activities shows only a small increase in output and a fall in employment. There are two reasons for this. Firstly, it only exports roughly a tenth of its output. Secondly, Other Business Activities experiences the largest negative competitiveness effect of the seven Finance sectors because of its high labour intensity. On the other hand Investment Trusts shows the largest proportional increase because it exports almost its entire output. Note that by 2011 employment changes in all sectors are lagging behind output changes due to the shortage of labour. The higher proportional increases in output are achieved as firms switch towards capital and away from labour due to the rise in cost of employing the latter.

Fig 9.3.1 Impact Of Nil Net Migration On GDP, GDP Per Head And Total Employment In Jersey, 2001-2011, With A 50% Export Demand Shock To The Finance Sector

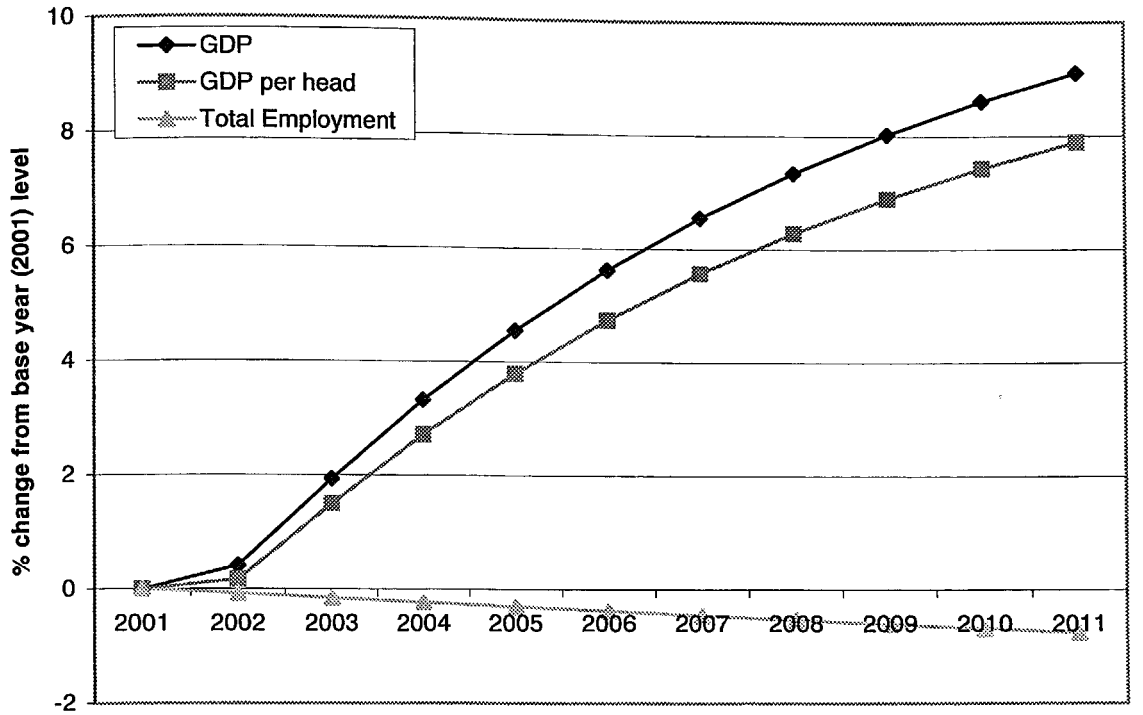


Fig 9.3.2 Impact Of Nil Net Migration On The CPI And On Before-Tax Real And Nominal Wages In Jersey, 2001-2011, With A 50% Export Demand Shock To The Finance Sector

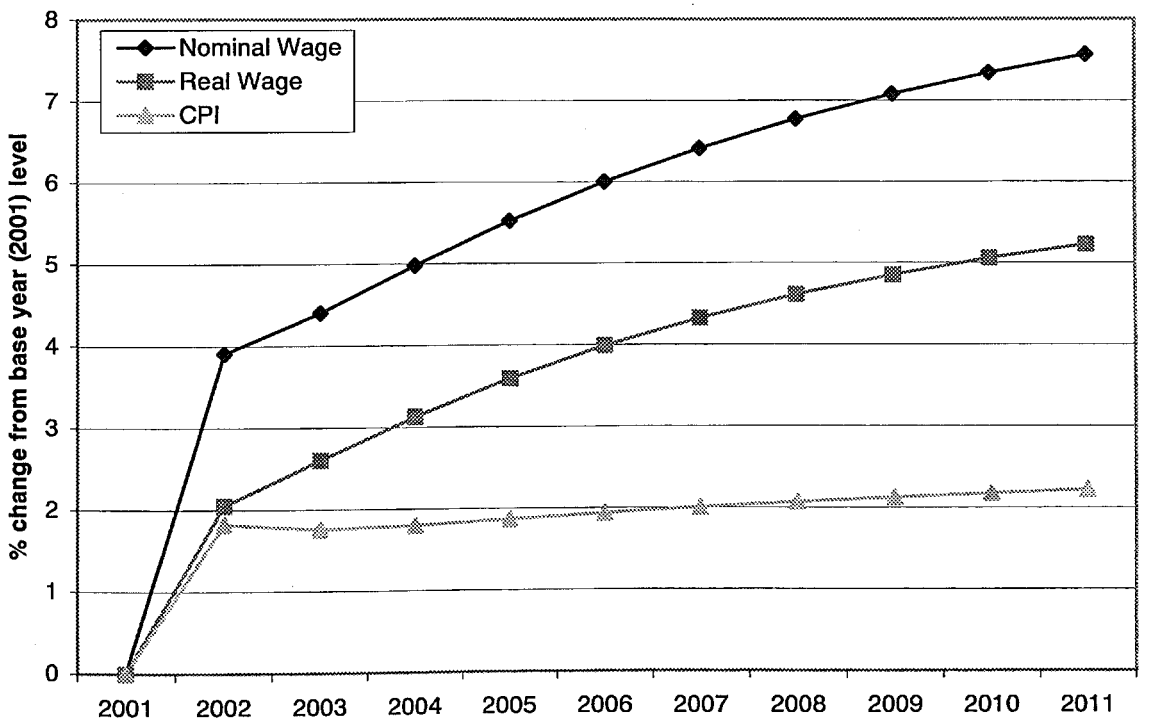


Fig 9.3.3 Impact Of Nil Net Migration On Competitiveness (Local Output Prices) In Jersey, 2001-2011, With A 50% Export Demand Shock To The Finance Sector

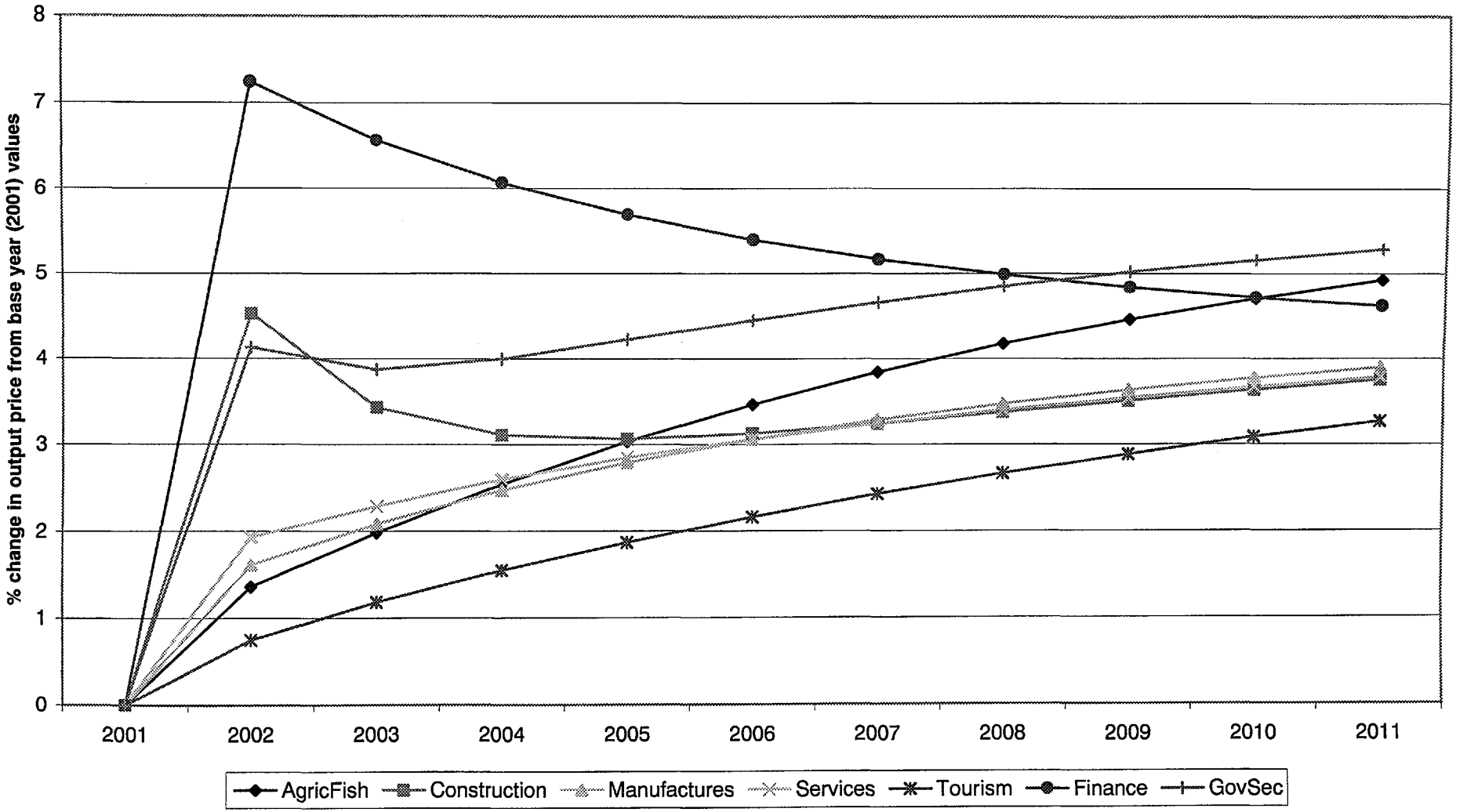


Fig 9.3.4 Impact By 2011 Of Nil Net Migration On Sectoral Employment And Output In Jersey With A 50% Export Demand Shock To The Finance Sector

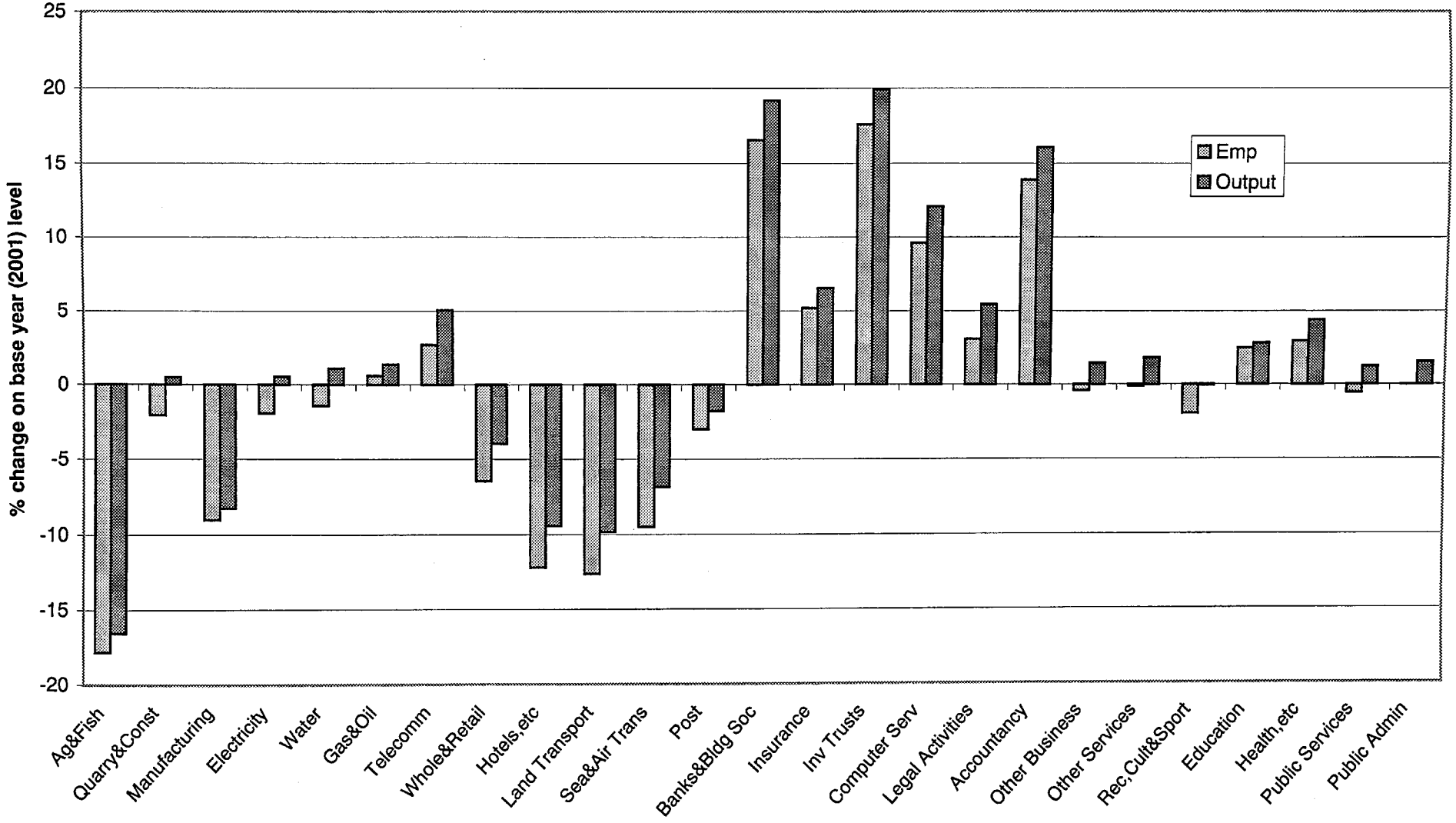


Fig 9.3.5 Impact Of Nil Net Migration On GDP And GNP In Jersey, 2001-2011, With A 50% Export Demand Shock To The Finance Sector

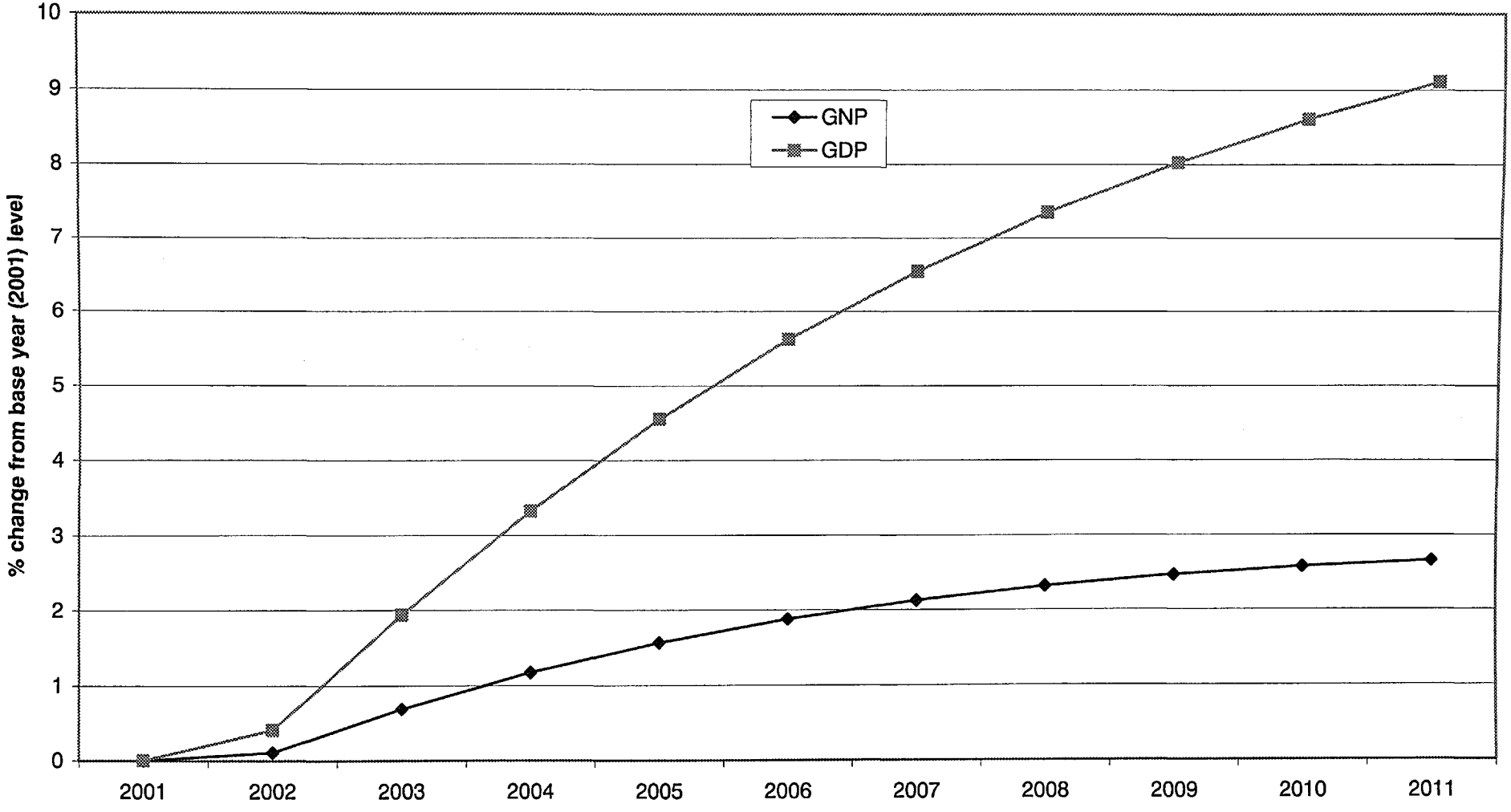


Fig 9.3.6 Impact Of Nil Net Migration On Sectoral Employment In Jersey, 2001-2011, With A 50% Export Demand Shock To The Finance Sector

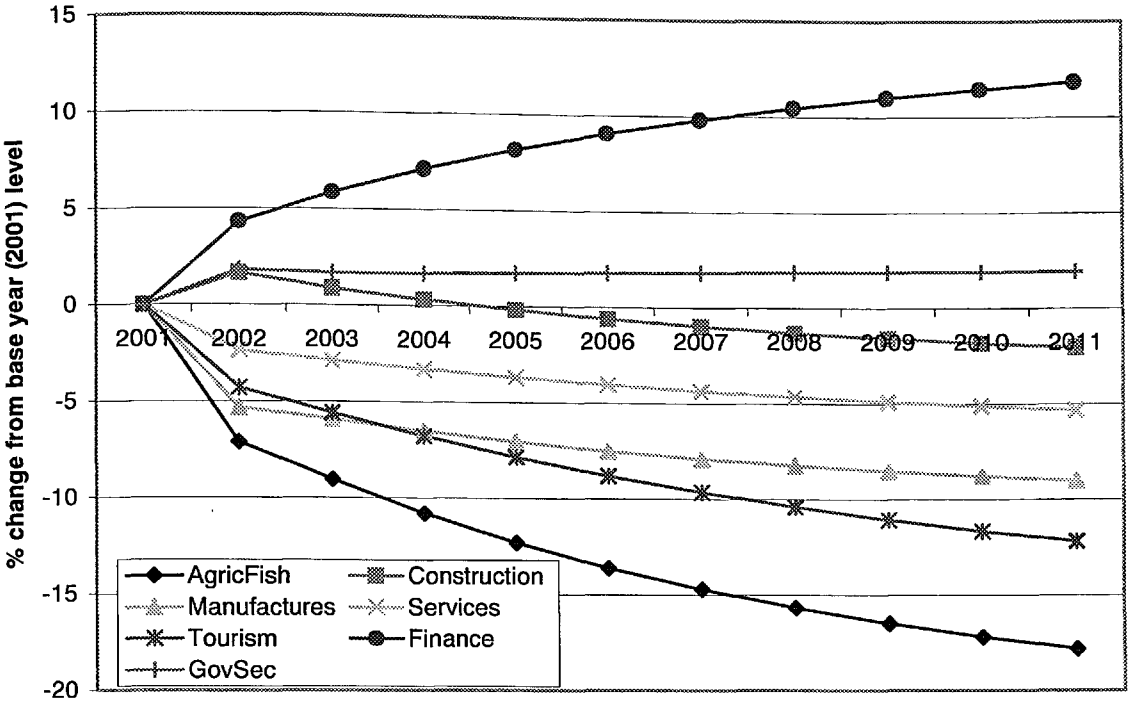
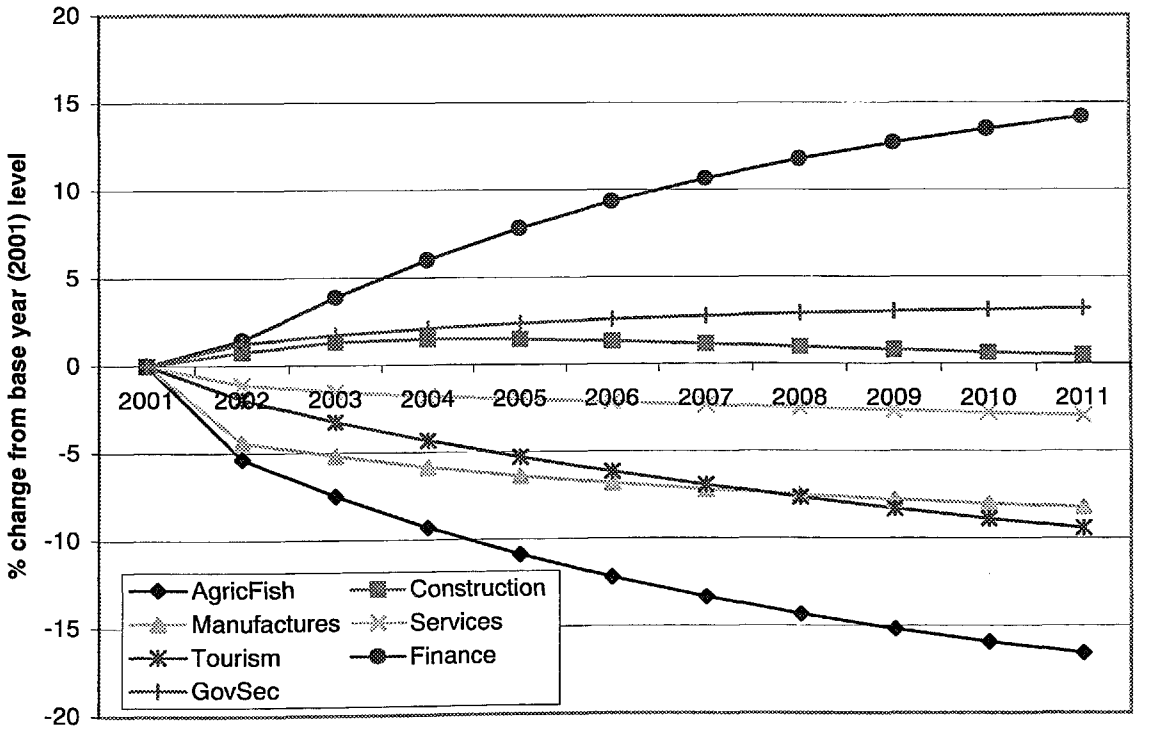


Fig 9.3.7 Impact Of Nil Net Migration On Sectoral Output In Jersey, 2001-2011, With A 50% Export Demand Shock To The Finance Sector



However, the impact of this export shock combined with the nil net migration scenario is not limited to the Finance sectors at which it is directed. The 25-sector results in Figure 9.3.4 and the 7-sector (time series) results in Figures 9.36 and 9.3.7 show that the Finance sectors *are* the clear winners in terms of increased output and employment. Not all sectors improve, however, and there are some notable falls in output and employment. This is a result of wage rates being bid up as the Finance sectors compete for a larger share of the limited labour supply in order to meet increased export demand.

The clear losers are the other major exporters and tourist industries. The biggest loser is Agriculture & Fishing, where production is very export-intensive – 61% of output is produced to meet non-local demand – and very labour-intensive, with the results that output and employment both fall by over 16% by 2011. Manufacturing, which exports a large proportion of its output, also suffers, as does Wholesale & Retail Trade. The other sectors to experience reductions in activity are those which service the tourist industry (Hotels, Restaurants & Catering) and the transport sectors (SATTS and Land Transport).

There is an intermediate group, composed of Quarrying & Construction, the four government sectors and the utilities sectors (Electricity, Water, Gas, Oil & Fuel Distribution and Telecommunications), which are largely sheltered from external competition and benefit from higher domestic demand (consumption, investment or government), but face higher wages. In these sectors output increases while employment falls, or shows only a slight increase (depending on the labour intensity of production).

For the first time there is also a significant difference between GDP and GNP, as illustrated in Figure 9.3.5. This reflects the crowding out effects identified above. The increase in GNP is much lower than that observed in GDP because much of the increased output resulting from the shock occurs in Finance firms that are not owned by Jersey nationals. GNP, on the other hand, only takes into account income accruing to local people and firms and therefore adjusts for the fact that much of the

income earned by foreign-owned firms accrues to foreign nationals and cannot therefore be counted as part of total Jersey income. At the same time, domestically owned firms, which add to GNP, are crowded-out. The combination of these two factors results in a relatively small increase in GNP.

Finally, I present a summary of results by 2011 in Tables 9.3.1 and 9.3.2. Even with a falling labour supply, the 50% export demand shock pushes up GDP and GDP per head, by 9.11% and 7.89% respectively. (However note that GNP and GNP per head, not shown, only increase by 2.65% and 1.69% respectively.) The tight labour market serves to push up real and nominal wages and local prices, which in turn reduces the competitiveness of all sectors. Export industries in particular suffer from the negative competitiveness effect. For example, in Table 9.3.2 Agriculture shows a 16.57% fall in output. In fact, all sectors apart from Finance, the Public Sectors and Construction are adversely affected under this scenario. Although Finance receives a 50% export shock, its output only increases by 14.16% by 2011 because the increase in factor prices (notably labour) reduces its competitiveness on the international market.

The column showing absolute changes in employment is interesting in that it demonstrates the extent of crowding-out in Jersey under the scenario simulated here. When it comes to competition over labour, the non-finance sectors are in a weak position because of the relatively low average wages that they can offer. Therefore, the non-Finance private sectors all suffer heavy employment losses as they are outbid for labour by Finance, which increases employment by 1,548 workers. This has implications for one other area of activity. The movement of labour into Finance sectors like Banks & Building Societies and Investment Trusts & Fund Managers, which pay relatively high average wages, has important consumption and income effects. Therefore, while total employment falls slightly, the reallocation of labour towards high wage activities, along with the general increase in the real wage that results from the tightness of the labour market, stimulates real household income and expenditure, which rises by 11.73% by 2011.

Summary of Results: Simulation 3 - Net Nil Migration with a 50% Export Demand Shock to the Financial and other Business Sector

Table 9.3.1 - Impact By 2011 Of Nil Net Migration On Aggregate Economic Variables In Jersey With A 50% Export Demand Shock To The Finance Sector

	% Change
GDP	9.11
GDP per head	7.89
Real Wage	5.227
Real HH Income & Expend.	11.73
Total Employment	-0.758
CPI	2.219

Table 9.3.2 - Impact By 2011 Of Nil Net Migration On Sectoral Employment, Output And Price Of Output In Jersey, With A 50% Export Demand Shock To The Finance Sector

	% Change			Absolute Change
	Employment	Output	Price of Output	Employment
AgricFish	-17.818	-16.572	4.928	-363
Construction	-2.049	0.481	3.754	-97
Manufactures	-9.020	-8.234	3.897	-192
Services	-5.328	-2.966	3.786	-646
Tourism	-12.193	-9.424	3.269	-735
Finance	11.825	14.164	4.626	1,548
GovSec	1.926	3.175	5.290	134

Figure 9.3.8 Impact Of Nil Net Migration On Energy And Water Consumption In Jersey, 2001-2011, With A 50% Export Demand Shock To The Finance Sector

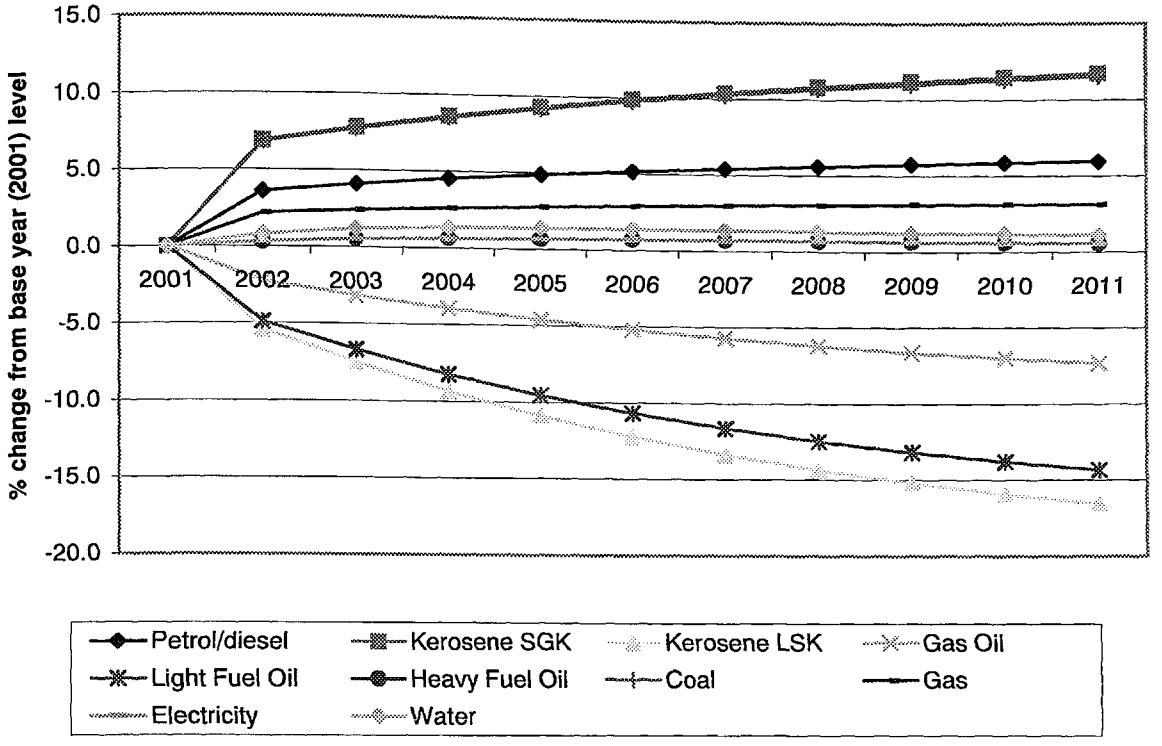
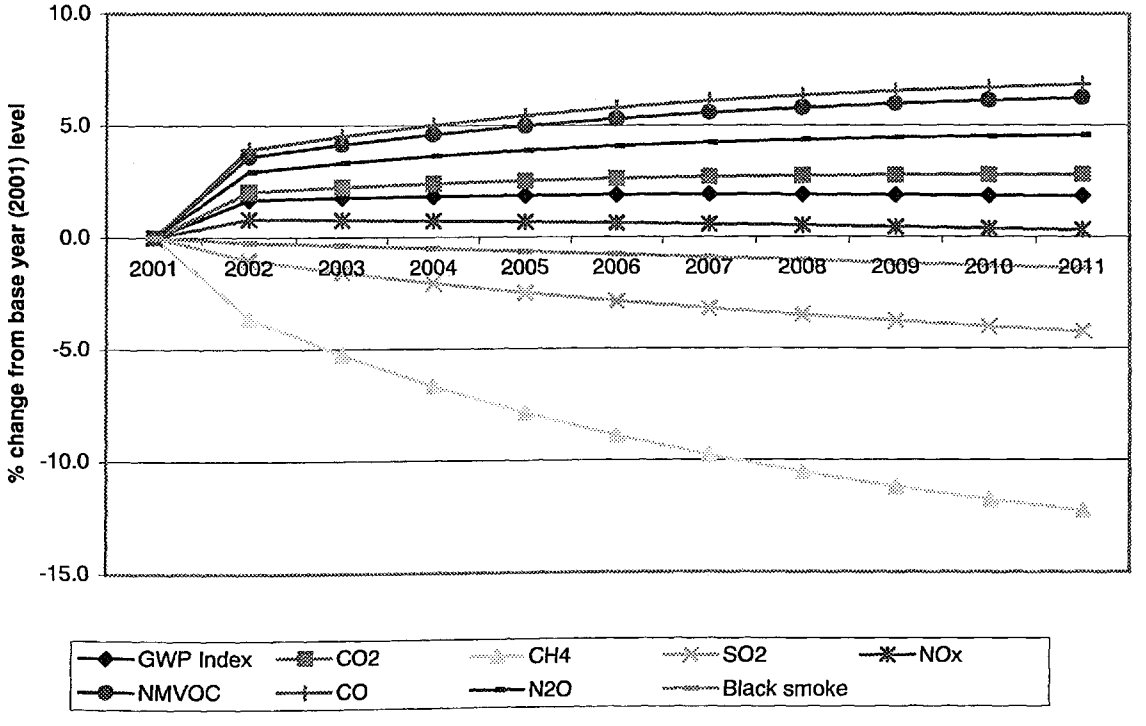


Figure 9.3.9 Impact Of Nil Net Migration On Emissions Of 8 Individual And 1 Composite Pollution Indicators In Jersey, 2001-2011, With A 50% Export Demand Shock To The Finance Sector



Environmental Impact By 2011 Of Nil Net Migration With A 50% Increase In Finance Sector Export Demand

Table 9.3.3 Impact by 2011 of Nil Net Migration On Traffic-Related Energy Consumption And Emissions Generation In Jersey, With a 50% Export Demand Shock To The Finance Sector

	Absolute Change (kg)	% Change from base
Total automotive fuel (petrol/derv) use	2483664	5.96
Government sector	4939	3.55
Other production	-329383	-3.54
Households	3445875	11.73
Tourists	-637767	-22.25
Emissions of:		
Non-methane volatile organic compounds (NMVOC)	155689	6.23
Carbon monoxide (CO)	934057	6.84
Nitrogen dioxide (N20)	88	4.56
Carbon dioxide (CO2)	8233940	2.78
Nitrous oxides (NOX)	6616	0.30

Table 9.3.4 Impact By 2011 Of Nil Net Migration On All Other Environmental Indicators In In Jersey, With A 50% Export Demand Shock To The Finance Sector

	Absolute Change (kg)	% Change from base
Total energy use		
Kerosene SGK	3435777	11.73
Kerosene LSK	-187107	-16.57
Gas Oil	-1840099	-7.34
Light Fuel Oil	-1171197	-14.33
Heavy Fuel Oil	372885	0.55
Coal	629686	11.53
Gas (Mains & Bottled Propane/Butane)	405674	3.14
Emissions		
Methane (CH_4)	-118040	-12.27
Sulphur dioxide (SO_2)	-43484	-4.24
Black smoke	-1042	-1.42
Value of Global Warming Potential (GWP) Index for Jersey	5782404	1.82

3.3.2 Environmental Impacts

In Figure 9.3.8 I report how the combination of the nil net migration scenario and a 50% increase in export demand to the Finance sectors affects energy and water consumption in the Jersey economy. It may be expected that because finance-related activities, which are among the least energy-intensive in the economy, crowd out the activities of more energy-intensive sectors, energy consumption in the economy will fall. However, the income and consumption effects of increased activity in the Finance sector and the higher general real wage rate have significant implications for energy consumption by Jersey households. The largest impact is on consumption of kerosene SGK and coal for household heating purposes. Use of these two types of fuel is almost exclusively associated with the household sector. Therefore there are virtually no reductions in consumption of these fuels from decreased activity elsewhere in the economy to limit the impact of increased household consumption. On the other hand, in the case of the increased consumption of automotive fuels by households, this is partially offset by reductions in usage elsewhere in the economy (particularly in the Agriculture & Fishing and Wholesale & Retail Trade sectors). However increases in automotive fuel use in the Household sector and in those production sectors where activity is stimulated are more than sufficient to bring about an increase in consumption that reaches almost 6% by 2011.

The only fuels for which there is a fall in consumption are LFO and kerosene LSK – both of which are used almost exclusively in Agriculture & Fishing activities – and gas oil. While the latter is used in most commercial sectors for heating purposes, four of the Finance sectors do not use gas oil (relying instead on gas and/or electricity) and the other three have relatively low gas oil intensities. The most gas oil intensive sectors are ones where the level of activity declines (e.g. Agriculture & Fishing, Manufacturing and Hotels, Restaurants & Catering). On the other hand, the impact on gas, electricity and water use is positive, largely reflecting the presence of household consumption (gas oil is not used in the household sector). The net impact on electricity and water consumption is small, only 0.55% and 1.1% respectively by 2001. The impact on gas use is more significant, 3.14% by 2011. Again, this type of

variation in results reflects differing sectoral breakdowns of total resource use – for example, the sector where activity falls most under this scenario, Agriculture & Fishing, does not use gas as an input to production.

I report the impacts on pollution generation from the export demand shock under the nil net migration hypothesis in Figure 9.3.9. In line with the increase in automotive fuels I find the biggest impacts in the case of the three mainly traffic-related pollutants – CO, NMVOC and N_2O. While there is some increase in these pollutants from the increase in Public Service (waste incineration) activities, and from automotive fuel use in those commercial sectors where positive output effects are observed, the bulk of the positive impact on these pollutants is due to increased real household income and expenditure.

There are smaller positive pollution impacts in the case of CO_2 and NO_X, and negative ones in the case of black smoke, SO_2 and methane (CH_4). Again, the direction and magnitude of the impacts on different pollutant variables depends on what happens to activity in different sectors of the economy. For example the large negative impact on methane generation is mainly explained by the decline in activity in the Agriculture & Fishing sector, as is the fall in SO_2 generation. The decline in emissions of black smoke is mainly due to the reduction in aircraft movements in the Sea & Air Transport and Transport Support (SATTS) sector, though this is slightly offset by the increase in generation of this pollutant that accompanies the increase in electricity production shown in Figure 9.3.8.

The impacts on NO_X and CO_2 are more complex: both of these pollutants are generated by a range of activities and are emitted in most sectors of the economy. The negative impact on NO_X generation is mainly driven by reductions in activity in Agriculture & Fishing and SATTS, both of which have extremely high NO_X-intensities. However a number of other sectors, such as Manufacturing, Hotels, Restaurants & Catering and Wholesale & Retail Trade also contribute to the negative effect. These are sectors that suffer significant declines in activity and which, while being much less NO_X-intensive than sectors like Agriculture & Fishing, SATTS and

Electricity, do have high NO_X-intensities relative to other sectors of the economy. The reduction in tourist expenditure contributes in a similar manner.

The negative effects on NO_X generation are partially offset by increases in activity in the most NO_X-intensive sector of the economy, Electricity, in Public Services and a range of other sectors with relatively high NO_X-intensities and/or where there is a large positive output effect (e.g. Investment Trusts & Fund Managers). However, the main contributory factor to the positive NO_X effect is increased energy consumption in the household sector. A similar story can be told in the case of CO_2. However, the contributions of individual production sectors to the total impact are less significant (although the key contributors tend to be the same as in the case of NO_X): the impact on total CO_2 generation is more clearly dominated by the increase in energy consumption in the household sector.

I summarise the impacts on energy consumption and pollution generation by 2011 from the 50% Finance sector export demand shock under the nil net migration hypothesis in Tables 9.3.3 and 9.3.4. The negative effect on the sectors that serve tourist demand is clearly reflected in Table 9.3.3, where I report that while the net effect on traffic-related energy consumption is positive, use of automotive fuel by tourists declines by almost a quarter. The other negative element of the total effect on automotive fuel use is the net change in private sector production activities, reflecting the fact that increased activity in the Finance sectors crowds out activity in sectors where production is more automotive fuel intensive. However, the income and consumption effects of the increased dominance of the relatively high wage Finance sectors and the upward pressure on real wages across the economy mean that these negative effects are more than offset by increased automotive fuel use in the household sector. There is also a general increase in the generation of traffic-related pollutants.

On the other hand, in Table 9.3.4 I report that the environmental impact of the increase in Finance sector activity under the nil net migration hypothesis is negative for a number of other types of energy consumption and pollution generation. This is

particularly the case where households are not direct users or polluters, with the implication that the impact of contracting sectors dominates.

3.4 Simulation 4: Additional Impact Of 200 Net In-Migration Per Annum With A 50% Export Demand Shock To The Financial And Other Business Services (Finance) Sector

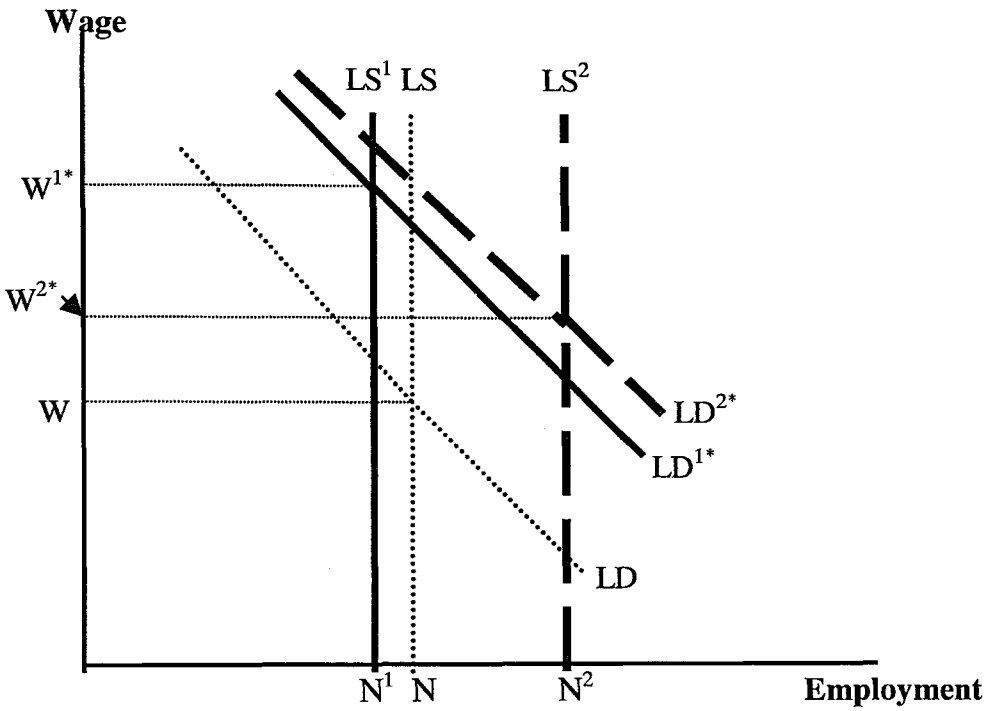
Here I examine the additional impact on the Jersey economy of allowing 200 net in-migration per annum, under the same demographic hypothesis as Simulation 2 (see Figure 9.2.1 and Table 9.2), but this time in the presence of the demand disturbance introduced in Simulation 3. To isolate the impact of allowing limited in-migration under this circumstance, the results reported in this section are compared to the nil net migration case reported in Section 3.3, in the same way as Section 3.2 reports the additional impacts of limited in-migration in Simulation 2 relative to Simulation 1. In fact, I find that the results generated by this fourth simulation are very similar to those reported for Simulation 2, in that they are concerned with what happens when the employment constraint is lifted through in-migration, only in this case under a different demand scenario.

In Figure 9.4 (below) I illustrate the basic analytical result of relaxing the labour supply constraint by allowing limited (200 per annum) net in-migration in the presence of the Finance sector demand shock.

As in Simulation 2 the general equilibrium labour supply curve shifts out from LS^1 to LS^2 (i.e. labour supply conditions are the same in Simulations 1 and 2 and Simulations 3 and 4 respectively). However, demand conditions are different here: in Section 3.3 above I explain that the Finance sector demand shock moves the general equilibrium labour demand curve up from LD to LD^{1*}. Here, there is a further increase, LD^{1*} to LD^{2*}, as public sector activity increases further to maintain fixed government expenditure per capita in the presence of the additional workers. However the net additional impact of relaxing the labour market constraint is to lower the real wage level in the economy, from W^{1*} to W^{2*}, as the total labour supply

and employment rise from N^1 to N^2. However, note that in the presence of the Finance sector export demand shock W^{2*} is higher than the original wage level, W (because of the large increase in labour demand that would be expected from a 50% increase in Finance sector export demand in Jersey).

Figure 9.4 General Equilibrium Labour Supply And Demand Under The 200 Net In-Migration Scenario Combined With A 50% Export Demand Shock To The Finance Sector



3.4.1 Economic Impacts

In Section 3.3 I report that the main problem for the Jersey economy is that it cannot gain the full benefits of the export demand shock because of the shortage of labour and subsequent crowding-out. Therefore, given the basic analytical argument presented in Figure 9.4, I would expect the additional economic impacts with 200 net in-migration to be positive.

Fig 9.4.1 Additional Impact Of 200 Net In-Migration Per Annum On GDP, GDP Per Head And Total Employment In Jersey, 2001-2011, With A 50% Export Demand Shock To The Finance Sector

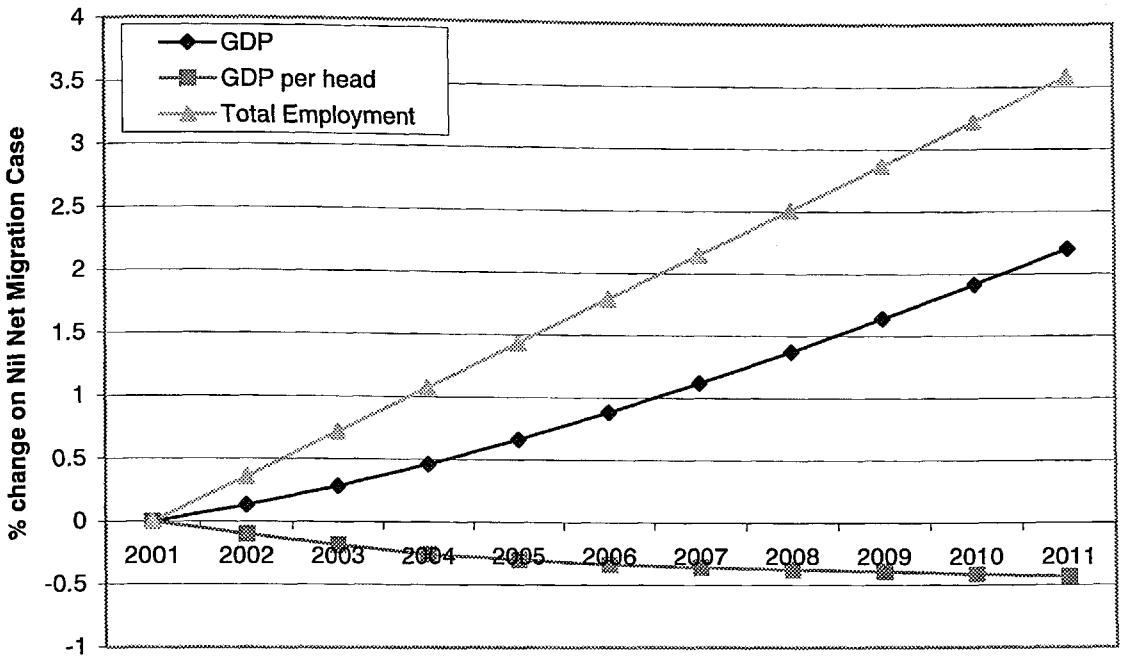


Fig 9.4.2 Additional Impact Of 200 Net In-Migration Per Annum On The CPI And On Before-Tax Real And Nominal Wages In Jersey, 2001-2011, With A 50% Export Demand Shock To The Finance Sector

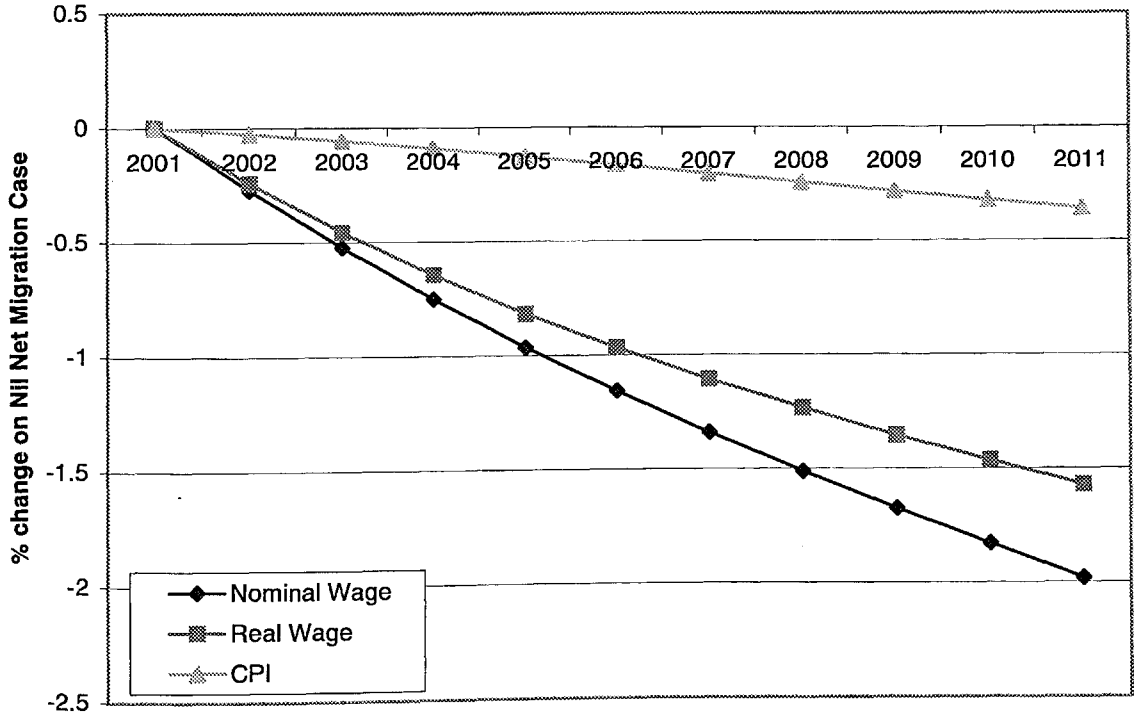


Fig 9.4.3 Additional Impact Of 200 Net In-Migration Per Annum On Competitiveness (Local Output Prices) In Jersey, 2001-2011, With A 50% Export Demand Shock To The Finance Sector

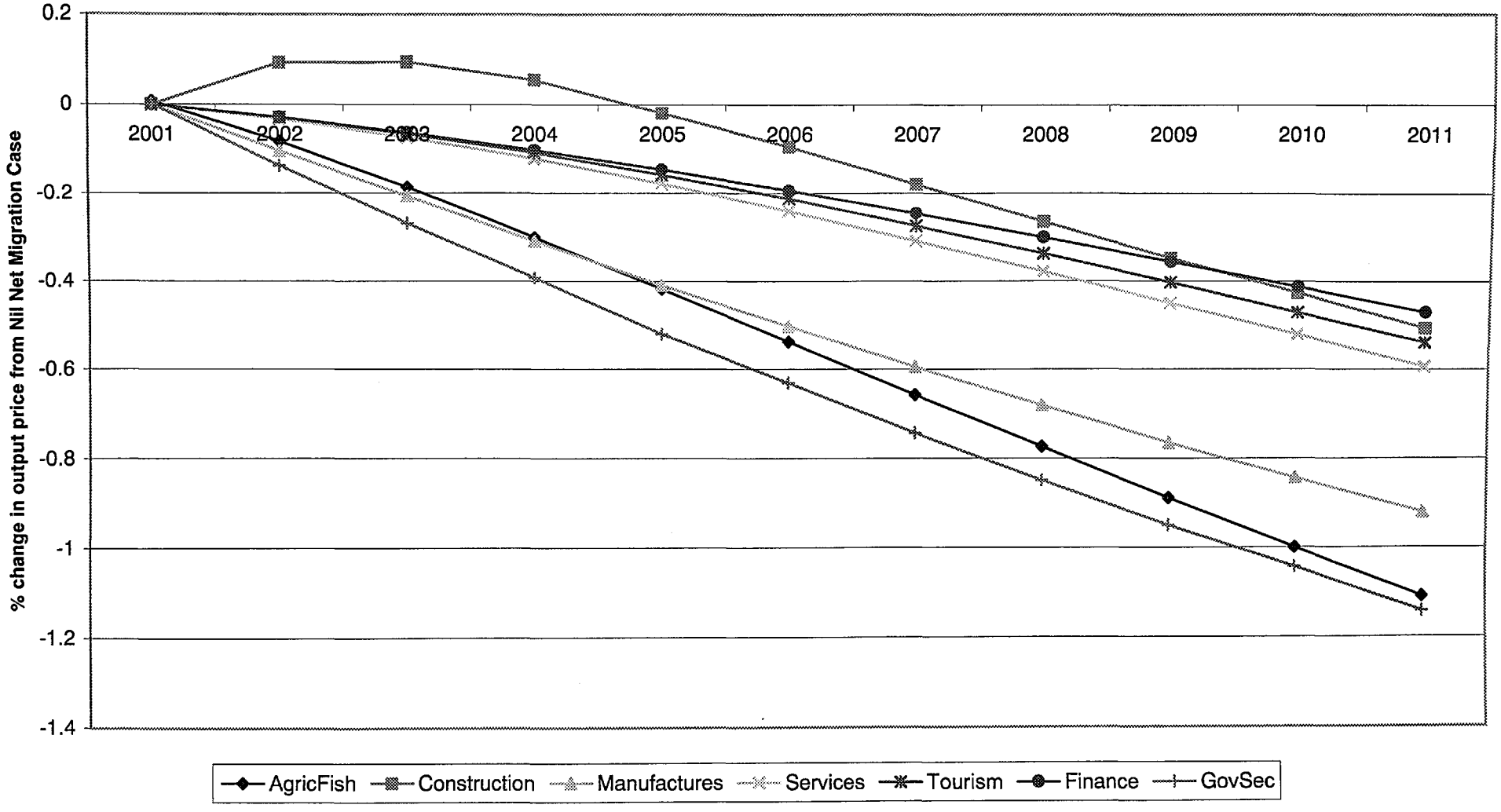


Fig 9.4.4 Additional Impact By 2011 Of 200 Net In-Migration Per Annum On Sectoral Employment And Output In Jersey, With A 50% Export Demand Shock To The Finance Sector

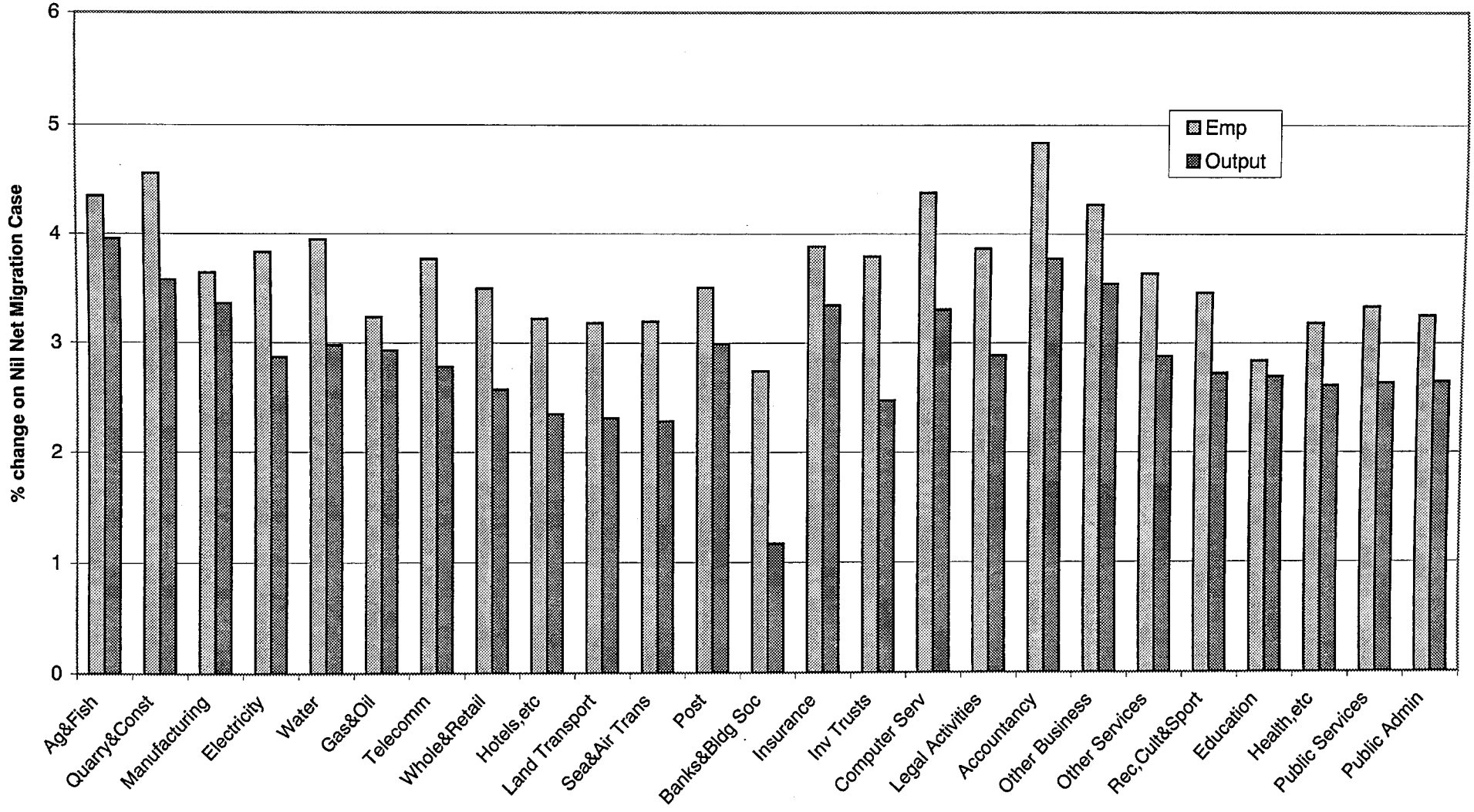


Fig 9.4.5 Additional Impact Of 200 Net In-Migration Per Annum On GDP And GNP In Jersey, 2001-2011, With A 50% Export Demand Shock To The Finance Sector

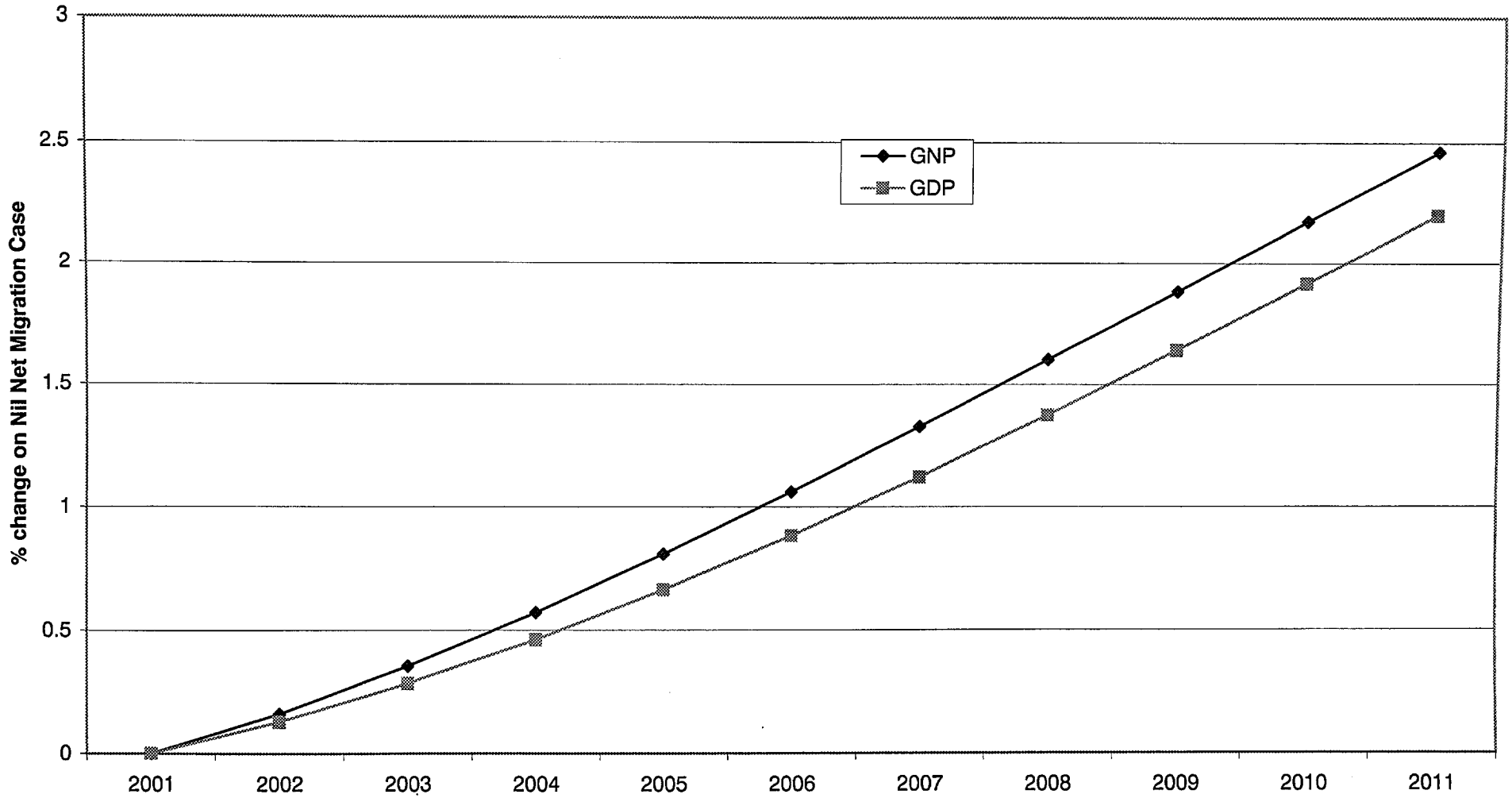


Fig 9.4.6 Additional Impact Of 200 Net In-Migration Per annum On Sectoral Employment In Jersey, 2001-2011, With A 50% Export Demand Shock To The Finance Sector

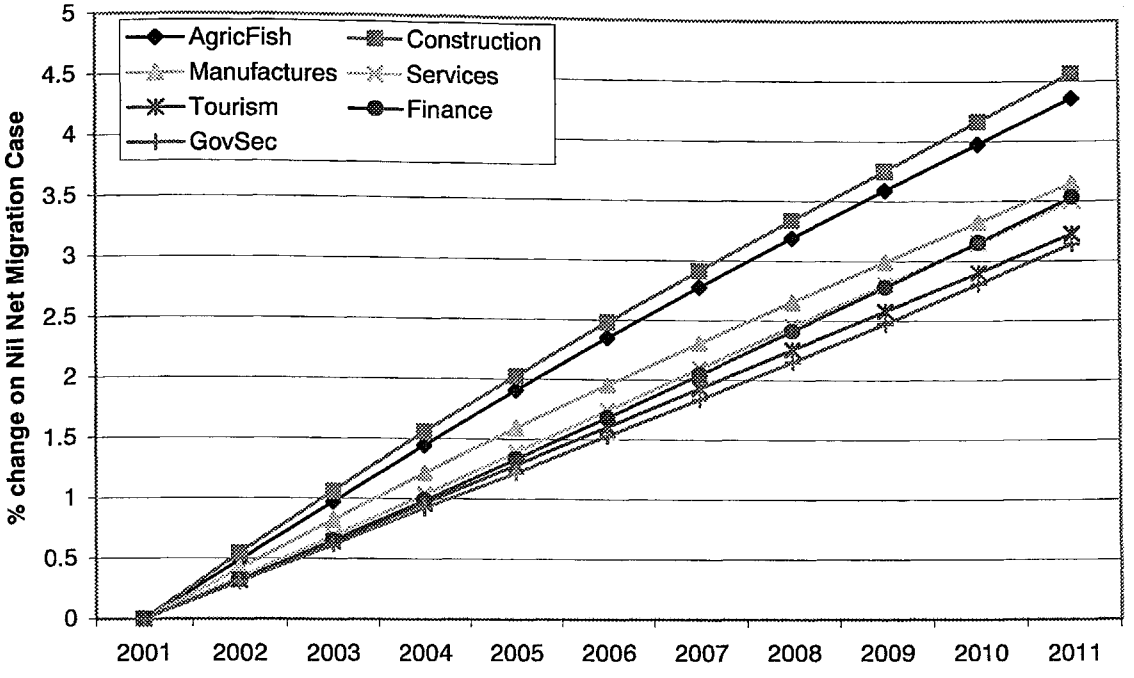
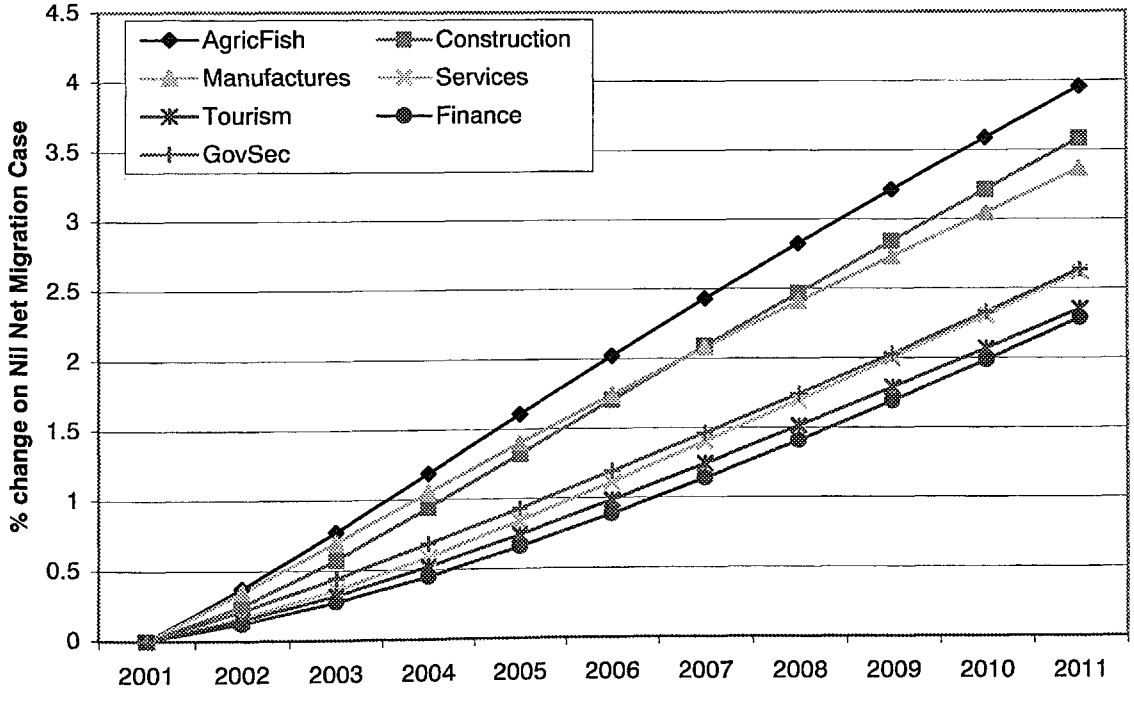


Fig 9.4.7 Additional Impact Of 200 Net In-Migration Per Annum On Sectoral Output In Jersey, 2001-2011, With A 50% Export Demand Shock To The Finance Sector



Looking at Figure 9.4.1 this certainly appears to be the case. GDP increases steadily and by 2011 is 2.197% above the nil net migration scenario. However, the additional increase in total population means that GDP per head is less than it is if migration is constrained.

In Figure 9.4.2 I report that increasing the labour supply in this way puts downward pressure on both the nominal and real wage levels and on the consumer price index. This is reflected in Figure 9.4.3, where I illustrate how loosening the employment constraint makes Jersey goods more competitive than they are under the nil migration scenario. After 2005, and the initial increase in Construction prices caused by the surge in demand from the increased population, the price of output in all sectors falls with the relaxation of the labour constraint.

Thus the problems identified in Figure 9.3.4 (Simulation 3), where I report that activity in a number of industries is crowded out by the expansion of the Finance sector, to some extent mitigated. In Figure 9.4.4 I report that the additional impact of 200 migrants is a uniformly positive increase in output and employment across all sectors by 2011.

However, it is still the case that the *total* effect of the 50% Export demand shock is negative for a number of sectors, which have lower employment and output than in the base case (with no population or demand changes). That is to say, allowing 200 in-migration per annum is not sufficient to off-set the negative output and employment effects of the export demand shock combined with the demographic changes of the zero migration hypothesis in sectors like Agriculture & Fishing, Manufacturing, the transport sectors and Hotels, Restaurants and Catering.

I summarise the results of simulating the 200 net in-migration per annum under the 50% Finance export demand shock scenario in Tables 9.4.1 and 9.4.2 below.

Summary of Results: Simulation 4 - Additional Impact of 200 Net In-Migration Per Annum With A 50% Export Demand Shock To The Finance Sector

Table 9.4.1 - Additional Impact By 2011 Of 200 Net In-Migration Per Annum On Aggregate Economic Variables In Jersey, With A 50% Export Demand Shock To The Finance Sector

	% Change
GDP	2.197
GDP per head	-0.433
Real Wage	-1.572
Real HH Income & Expend.	1.98
Total Employment	3.58
CPI	-0.36

Table 9.4.2 - Additional Impact By 2011 Of 200 Net In-Migration Per Annum On Sectoral Employment, Output And Price Of Output In Jersey, With A 50% Export Demand Shock To The Finance Sector

	% Change			Absolute Change
	Employment	Output	Price of Output	Employment
AgricFish	4.355	3.957	-1.110	89
Construction	4.563	3.582	-0.507	217
Manufactures	3.646	3.363	-0.921	78
Services	3.495	2.614	-0.594	424
Tourism	3.223	2.351	-0.540	194
Finance	3.529	2.285	-0.471	462
GovSec	3.137	2.634	-1.142	218

The additional increases in GDP and employment and a fall in prices demonstrate that activity in Jersey benefits from the additional workers. The impacts are not large, however, with only an additional 2.197% on the change in GDP identified in Simulation 3. Therefore, while economic conditions in Jersey improve as a result of allowing limited in-migration, this is not by a huge amount. The reason for this can be seen in the absolute change in employment column in the Table 9.4.2, where all sectors are competing for labour and every sector gains workers. Considering the previous results it might have been assumed that all the extra labour would go into Finance, but this is not the case: crowding-out is reduced and sectors are allowed to grow. GDP does not increase dramatically because labour is settling into low value added activities such as Agriculture & Fishing as well as high value added activities such as Finance. This is also the reason why the additional impacts on GDP and GNP are of similar magnitude (Figure 9.4.5). In contrast to Simulation 3, activity is expanding in sectors that are mainly composed of domestically owned firms, with the implication that profits accruing to foreign owners of firms operating in Jersey does not form such a high proportion of the increase in GDP.

It may seem unusual that while the additional increase in GDP is 2.197%, every sector increases its output by more than this amount. The explanation behind this is that GDP is determined by summing the increases in sectoral value-added, rather than gross outputs. If I were to report proportionate changes in *value added,* the figure in the key sector Finance would be much lower. In other words, weighting the results by output gives the impression that the change in GDP should be higher than it actually is.

An interesting comparison can be made between the results generated by this simulation and those I report in Section 3.2 for Simulation 2, which reports the impact of 200 in-migration per annum with no added demand stimulus. The changes in GDP produced by relaxing the population, and therefore employment, constraint are surprisingly similar. In Simulation 2 GDP increases by an additional 2.041% by 2011 and in Simulation 4 by 2.197%. Why does adding the export shock make so little difference? At the margin, all firms bid for workers on a level playing field and

the additional workers are distributed across sectors according to their demand for labour. This is quite different to the situation in Simulation 3 where hundreds of employees move into Finance from other sectors with a corresponding increase in GDP of 9.11% by 2011. Rather, the extra employees here are distributed across sectors in a relatively even fashion, similar to Simulation 2. The slightly higher additional impact on GDP that is found in Simulation 4 can be attributed to the increase in the productivity of the Jersey economy as a whole that is caused by the export demand shock. In Simulation 3, the effect of the export demand stimulus to the Finance sector is to increase GDP per head by 7.89%. This is almost exactly the increase in additional GDP reported in Simulation 4, as against Simulation 2. That is to say, an increase of 7.89% to the figure 2.041% (the increase in GDP in simulation 2) gives 2.202%, marginally above the figure for the increase in GDP in simulation 4.

However, one key observation can be made. In Simulation 2, I find that the additional impacts of allowing 200 net in-migration per annum are enough to outweigh all the negative economic effects of the demographic changes in the nil net migration scenario reported in Simulation 1. This is not true in the presence of a 50% increase in Finance sector export demand. The positive impacts on output, employment and competitiveness across all sectors in Simulation 4 are not enough to outweigh the negative ones in Simulation 3 for a number of sectors. Similarly the downward pressure on the real wage level and CPI from allowing 200 in-migration per annum is not enough to combat the upward pressure on both these variables reported in Table 9.3.1 for the nil net migration case in the presence of the export demand shock. In other words, while allowing 200 net in-migration per annum does ease economic conditions, the economy is still sufficiently labour constrained to cause crowding out of activities and general upward pressure on prices.

3.4.2 Environmental Impacts

The environmental results for Simulation 4 are reported in Figures 9.4.8 and 9.4.9 and summarised in Tables 9.4.3 and 9.4.4.

Figure 9.4.8 Additional Impact Of 200 Net In-Migration Per Annum On Energy And Water Consumption In Jersey, 2001-2011, With A 50% Export Demand Shock To The Finance Sector

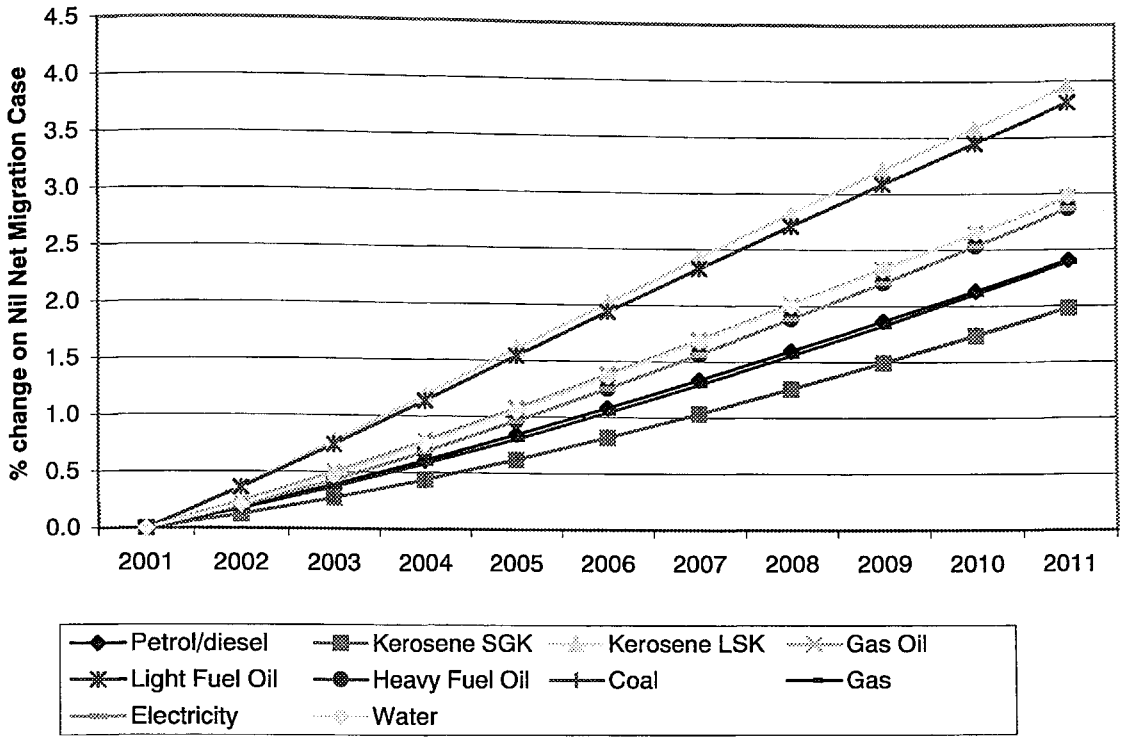
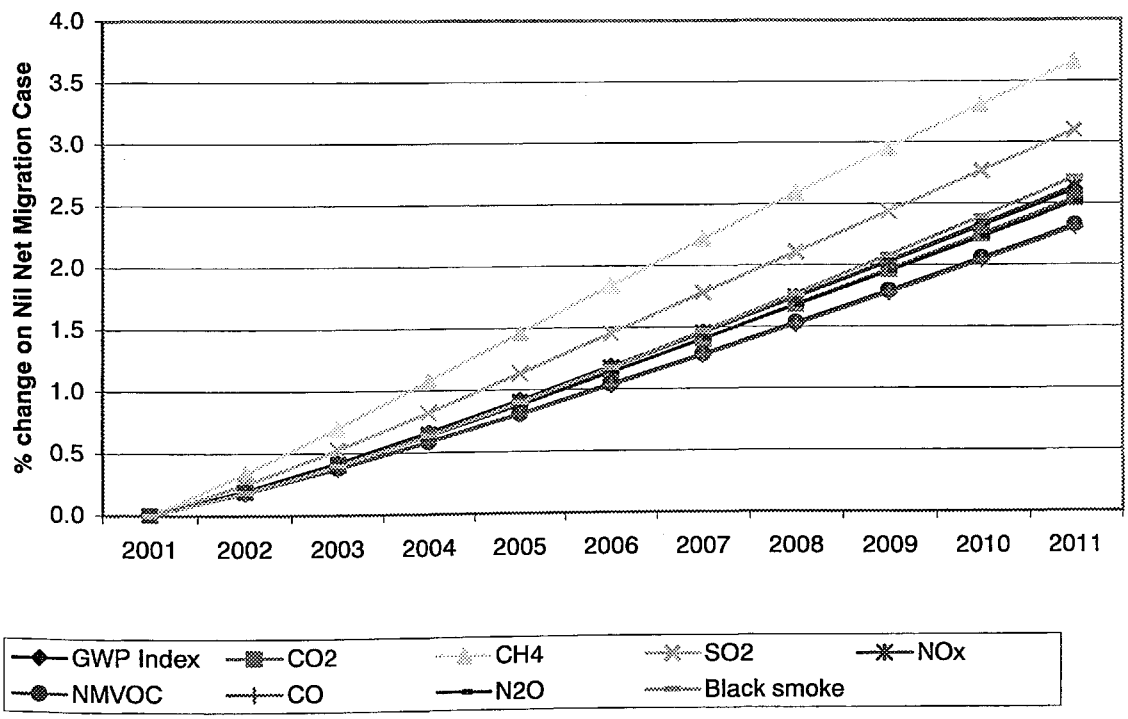


Figure 9.4.9 Additional Impact Of 200 Net In-Migration On Emissions of 8 Individual And 1 Composite Pollution Indicators In Jersey, 2001-2011, With A 50% Export Demand Shock To The Finance Sector



Additional Environmental Impact By 2011 Of 200 Net In-Migration With A 50% Increase In Finance Sector Export Demand

Table 9.4.3 Additional Impact By 2011 Of 200 Net Migration On Traffic-Related Energy Consumption And Emissions Generation in Jersey, With A 50% Export Demand Shock To The Finance Sector

	Absolute Change (kg)	% Change from base
Total automotive fuel (petrol/derv) use	1003185	2.41
Government sector	3663	2.63
Other production	284619	3.06
Households	581657	1.98
Tourists	133247	4.65
Emissions of:		
Non-methane volatile organic compounds (NMVOC)	58076	2.32
Carbon monoxide (CO)	314665	2.30
Nitrogen dioxide (N20)	49	2.51
Carbon dioxide (CO2)	7531080	2.54
Nitrous oxides (NOX)	58987	2.63

Figure 9.4.4 Additional Impact By 2011 Of 200 Net In-Migration On All Other Environmental Indicators In Jersey, With A 50% Export Demand Shock To The Finance Sector

	Absolute Change (kg)	% Change from base
Total energy use		
Kerosene SGK	579952	1.98
Kerosene LSK	44677	3.96
Gas Oil	744550	2.97
Light Fuel Oil	311251	3.81
Heavy Fuel Oil	1953728	2.87
Coal	108304	1.98
Gas (Mains & Bottled Propane/Butane)	308831	2.39
Emissions		
Methane (CH_4)	35198	3.66
Sulphur dioxide (SO_2)	31726	3.10
Black smoke	1990	2.71
Value of Global Warming Potential (GWP) Index for Jersey	8285295	2.61

I illustrate the additional impact of 200 net in-migration per annum under the 50% increase in Finance export demand scenario on energy and water consumption and pollution generation in Figures 9.4.8 and 9.4.9. The additional impacts by 2011 are summarised in Tables 9.4.3 and 9.4.4. The first thing to note is that the magnitude and ordering of effects on different environmental variables are broadly similar to what was found in Simulation 2 for 200 net in-migration under the assumption of no exogenous changes in the economy. This is in line with what I report above for the economic impacts of relaxing the labour supply constraint in this way under the two alternative scenarios.

However, note that the *economic* impacts of allowing 200 in-migration per annum are positive in that the negative effects of the 50% export demand shock under the constraint of nil net migration are partly mitigated by relaxing the labour supply constraint in this way. This good news for the economy contrasts with what is uniformly bad news for the environment. In Figures 9.4.8 and 9.4.9 and Tables 9.4.3 and 9.4.4 I report that the additional environmental impact of allowing 200 net in-migration per annum is an increase in all types of energy-use, water consumption and pollution generation. This is because the additional impact of allowing this in-migration is an increase in activity in all sectors, which means increased energy and water consumption and pollution generation in each sector. Moreover, the impact on real household income and expenditure is positive, though due to the downward pressure on real wages this is limited (note that in the case of environmental variables that are dominated by household behaviour the smallest increases are observed).

Nonetheless, the *additional* impact of 200 net in-migration per annum is uniformly detrimental on all environmental indicator variables, just as I report above for Simulation 2. The difference between the situation reported in Simulation 2, where I assume no exogenous changes in demand, and here, assuming a 50% increase in Finance export demand is that in the former case all the environmental costs were enough to negate the environmental benefits of the nil net migration scenario. However, comparing the results of Simulation 4 with those reported for Simulation 3

it is clear that the upward pressure on several environmental variables from allowing 200 net in-migration per annum is not enough to outweigh the reductions that result from the demographic changes and export demand shock. In particular, the reductions in automotive fuel use by tourists and all types of energy use in those private production sector activities that are crowded out by increased Finance sector activities with nil net migration are larger than the increases that result from the in-migration. For example, consider the total effect of 200 net in-migration per annum combined with the 50% increase in Finance sector export demand on the types of fuel use and pollution generation that are dominated in Jersey by Agriculture & Fishing – i.e. use of kerosene LSK and LFO, and methane generation. The total impact on all these variables is a reduction in line with the overall reduction in Agriculture & Fishing activity, which suffers the greatest proportionate decline in output due to crowding out by finance sector activities, even where 200 in-migration per annum is permitted.

4. Sensitivity Analyses

4.1 Simulation Strategy For Sensitivity Analysis Of Environmental Results

In this section I conduct some initial sensitivity analyses of the simulation results reported above. The general motivation for carrying out sensitivity analysis is to determine whether simulation results are sensitive to changes in the parameter values that I impose in the JEMENVI model configuration (particularly given the lack of data for econometric estimation in Jersey). I begin with two key variables: the Armington price elasticities of export demand for local outputs (which are particularly important in the Jersey case, given the openness and export orientation of most of production sectors) and the elasticity of substitution between capital and labour in the CES production functions.

However, in the initial sensitivity analysis conducted here I also want to examine an issue that relates specifically to the environmental results reported in this chapter. The results in Section 3 show that the main factor driving the environmental impacts

in all four of the simulations is what happens to the level of real household consumption. Therefore, a specific question I wish to address is whether, when considering changes in wages resulting from adjustments to labour supply, it may be possible, depending on the value of the wage elasticity of labour demand, to find perverse variations in household income, and therefore on the generation of pollutants. That is to say, if labour demand is sufficiently wage inelastic, it may be that household income will actually fall as employment rises, with the implication that it is possible for a general increase in economic activity to be accompanied by a decline in some types of pollution generation.

In partial equilibrium the wage elasticity of derived demand for labour, λ, is given by (Hicks, 1963, p.374):

$$\textbf{(9.1)} \quad \lambda = \frac{\sigma\eta + e\left(k\eta + \overline{1-k\sigma}\right)}{\left(k\sigma + \overline{1-k\eta}\right) + e}$$

That is to say, the wage elasticity of labour demand, λ, is a complex function of σ, the elasticity of substitution between labour and the second (primary) factor of production, capital, η, the elasticity of product demand, e, the elasticity of supply of the second factor, and k, a labour intensity factor. In general equilibrium the relationship will also take into account the impact of income changes in shifting product demand.

I have already identified two of these elasticities as key parameters for initial sensitivity analyses. Firstly, the Armington elasticities are important, given that the main source of product demand for most sectors in Jersey is export demand. For simplicity I refer to these as η (no other type of product demands is considered in this initial sensitivity analysis). The other is the elasticity of substitution between capital and labour in the CES production functions determining the primary input composition of sectoral outputs.

Table 9.5 Sensitivity Analysis - Simulation 3: Impact By 2011 Of Nil Net Migration With A 50% Export Demand Shock To The Finance Sector (% change in key variables)

(a)Real wage level (average change across all sectors)

CES elasticity of subsitution capital and labour	Armington elasticity of export demand				
	0.5	CD (1)	2	3	5
1.5	*	*	9.09	7.25	5.01
1.2	*	13.54	9.93	7.68	5.14
CD (1)	18.53	14.87	10.53	7.96	5.20
0.8	21.10	16.44	11.14	8.21	**5.23**
0.5	26.59	19.34	11.98	8.45	5.21
0.3	32.30	*	12.32	8.45	5.19
0.1	*	23.51	12.59	8.89	5.95

(b)CPI

CES elasticity of subsitution capital and labour	Armington elasticity of export demand				
	0.5	CD (1)	2	3	5
1.5	*	*	3.55	2.93	2.12
1.2	*	5.08	3.90	3.14	2.19
CD (1)	6.74	5.54	4.16	3.27	2.21
0.8	7.52	6.10	4.42	3.39	**2.22**
0.5	9.15	7.12	4.76	3.46	2.16
0.3	10.65	*	4.79	3.35	2.04
0.1	*	7.91	4.41	3.08	1.97

(c)Change in Finance sector output

CES elasticity of subsitution capital and labour	Armington elasticity of export demand				
	0.5	CD (1)	2	3	5
1.5	*	*	26.05	23.05	18.93
1.2	*	28.74	24.47	21.37	17.22
CD (1)	30.80	27.68	23.17	20.00	15.83
0.8	29.70	26.35	21.59	18.33	**14.16**
0.5	27.38	23.56	18.18	14.79	10.82
0.3	25.00	*	14.27	11.04	7.66
0.1	*	11.29	6.80	4.89	3.08

(d)Change in Finance sector employment

CES elasticity of subsitution capital and labour	Armington elasticity of export demand				
	0.5	CD (1)	2	3	5
1.5	*	*	14.66	14.33	13.48
1.2	*	15.23	14.82	14.30	13.07
CD (1)	15.80	15.50	14.91	14.17	12.59
0.8	16.28	15.83	14.91	13.85	**11.83**
0.5	17.24	16.33	14.32	12.47	9.75
0.3	18.04	*	12.47	10.08	7.26
0.1	*	10.67	6.60	4.78	3.00

(e)GDP

CES elasticity of subsitution capital and labour	Armington elasticity of export demand				
	0.5	CD (1)	2	3	5
1.5	*	*	18.82	16.41	13.03
1.2	*	20.84	17.49	14.98	11.59
CD (1)	22.35	19.94	16.39	13.82	10.45
0.8	21.39	18.81	15.05	12.42	**9.11**
0.5	19.36	16.44	12.19	9.54	6.56
0.3	17.34	*	9.11	6.72	4.33
0.1	*	7.11	3.87	2.59	1.47

(f)Real household income and expenditure

CES elasticity of subsitution capital and labour	Armington elasticity of export demand				
	0.5	CD (1)	2	3	5
1.5	*	*	17.16	15.35	12.95
1.2	*	20.50	17.30	15.20	12.55
CD (1)	24.17	21.08	17.37	15.04	12.20
0.8	25.56	21.78	17.40	14.77	**11.73**
0.5	28.63	23.08	17.17	14.00	10.70
0.3	32.02	*	16.48	12.96	9.69
0.1	*	24.02	14.69	11.35	8.59

(g)Total automotive fuel use

CES elasticity of subsitution capital and labour	Armington elasticity of export demand				
	0.5	CD (1)	2	3	5
1.5	*	*	11.21	9.41	7.18
1.2	*	14.01	10.94	9.00	6.72
CD (1)	16.94	14.11	10.71	8.67	6.36
0.8	17.53	14.22	10.44	8.29	**5.96**
0.5	18.91	14.45	9.87	7.53	5.22
0.3	20.61	*	9.24	6.81	4.60
0.1	*	14.62	8.22	5.91	3.96

(h)GWP Index

CES elasticity of subsitution capital and labour	Armington elasticity of export demand				
	0.5	CD (1)	2	3	5
1.5	*	*	5.85	4.40	2.73
1.2	*	7.74	5.34	3.88	2.33
CD (1)	9.55	7.48	4.94	3.51	2.07
0.8	9.50	7.16	4.51	3.13	**1.82**
0.5	9.48	6.61	3.85	2.61	1.53
0.3	9.72	*	3.49	2.36	1.46
0.1	*	6.51	3.52	2.53	1.75

Table 9.6 Sensitivity analysis - Simulation 4: Additional Impact By 2011 Of 200 Net In-Migration Per Annum With A 50% Export Demand Shock To The Finance Sector (% change in key variables)

(a)Real wage level (average change across all sectors)

CES elasticity of subsitution capital and labour	Armington elasticity of export demand				
	0.5	CD (1)	2	3	5
1.5	*	*	-1.56	-1.31	-1.06
1.2	*	-2.33	-1.77	-1.49	-1.21
CD (1)	-3.27	-2.61	-1.97	-1.66	-1.36
0.8	-3.80	-2.98	-2.25	-1.90	**-1.57**
0.5	-5.17	-3.98	-3.01	-2.58	-2.18
0.3	-7.22	*	-4.24	-3.70	-3.20
0.1	*	-11.88	-9.65	-8.74	-7.88

(b)CPI

CES elasticity of subsitution capital and labour	Armington elasticity of export demand				
	0.5	CD (1)	2	3	5
1.5	*	*	-0.50	-0.41	-0.30
1.2	*	-0.74	-0.54	-0.44	-0.32
CD (1)	-1.01	-0.80	-0.58	-0.46	-0.34
0.8	-1.11	-0.86	-0.62	-0.49	**-0.36**
0.5	-1.31	-1.00	-0.71	-0.57	-0.42
0.3	-1.55	*	-0.85	-0.68	-0.51
0.1	*	-1.91	-1.42	-1.17	-0.91

(c)Change in Finance sector output

CES elasticity of subsitution capital and labour	Armington elasticity of export demand				
	0.5	CD (1)	2	3	5
1.5	*	*	2.13	2.25	2.32
1.2	*	1.92	2.20	2.29	2.32
CD (1)	1.69	2.01	2.24	2.30	2.31
0.8	1.81	2.10	2.28	2.31	**2.29**
0.5	2.03	2.24	2.31	2.29	2.23
0.3	2.22	*	2.28	2.23	2.16
0.1	*	2.28	2.17	2.11	2.05

(d)Change in Finance sector employment

CES elasticity of subsitution capital and labour	Armington elasticity of export demand				
	0.5	CD (1)	2	3	5
1.5	*	*	3.95	3.89	3.77
1.2	*	3.94	3.89	3.83	3.69
CD (1)	3.91	3.90	3.85	3.77	3.62
0.8	3.85	3.85	3.79	3.70	**3.53**
0.5	3.76	3.76	3.65	3.53	3.34
0.3	3.72	*	3.49	3.35	3.16
0.1	*	3.37	3.15	3.03	2.89

(e)GDP

CES elasticity of subsitution capital and labour	Armington elasticity of export demand				
	0.5	CD (1)	2	3	5
1.5	*	*	2.09	2.19	2.24
1.2	*	1.93	2.15	2.22	2.23
CD (1)	1.76	2.01	2.19	2.23	2.22
0.8	1.86	2.09	2.22	2.23	**2.20**
0.5	2.04	2.19	2.22	2.19	2.13
0.3	2.17	*	2.18	2.13	2.06
0.1	*	2.10	2.02	1.98	1.95

(f)Real household income and expenditure

CES elasticity of subsitution capital and labour	Armington elasticity of export demand				
	0.5	CD (1)	2	3	5
1.5	*	*	2.02	2.17	2.29
1.2	*	1.57	1.93	2.08	2.20
CD (1)	0.98	1.45	1.84	2.00	2.11
0.8	0.72	1.27	1.70	1.87	**1.98**
0.5	0.01	0.79	1.31	1.49	1.62
0.3	-1.08	*	0.66	0.88	1.07
0.1	*	-3.26	-2.11	-1.68	-1.30

(g)Total automotive fuel use

CES elasticity of subsitution capital and labour	Armington elasticity of export demand				
	0.5	CD (1)	2	3	5
1.5	*	*	2.14	2.31	2.48
1.2	*	1.77	2.12	2.29	2.46
CD (1)	1.30	1.71	2.09	2.26	2.44
0.8	1.16	1.63	2.03	2.21	**2.41**
0.5	0.74	1.37	1.84	2.06	2.30
0.3	0.05	*	1.50	1.78	2.12
0.1	*	-1.10	0.03	0.61	1.39

(h)GWP Index

CES elasticity of subsitution capital and labour	Armington elasticity of export demand				
	0.5	CD (1)	2	3	5
1.5	*	*	2.32	2.45	2.59
1.2	*	2.09	2.34	2.46	2.60
CD (1)	1.81	2.09	2.34	2.46	2.61
0.8	1.77	2.07	2.33	2.46	**2.61**
0.5	1.60	1.97	2.27	2.42	2.61
0.3	1.26	*	2.13	2.33	2.57
0.1	*	0.78	1.44	1.76	2.16

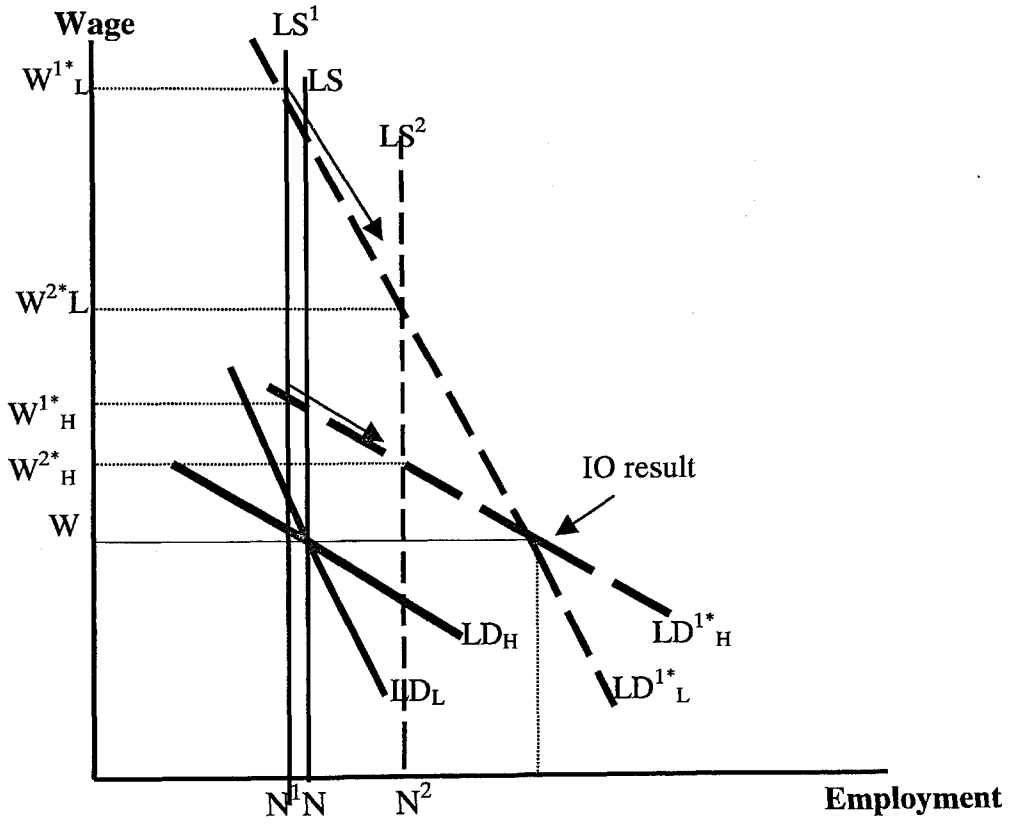
In the simulations reported in this chapter I assume that the Armington price elasticity of export demand, η, has a value of 5.0 for all sectors (see Chapter 8, Section 3.1 and Section 2 above). However, if export demand for local outputs is less price elastic than this, I would expect that the (derived) demand for labour to produce these outputs will also be more wage inelastic. In terms of the production of sectoral outputs, I assume that the constant elasticity of substitution, σ, between capital and labour has a value of 0.8 in all sectors. If this parameter is lower – i.e. if it is more difficult to substitute between capital and labour in response to changes in relative prices – then labour demand will also be more inelastic. In the case of the export demand shock simulated here, the more wage inelastic labour demand is, the bigger the *positive* impact on wages will be. In terms of the supply-side shock in the labour market, the more wage inelastic the labour demand curve, the bigger the *negative* impact on wages will be. Of particular interest here is the question as to whether the downward pressure on real wages from allowing limited in-migration may actually result in pollution generation in Jersey falling as output rises if labour demand is assumed to be sufficiently inelastic.

I limit the sensitivity analysis reported here to the two scenarios where the most significant environmental impacts are observed. These are Simulation 3, where a 50% export demand shock to the Finance sector is introduced under the assumption of nil net migration, and Simulation 4, where the labour supply constraint is partially relaxed under these demand conditions, by allowing 200 in-migration per annum. I re-run these two simulations with 4 alternative values for the Armington elasticity of export demand, namely 0.5, 1.0 (using a Cobb-Douglas instead of a CES function), 2.0 and 3.0, and 6 alternative values for the constant elasticity of substitution between capital and labour, namely 0.1, 0.3, 0.5, 1.0 (Cobb Douglas), 1.2 and 1.5. All other model specifications are unchanged. I run simulations for each possible combination of these values, plus the original values. This equates to 35 simulations for the nil migration scenario (combined with the export demand shock) and 35 to report the additional impacts of allowing 200 net in-migration per annum. However, the model will not solve for 5 combinations in both cases. These are scenarios where labour demand becomes so wage inelastic that the model cannot adjust to a new

equilibrium. See Tables 9.5 (Simulation 3) and 9.6 (Simulation 4) above for the composition and results of each simulation (cases where the model fails to solve are indicated by an asterix). I discuss the results reported in these tables in Sections 4.3 and 4.4 respectively. However, before examining the simulation results for Jersey, it is informative to use the theoretical general equilibrium labour supply and demand framework to understand the basic impacts of varying the parameters that determine the elasticity of labour demand.

4.2 Variation In The Elasticity Of Labour Demand – The Basic Analytical Argument

Figure 9.5 General Equilibrium Labour Supply And Demand Under Different Assumptions About The Elasticity Of Labour Demand



In Figure 9.5 I illustrate how the impact on wages and total income from employment of introducing a large labour demand shock in a labour supply

constrained economy varies under different assumptions of the elasticity of labour demand.

The economy is initially in long-run equilibrium where LS = LD, with the real wage level, W, and employment, N. (Total household income from employment will be W times N.) If there is a large increase in demand for local outputs (such as the Finance sector export demand shock in Simulation 3) the general equilibrium labour demand curve will shift outwards from LD to LD^1. In Figure 9.5 In Figure 9.5 I illustrate two general equilibrium labour demand curves that reflect different (qualitative) assumptions about the elasticity of labour demand: LD_H applies where the elasticity of labour demand is assumed to be relatively high and LD_L when it is assumed to be relatively low. Where the wage is fixed, both curves will pass through the same point – this would be the IO result (McGregor *et al* 1994, 1996). However, if the total labour supply is fixed, there will be a rise in the real wage. If the increase in demand is combined with a contraction in labour supply (such as that implied by the nil net migration scenario[10]), there will also be a simultaneous inward shift in the general equilibrium labour supply curve, from LS to LS^1. This puts even more upward pressure on the wage level before the economy can reach a new long-run equilibrium where $LS^1 = LD^1$.

However, the main factor influencing the magnitude of the impact of the demand shock in Figure 9.5 is the elasticity of labour demand (the impact on the wage level will be positive in both cases). LD_H and LD_L move out to LD^{1*}_H and LD^{1*}_L respectively in response to the direct increase in Finance[11] demand. However, the more inelastic LD^{1*}_L intersects the new fixed labour supply curve, LS^1, at a higher wage level, W^{1*}_L, than LD^{1*}_H, which intersects LS^1 at W^{1*}_H. Consequently the impact on total income from employment is greater where the elasticity of labour demand is relatively low ($W^{1*}_L.N^1 > W^{1*}_H.N^1$).

[10] As I explain in Section 3.3, the population changes implied by the nil net migration scenario will also add to the upward pressure on total labour demand because public sector activity must increase to maintain a fixed level of government expenditure per capita as total population increases.

[11] See Footnote 10 – the increase in labour demand also reflects increased public sector activity to maintain a constant level of government expenditure per head of population.

When the labour constraint is partially relaxed, increasing the labour supply from LS^1 to LS^2 (for example, by allowing the 200 net in-migration per annum that I assume in Simulation 4) the economy moves down the general equilibrium labour demand curve[12]. However, note that the movement down the low elasticity labour general equilibrium demand curve LD^{1*}_L, and the associated drop in the real wage from W^{1*}_H to W^{2*}_H, represents a larger adjustment than the equivalent move down LD^{1*}_H.

The difference in the magnitude of adjustment when the labour supply constraint is relaxed can be explained by considering what would be the long-run (input-output) result of the demand shock if there were no supply constraints in the system. The IO result is illustrated in Figure 9.5. What this indicates is that, if the flow of net in-migration were to continue, the increase in all price levels, including the wage, would be eliminated in the long-run when both the capital and labour markets have fully adjusted to the change in demand conditions in the economy. However, the ability of the economy to reach the IO outcome is limited by the presence of the labour supply constraint. Moreover, the *path* of this adjustment will be affected by the substitution possibilities that determine the elasticity of labour demand. In Figure 9.5, the wage level rises further in response to the demand shock when the labour demand curve is inelastic. This is because of the improvement in the terms of trade that apply when a demand shock is introduced under conditions where it is difficult to switch away from the region-specific labour either towards (elastically) available capital or through purchasing foreign goods. Thus, under the fixed labour supply LS^1, the economy is further away from the IO long-run equilibrium the more inelastic the labour demand curve. This has the implication that when the labour supply constraint is partially relaxed (e.g. by allowing 200 net in-migration per annum) to move the labour supply curve out to LS^2 the consequent adjustment in the wage level must be larger in order to move the economy towards the IO outcome. The effect on total income from employment will depend on whether the increase from the rise in the number employed is sufficient to outweigh the reduction in the

[12] Note that, for clarity of exposition, in Figure 9.5 I ignore the additional increase in labour demand as public sector activity rises to maintain constant government expenditure per head of population, as

real wage paid per employee. Essentially, under these conditions total wage income will fall when labour supply rises if labour demand is inelastic.

It is important to note, however, that what I illustrate in Figure 9.5 is the impact on the *general equilibrium* (aggregate) labour supply and demand curves. However, as will become apparent below, the impacts are less straightforward at the sectoral level. For example, in Simulation 3, the increase in aggregate labour demand arising from the Finance sector export demand shock occurs under the constraint of a fixed (and, indeed, falling) total labour supply. However, at the sectoral level, the labour supply is not fixed and there are changes in the distribution of employment among the 25 production sectors. As I explain in Section 3.3, the impact of the resulting increase in the general wage level will vary across sectors, depending on factors such as the labour intensity and export orientation of production.

4.3 Sensitivity Analysis Results – Nil Net Migration With A 50% Export Demand Shock To The Finance Sector (Simulation 3)

The findings of my sensitivity analysis for Simulation 3 for the impact on the real wage level (Table 9.5, grid (a)) are broadly consistent with the qualitative analysis in Figure 9.5. In Table 9.5 (above) the percentage change in the real wage level by 2011 increases as the values of the Armington elasticity of export demand, η, and the constant elasticity of substitution between capital and labour, σ, fall (i.e. along each row and down each column). As I change the parameter values to assume that it is more difficult for producers to substitute out of labour as it becomes scarcer, and/or for foreigners to substitute away from Jersey goods and services as local output prices increase, the price of labour is bid up higher. Note that the results in the last column (η = 5.0) of grid (a) do not quite follow this pattern. This reflects some disequilibrium effects – note that sensitivity results in Table 9.5, as with all the simulation results in this chapter, relate to the end of time period studied, 2011, which is not a long-run equilbrium. Given that the population changes are still

shown in Figure 9.4, because this does not significantly affect the qualitative impact on the wage level.

occurring in 2010, the capital stock is not fully adjusted to bring the economy to long-run equilibrium by 2011.

However, in terms of the sensitivity of the quantitative results that I report in Section 3, it is important to note there is a significant degree of variation in the model results for the impact on the real wage level across different assumptions about the value of σ and η. The result reported in Section 3.3 (where $\sigma = 0.8$ and $\eta = 5.0$), a 5.23% increase in the real wage level by 2011, is at the lower end of the range reported in Table 9.5, where the smallest increase is 5.01% ($\sigma = 1.5$ and $\eta = 5.0$) and the highest is 32.3% ($\sigma = 0.3$ and $\eta = 0.5$).

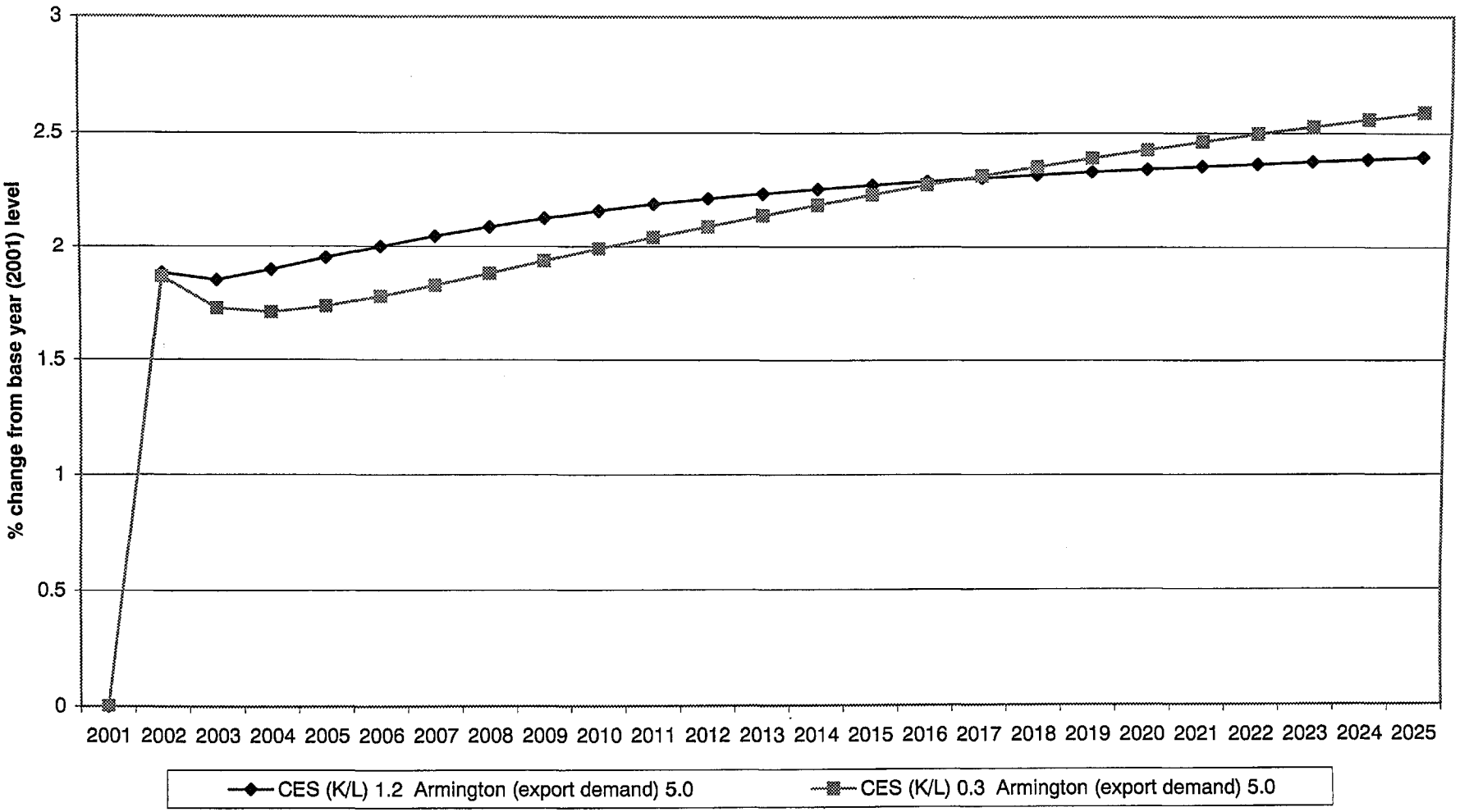
The impact of the demand disturbance on output prices in any one sector is a function of the real wage, the labour intensity of production and capital rental rates. The overall effect on the price level in Jersey is reflected in the consumer price index (CPI). Note that while the sensitivity analysis results for the CPI, reported in Table 9.5, grid (b), broadly follow the expected pattern, the disequilibrium effects that I mention above are clearly present. As with the real wage, I would expect the impact on the CPI from the demand shock to increase as the elasticity of substitution between capital and labour, σ, falls. However, this is clearly not true of the results reported in the last two columns of grid (b) ($\eta = 3.0, 5.0$). For example, where $\eta = 5.0$, the change in the CPI rises then falls as the value of σ falls. The explanation for this is that, as I emphasise throughout this chapter, the simulation results reported here are not long-run equilibrium results. That is to say, with population changes occurring up to and including 2011, the economy is not fully adjusted to a new long-run equilibrium in the end period (2011) results reported in Table 9.5. This is apparent in the CPI results in grid (b), which reflect the short-run investment effects that I identify in Section 3, with respect to output prices in the sector responsible for the bulk of fixed capital formation in Jersey (Quarrying & Construction). In Figure 9.6 I illustrate how, over a longer time period, the continuing adjustment process leads to the expected pattern being observed by 2017, with the increase in the CPI where $\sigma = 0.3$ becoming greater than where $\sigma = 1.2$. So, as expected, over time the impact on the CPI becomes larger as the elasticity of labour demand falls.

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However, in terms of the sensitivity of the quantitative results that I report in Section 3, it is important to note there is a significant degree of variation in the model results for the impact on the real wage level across different assumptions about the value of σ and η. The result reported in Section 3.3 (where $\sigma = 0.8$ and $\eta = 5.0$), a 5.23% increase in the real wage level by 2011, is at the lower end of the range reported in Table 9.5, where the smallest increase is 5.01% ($\sigma = 1.5$ and $\eta = 5.0$) and the highest is 32.3% ($\sigma = 0.3$ and $\eta = 0.5$).

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Figure 9.6 Adjustment Path Of The Impact Of Nil Net Migration On The CPI In Jersey, 2001-2025, With A 50% Export Demand Shock To The Finance Sector Under Alternative Assumptions About The Substitutability Of Capital And Labour



In terms of commodity demands, in Section 3.3 I explain that a number of sectors suffer due to the increased cost of labour and resulting negative competitiveness effects. Even in the Finance sector, where the demand shock is directed, the 50% increase in export demand does not actually transpire because of the increase in Finance sector output prices. However, the sensitivity results in Table 9.5, grid (c) show that the size of the actual increase in demand for Finance sector outputs depends on what I assume about the price elasticity of export demand and the substitutability of capital for labour. As it becomes easier for firms to substitute capital for labour, and more difficult for foreign consumers to find alternatives for Jersey financial commodities (i.e. as σ rises and η falls) the increase in Finance sector output becomes larger. Again, the result reported in Section 3.3 (where $\sigma = 0.8$ and $\eta = 5.0$), the 14.16% increase by 2011 is at the lower end of the range in grid (c), where the smallest increase is 3.08% ($\sigma = 0.1$ and $\eta = 5.0$) and the highest is 30.8% ($\sigma = 1$ (Cobb Douglas) and $\eta = 0.5$).

These output effects are as I would predict based on the long-run analysis in Figure 9.5. However, the sensitivity results for the change in Finance sector employment by 2011 (grid (d)), on the other hand, follow the expected pattern for variation in the value of η but not σ. Specifically, the size of change in employment decreases as σ rises in the case of $\eta = 0.5$, despite the increase in output. However, I find that this anomaly only occurs in the case of Banks & Building Societies and Investment Trust and Fund Managers. In the other 5 Finance sub-sectors (see Appendix 9A), employment rises with activity as the value of σ increases (but obviously at a slower rate because firms are substituting towards capital). Banks & Building Societies and Investment Trusts and Fund Managers share the common characteristic of having a high average wage rate and low labour intensity relative to the other finance sectors. It would seem that in the case of $\eta = 0.5$ (i.e. where export demand is highly price inelastic) the interaction between the change in wages and the elasticity of substitution between capital and labour causes the relative importance of the positive output effect on sectoral employment to increase at lower values of σ.

I report the sensitivity results for the impact of the nil net migration scenario combined with the Finance sector export demand shock on Jersey GDP in Table 9.5, grid (e). These follow the expected pattern, with the expansion in the economy becoming greater as it is easier for producers to substitute capital for labour, and more difficult for foreign consumers to find alternatives for Jersey commodities (i.e. as σ rises and η falls). Again, the main observation is the sensitivity of the result reported in Section 3.3 (where $\sigma = 0.8$ and $\eta = 5.0$). There I report a 9.11% increase in GDP by 2011, which is at the lower end of the range in grid (e), where the smallest increase is 1.47% ($\sigma = 0.1$ and $\eta = 5.0$) and the highest is 22.35% ($\sigma = 1$ (Cobb Douglas) and $\eta = 0.5$).

The presence of differential sectoral effects is most apparent in the sensitivity results for the impact on total household income and expenditure, which I report in Table 9.5, grid (f). The general impact on wages that I report here (grid (a)) shows the average percentage change in the real wage level across all sectors. However the initial (equilibrium) average wage rate is different in each sector. In Simulation 3 the fixed labour supply is shifting among sectors with different average wage rates. As I report in Section 3.3, in the presence of the 50% export demand shock to the Finance sector, the nature of this redistribution of employment is such that labour is drawn into sectors that pay relatively high average wage rates. Therefore, the impact on total household income and expenditure is greater than the increase in the general wage level. Moreover, the impact of changing the main parameter values that govern the wage elasticity of labour demand (i.e. σ and η) varies across sectors, depending on factors such as the initial actual wage level and the labour intensity of production.

If I hold the elasticity of substitution between labour and capital constant (i.e. along each row of grid (f)), the impact on total household income and expenditure decreases as export demand becomes more price elastic. However, reading down the columns of grid (f), the sensitivity results do not follow a common pattern, with the change in household income and expenditure falling as σ rises in the case of $\eta = 0.5$ and $\eta = 1$ (Cobb Douglas), rising then falling under $\eta = 2$ and rising under $\eta = 3$ and $\eta = 5$. What is happening here appears to be dominated by the changes in Finance

sector employment. As I explain above where export demand is highly price inelastic the interaction between the change in wages and the elasticity of substitution between capital and labour in Banks & Building Societies and Investment Trusts & Fund Managers causes the impact on employment to be greater at lower values of σ.

However, perhaps the key point, given the environmental focus of my study, is the fact that the impact on household expenditure in Simulation 3 is extremely sensitive to what I assume about the values of σ and η. In Figure 9.5, grid (g) I report the sensitivity results for the impact on total automotive fuel use. In all cases household effects dominate the change in automotive fuel use. A constant proportional relationship is assumed between total household expenditure and household consumption of fuels. This means that the percentage changes in household automotive fuel use in Simulation 3 are the same as the percentage changes in total household expenditure, reported in grid (f). However, the net effect on total automotive fuel use is generally smaller and slightly less variable across alternative assumptions about the value of σ and η because of downward pressure from reductions in activity elsewhere in the economy. Nonetheless the sensitivity analysis shows that the result I report in Section 3.3 for the impact on total automotive fuel use (and, therefore, emissions of all traffic-related pollutants) is sensitive to what I assume about the substitutability of capital for labour and the price elasticity of export demand. In Section 3.3 I report a 5.96% increase in total automotive fuel use for Simulation 3, which is at the lower end of the range in grid (g), where the smallest increase is 3.96% ($\sigma = 0.1$ and $\eta = 5.0$) and the highest is 20.61% ($\sigma = 0.3$ and $\eta = 0.5$).

In the final grid (h) of Table 9.5 I report the sensitivity results for the composite GWP Index. Emissions of the three pollutants that contribute to the GWP Index (CO_2, N_2O and methane) are generated during a wide variety of activities that take place in the Jersey economy. Nonetheless, the upward pressure on the GWP Index in response to the demographic changes in Finance sector demand shock in Simulation 3 mainly comes from the increase in household final consumption. However, the decline in tourist demand and the decrease in manufacturing, transport, other service

activities and particularly agricultural activities (the main source of methane emissions in Jersey) negate a large proportion of this. Therefore in Section 3.3 (Table 3.4) I report a much smaller increase in the value of the GWP Index than what is observed for traffic-related pollution. Relative to the results reported for other variables in Table 9.5, this result (a 1.82% increase) does not appear to be as sensitive to what I assume about the substitutability of capital for labour and the price elasticity of export demand. Nonetheless, the implications of the results reported in grid (h) are significant – for example, the impact on the GWP index increases by more than half (to 3.13%) if I assume that the Armington elasticity of export demand is 3.0 rather than 5.0.

4.4 Sensitivity Analysis Results – Additional Impact Of 200 Net In-Migration With A 50% Export Demand Shock To The Finance Sector (Simulation 4)

In my qualitative analysis in Section 4.2 I explain that the additional impact of allowing limited net in-migration in response to a large demand shock of the type considered in Simulation 3 will be to move the fixed (aggregate) labour supply curve, putting downward pressure on wages across the economy. However I explain that the magnitude of the adjustment will be greater the more inelastic the general equilibrium labour demand curve. Therefore I would expect that as I reduce the value of the parameters determining the price elasticity of export demand for local outputs and the substitutability of capital for labour (referred to as σ and η respectively) in producing these outputs, the greater will be the impact on the real wage. The results that I report for the sensitivity analysis of the additional impact on the real wage of allowing 200 in-migration per annum in Simulation 4 in Table 9.6, grid (a) are consistent with this argument.

Again there is significant variation in the model results for the additional impact on the real wage from allowing 200 net in-migration across different assumptions about the value of σ and η. The result reported in Section 3.4 (where $\sigma = 0.8$ and $\eta = 5.0$), a 1.57% drop in the real wage level by 2011, is at the lower end of the range reported

in Table 9.6, grid (a). The size of the impact ranges from -1.06% (σ = 1.5 and η = 5.0) to -11.88% (σ = 0.1 and η = 1 (Cobb Douglas)).

However, in terms of magnitude, the results for all the other variables reported in Table 9.6 are less sensitive to what I assume about the substitutability of capital for labour and the price elasticity of export demand than is the case for Simulation 3. The core explanation is likely to be the size and nature of the disturbance. While the additional shock that I apply in Simulation 4 is not insignificant – 200 net in-migration per annum equates to a 3.58% increase in total Jersey employment by 2011 – it constitutes a minor disturbance relative to the introduction of a 50% increase in Finance sector export demand.

Moreover, the change in the labour supply that I introduce in Simulation 4 constitutes a far less complex disturbance to the system. Under the assumption of a unified labour market (see Chapter 8, Section 2.1.1), the expansion I simulate here is much more evenly distributed than is the case when the shock takes the form of an injection to one particular sector, or set of sectors, in the economy.

However, the results in Table 9.6 clearly reflect a number of disequilibrium and sectoral effects. Take, for example, the impacts on Finance sector output and GDP in grids (c) and (e) respectively. I would expect the general additional expansion across all sectors of the economy to be greater the more responsive export demand is to the fall in output prices (i.e. the greater the value of η), and as it becomes easier to substitute between capital and labour (i.e. as σ increases). This pattern is not universally evident in grids (c) and (e). However, if we bear in mind the fact that under the 200 net-in migration per annum scenario changes in the labour supply occur in every year up to 2010. Thus, by the year 2011 (the final period studied, and the year for which the results in Table 9.6 are reported) the economy in general and the Finance sectors in particular have not had sufficient time to adjust capital stock and employment to their optimal levels.

However, in terms of the environmental focus of the simulations that I present in this chapter, the most interesting results are to be found in the case of the impact on household income and expenditure. In Sections 3.2 and 3.4 I find that the additional impacts of allowing 200 in-migration per annum are universally detrimental on all environmental indicator variables. I explain that this is mainly because of the upward pressure on the level of total household consumption, which is the main source of most types of pollution, particularly traffic-related emissions, in the Jersey economy. However, I have speculated that if labour demand is sufficiently inelastic, the reduction in real wages from relaxing the labour supply constraint may be enough to offset the increase in employment, with the implication that total household income and expenditure must fall. This in turn may lead to some types of pollution generation in the economy falling as the aggregate level of activity increases. In the introduction to this section I explain that this possibility is the main motivation for focussing my initial sensitivity analyses on the parameters that determine the elasticity of labour demand.

I report the sensitivity results for the impact on the level of total real household income and expenditure in Table 9.6, grid (f). In Section 3.4 I find that, where σ = 0.8 and η = 5.0, total household income and expenditure increases by an additional 1.98% by 2011 when 200 net in-migration per annum is allowed in the presence of the 50% increase to Finance sector export demand. However, grid (f) shows that the *direction* of this effect *is* sensitive to what I assume about the elasticity of labour demand, particularly the elasticity of substitution between capital and labour. Specifically, if the value of σ is assumed to be 0.1 (in all sectors), total household income and expenditure falls as output and employment rises in all sectors of the economy. This is independent of the value of η. If the elasticity of export demand, η, is reduced to 0.5 the net impact on total household income and expenditure is almost zero impact where σ = 0.5, and negative where σ = 0.3.

However, in terms of actual policy analysis, one would have to consider the plausibility of labour demand in Jersey actually being as highly inelastic as is required to bring about this decline in total household income and expenditure.

Moreover, note from grid (g) that the decline in household consumption is only sufficient to bring about a net decline in *total* automotive fuel use in the case where $\sigma = 0.1$ and $\eta = 1.0$ (Cobb Douglas). Although I do not report it here, in this one case the net impact on emissions of the main traffic-related pollutants, NMVOC, CO and N_2O, is also negative. However, I find that the additional impact on all other types of pollution is uniformly positive regardless of what I assume about the substitutability of labour for capital or the price elasticity of export demand. This is due to the increase in productive activity across the economy when the labour supply constraint is partially relaxed, particularly in the Agriculture & Fishing sector, as reflected in the sensitivity results for the impact on the GWP Index by 2011 in grid (h). Nonetheless, the results reported here only apply to the specific time period (and do not reflect a long-run equilibrium) and scenario studied. I would argue that the suggestion of any type of negative relationship between the level of economic activity and environmental indicator variables indicates a need to focus research effort on finding out more about the nature of labour demand in the Jersey economy. In particular, it is likely that labour demand relationships will in fact vary over different industries, a factor that I do not consider in the present study.

5. Chapter Summary And Conclusions

In this chapter I discuss the results of four separate population policy simulations carried out under different assumptions about demographic changes, migration and demand conditions in the Jersey economy. Here I summarise the key results and draw conclusions on how the type of simulation results reported here should be used to inform policymakers considering sustainability issues such as population changes and pollution generation.

5.1 Summary Of Simulation Results

In the first simulation I find that with no exogenous changes in external demand conditions, the impact on economic activity in Jersey of the demographic changes imposed in the zero net migration hypothesis is slightly negative. Gross Domestic

Product (GDP) and Gross National Product (GNP) fall by 0.44% and 0.42% respectively by 2011. In Section 3.1 I explain that this is primarily because of the reduction in labour supply accompanying the ageing of Jersey's population. Relaxing this labour constraint, in terms of allowing in-migration in the second simulation, reduces the tightness in the labour market, leading to a subsequent expansion in the economy.

However, in Section 3.2 I note that the associated increases in GDP and GNP are relatively small: the additional impact on GDP by 2011 is only an increase of 2.04% under the 200 in-migration per annum hypothesis. The corresponding additional impact on GNP is slightly higher, with an increase of 2.38%. Further, these expansions in activity are accompanied by reductions in the real wage, which is not necessarily in the interest of existing Jersey residents – for example, GDP *per capita* actually falls by 0.59% by 2011 in the 200 in-migration scenario.

In Simulation 3 (Section 3.3) I introduce a large export demand shock to the aggregate Finance sector under the zero migration hypothesis. This leads to a positive impact on both GDP and GNP, which increase by 9.11% and 2.65% respectively by the end of the period of study, 2011. The smaller impact in the case of GNP is due to the high degree of foreign ownership in the Jersey Finance sector, which means that a significant proportion of the additional income from the export demand boost accrues to non-Jersey residents.

However, I find that the response of the economy to this increase in demand entails labour shifting between sectors so that output and employment fall in a number of other sectors, such as 'Agriculture & Fishing', 'Hotels, Restaurants & Catering', 'Wholesale & Retail Trade' and the transport sectors. The tightness of the labour market is reflected in the real wage level, which increases by 5.23% by 2011. The competitiveness of all Jersey sectors is affected by the increased costs of production (with the implication that the initial 50% increase in export demand to the Finance sector is not fully realised).

In Simulation 4 (Section 3.4) I find that these negative effects are partly mitigated under the 200 net in-migration per annum scenario, which increases competitiveness by reducing the rise in the real wage. However, the additional GDP and GNP generated by relaxing the labour constraint in this way in the presence of increased demand to the Finance sector is not very much greater than the additional changes when the demand shock is not present (i.e. in Simulation 2).

I find that the key factor determining the environmental impacts of all the simulations is the effect on the level of real consumer expenditure in Jersey. This is because, as is I find in the environmental accounting study in Chapters 6 and 7, household income and expenditure is the dominant factor determining the level of emissions of most of the major pollutants identified in Jersey, particularly traffic-related emissions. In all the scenarios I study here, with the exception of the zero migration hypothesis combined with no exogenous change in demand (Simulation 1), real household expenditure rises, which increases automotive fuel use and, consequently, the generation of all traffic-related emissions.

In Simulation 1 (Section 3.1) I find that under the zero migration scenario traffic-related emissions fall. The addition of either the demand shock or positive migration generates an increase in these pollutants as against the 2001 base level. I find that the biggest impact on automotive fuel-use occurs in the cases where a 50% increase in export demand is assumed to be present (Simulations 3 and 4). This is because increases in activity are concentrated in high wage sectors, thus increasing the level of real income and expenditure per household.

Generally I find that when the population constraint is relaxed (with or without the export demand shock), all types of energy and water use and pollution generation in Jersey increase, because the level of activity in all sectors of the economy improves.

However, I report that the demand shock does crowd out a number of activities. In particular, the Agriculture & Fishing sector suffers most through increased costs of production and reduced competitiveness. Agriculture & Fishing is a key energy user

and generator of a number of pollutants. However, the primary pollutant associated with agricultural activities in Jersey is methane (generated by livestock). Methane is a major component of the Global Warming Potential (GWP) Index, which is widely accepted as an indicator of the impact of individual economies on the climate change problem. I find that the increase in the GWP Index in the presence of the demand shock (Simulation 3) is less significant than the increase in traffic-related emissions, increasing by only 1.82% by 2011 compared to increase in CO_2 and NO_X emissions of 2.78% and 4.56% respectively. The GWP Index *is* influenced by traffic-related emissions. However the weight attached to methane, and the absolute reduction in methane emissions due to the crowding out of agricultural activity serve to pull the value of the increase down. Note, however, in Section 3.4 I report that when limited net in-migration (200 working age people per annum) occurs there is a marked increase in GWP emissions (an additional 2.61% by 2001) due to the general increase in activity, both agricultural and non-agricultural, in the economy. However, the total percentage change in the GWP Index remains lower than the change in either CO_2 or N_2O, reflecting the overall fall in methane emissions, even with migration.

5.2 Conclusions on the construction and use of the JEMENVI modelling framework for Jersey

If a CGE model is to be used to inform policy debate, it is important that the policymaker is aware of the precise assumptions under which simulation results apply so that he or she can appropriately interpret the results. I outline the model specification and default configuration adopted for the simulations conducted here in Chapter 8 and in the Simulation Strategy section of this chapter (Section 2). Making the assumption that everything apart from the demographic changes and the financial demand shocks remains constant allows me to study the impact of the various population scenarios in isolation. Therefore it is important to emphasise to policymakers that CGE modelling results of the type I report here are not *forecasts* of what is likely to happen - assuming no other change in the economy is unrealistic. Rather, the results are designed to isolate the influence of specific factors on the

economy. For example, the results I present in this chapter are aimed at isolating the effects of population influences on the Jersey economy.

Therefore in Section 2 I argue that, ideally, there should be interaction between the modellers and policymakers in terms of the type of sensitivity analysis of key parameter values and model configuration required, and whether the simulation strategy or questions posed should be refined[13].

In the first instance, the sensitivity analyses that I report in Section 4 of this chapter focus on two sets of key parameter values – the CES elasticity of substitution between labour and capital and the Armington price elasticity of export demand for local outputs. The Armington elasticities are particularly important in modelling a small open economy like Jersey because of their importance in determining the impact of disturbances on traded sectors. The CES elasticity of substitution between primary factors is of general importance because of the implications for the flexibility of production. Indeed, while there are a number of other parameter values that should be the subject of future sensitivity analysis within the JEMENVI framework, more extensive analysis of these two parameters is a priority. Specifically, I hope to examine the impact of varying the values of these parameters across different sectors. In other words, one of my main research objectives is to attempt more detailed modelling of individual sectors, particularly the main finance sectors (Banks & Building Societies and Investment Trusts & Fund Managers).

The Armington elasticities of export demand and the CES substitutability between capital and labour are also key determinants of the wage elasticity of the general equilibrium labour demand curve. Therefore, the choice of these two parameters is especially appropriate in terms of assessing the sensitivity of the environmental impacts of the shocks simulated here, as these are largely driven by the impact on household income and expenditure. The results of the sensitivity analyses in Section

[13] I hope that this will be the outcome of reporting the simulation results contained in this chapter to the Policy and Resources Committee of the States of Jersey. (A report 'Strathclyde Economic-Environmental Model of Jersey (JEMENVI): Simulations on the Economic and Environmental Impacts of Population Changes' based on the empirical work carried out in this thesis was presented to the States of Jersey in November 2001 (Fraser of Allander Institute, 2001).)

4 do in fact show that the magnitude of environmental impacts reported in this chapter are sensitive to the precise assumptions made about the substitutability of capital and labour and the price elasticity of export demand. For example, in the nil net migration scenario combined with the Finance sector demand shock, I find that the impact on the GWP Index by 2011 increases by more than 50% if I assume that the value of the Armington elasticity of export demand is 3.0 rather than 5.0.

The *magnitude* of the additional environmental impacts of relaxing the labour constraint by allowing 200 in-migration per annum is less sensitive to what is assumed about the wage elasticity of labour demand. However, I find that the *direction* of the relationship between the generation of the main traffic-related pollutants (CO, N_2O and NMVOC) is sensitive to what I assume about these parameters. Specifically, I find that emissions of these pollutants by households (the main generators of traffic-related emissions in Jersey) fall if both the price elasticity of export demand and the constant elasticity of substitutability of capital for labour are assumed to be sufficiently low. (However, as I explain in Section 4.4, the net impact on *total* emissions of CO, N_2O and NMVOC is only negative under quite extreme assumptions about these parameter values.)

That the JEMENVI framework offers the facility of varying parameter values and model structure for testing the sensitivity of results to factors such as the elasticity of labour demand is illustrative of the added value gained from constructing a CGE framework relative to the IO system in Chapter 7. In Chapter 8 I explain that, due to the lack of data for econometric estimation of parameter values for Jersey, it is necessary to impose what are essentially "best-guess" estimates for key relationships like factor substitutability. However, in an IO framework, which assumes Leontief technology in all production (and consumption) relationships, the best guess is constrained to a value of zero, and this is not open to sensitivity analysis.

Generally, an IO model is too limited a framework for the type of analyses required to address policy issues of the type I examine in this chapter. Firstly, as I explain above, the assumption of universal fixed coefficients in production basically implies

that the best guess is zero substitutability between all inputs to production. Secondly, the assumption of infinitely elastic supply is a problem for economies that are in any way resource constrained. Specifically, the type of labour expansion simulated in this chapter could not be introduced to a conventional (demand-driven) IO model without either making arbitrary assumptions about exogenous demand (see, for example, the IO modelling application in Appendix 7B) or adapting the IO framework to develop a supply-driven system. The latter approach has been attempted by Ghosh (1958) but involves making a number of questionable assumptions that have been severely criticised by Oosterhaven (1988, 1989).

Thus, the existence of the supply constraint in the Jersey labour market is the key factor motivating the development of a CGE modelling framework for Jersey as the core element of my thesis. Specifically, the central focus of the policy questions addressed in this chapter is the implications of the existence of a supply constraint in the local labour market and of attempting to relax this supply constraint by allowing limited in-migration over a given time period. These are quite simply questions that cannot be addressed in an IO framework: even adopting the supply-driven IO approach of Ghosh (1958) would only allow me to examine the long-run impact of the existence labour supply constraint, not the impact of relaxing this constraint over a given period of time.

Generally, I have argued that while CGE retains the multi-sectoral data driven focus of IO it offers a richer more theory-consistent approach (while encompassing IO as a limiting case). Crucially, adopting a CGE approach allows me to model both production and consumption using standard economic theory, particularly by allowing substitution between inputs/commodities and modelling of competitiveness effects. I believe that my analysis in this chapter shows that these elements are clearly relevant to the Jersey case.

More generally, the added value gained from adopting a CGE approach relative to an IO one is an important issue in economic-environmental analysis. In Chapter 1 I explain that this is currently an area of active debate in the UK. The UK

Environment Agency, the English Regional Development Agencies (RDAs) and the National Assembly for Wales have commissioned scoping studies on the type of model that would be appropriate for analysing the environmental impact of economic behaviour. The environmental IO approach has attracted the most interest in this process, as is commonly the case, due to its being relatively straightforward to understand and implement (given the availability of an appropriate database[14]). However, one of the core arguments of my thesis is that while construction of an environmental IO system provides an invaluable data base for analysis and extremely useful accounting framework (see Chapters 6 and 7), it is of limited usefulness addressing policy questions where supply-side responses matter at all. In particular, if the economy being studied is characterised by any supply-side constraints, IO will be of limited applicability.

Moreover, I have also argued that adopting an IO approach is likely to be particularly unsuitable for analysing issues relating to the use of environmental policy instruments, which are commonly aimed at the supply-side of the economy. For example, policy instruments aimed at improving energy efficiency or the use of less polluting types of energy or non-energy inputs (such as carbon taxes) typically work by changing relative prices to induce substitution between different types of input. Analysis of the likely impacts of implementing such policies would not be possible in an IO framework, where input substitution is not possible. Of course, as I explain in Chapter 6 (Section 4), the current specification and software available to me for construction of the JEMENVI framework render it unsuitable, at present, for the full analysis of these types of environmental policy. Specifically, this would require a more flexible treatment of energy inputs and input-pollution relationships than is currently specified, which is a development that I recommend if the States of Jersey chooses to consider the use of environmental policy instruments. I discuss this issue in more detail in the next chapter.

[14] One other element of the current UK debate is the costs and benefits of using region-specific data for multi-sectoral accounting and/or modelling analysis of economic-environmental interaction, independent of whether an IO or CGE approach is adopted. In Turner (2002) I discuss this subject, based on the findings discussed in Chapter 6 (Section 5) of this dissertation.

In conclusion, in this chapter I demonstrate the fulfilment of the core objective of my study, which is the construction of a multi-sectoral economic-environmental model for policy analysis in a small open economy. I use Jersey as an empirical example, with the aim of developing a framework that facilitates analysis of the impact of policy and other disturbances on stated sustainability objectives. I have achieved this objective firstly by constructing a multi-sectoral modelling framework with endogenous environmental variables, making it possible to track and explain the movement of chosen 'sustainability' indicators in response to changes in economic activity. Secondly, by adopting a flexible CGE approach to modelling the economy I have developed a framework that is appropriate for analysing the type of supply-side issues that are so important in an economy like Jersey, where problems of population and labour supply constraints have an important impact on economic activity.

Chapter 10. Conclusions And Suggestions For Future Research

1. Summary

The main objective of this dissertation is to develop a modelling framework that allows analysis of the impact of policy changes and other disturbances on key economic and environmental indicators, with specific reference to the objective of sustainable development.

In the first stage of the study I investigate measurement of sustainable development in the UK and Jersey. In Chapter 2 I conclude that it is commonly agreed that there is a need to choose and monitor a set of indicators representing variables that are considered important for economic development to be sustainable. For example, suppose it were agreed that one element of achieving sustainable economic development is to have economic growth without an increase in emissions of pollutants that contribute to global warming. If this were the case, appropriate indicators would be the level of emissions of gaseous pollutants like carbon dioxide, methane and nitrogen dioxide, and/or a composite measure of more than one pollutant, each weighted according to its global warming potential. Another set of possible candidate indicators would be the use of different types of fuels that give off global warming gases when combusted.

The example of global warming perhaps gives a misleading impression of consensus in the sustainability policy debate. In Chapter 2 I found that, aside from this particular example, there exists a great deal of uncertainty over what is meant by 'sustainable development' and therefore over defining sustainability objectives and the type of indicators that should be used to monitoring progress towards their achievement. However, while I did consider and attempt to clarify some of the issues involved, it has not been the primary purpose of this study to answer these questions. (The study focuses on pollution generation issues, only for the reason that this is the element of sustainable development that most policymakers seem to focus on.) Rather, the primary issue that the study has been concerned with is, once

policymakers have chosen a set of sustainability indicators, identifying the best way to track and analyse their movement. My main conclusion in Chapter 2 was that the proposed process of monitoring a set of sustainability indicators that reflect sustainability objectives is a purely *descriptive* one, simply stating whether or not development is becoming more or less sustainable (subject to the stated definition of sustainable development). I argued that what is missing from this process is an *explanation* as to *why* indicators move in an observed direction, and what may cause them to move in a particular way. Therefore, I went on to argue that what is required is knowledge of the *transmission mechanism* linking economic activity to any disturbance to the system (e.g. policy) and to the variables that indicate sustainability.

This requirement provided the motivation for this study. In common with many other regions and nations, the States of Jersey has identified environmental issues, specifically pollution generation and resource use, as a key area of concern in defining sustainability objectives. With this focus, knowledge of the transmission mechanism implies a need to model the relevant behavioural relationships and interdependencies in the economic-environmental system, incorporating environmental indicator variables as endogenous variables. This would make it possible to capture the sequence of causality between any activity or disturbance and any change in the indicator variables.

In Chapter 3 I then begin considering the type of approach that would be appropriate for modelling economy-environment interaction. The first issue is what type of *economic* model is required (given that we are concerned with the impact of the economy on the environment). In the literature it is generally accepted that the primary requirement is for a system-wide multi-sectoral model of the economy because of the importance of the composition of economic activity in governing its impact on environmental variables. Because it is necessary to have a level of sectoral disaggregation that reflects different resource-use and pollution characteristics in different production and consumption activities in the economy, single sector macroeconomic models are of limited usefulness. Partial equilibrium models are also

unsuitable because the full environmental impact of any one economic activity is likely to be governed by a complex chain of interactions and interdependencies between different sectors of the economy. Thus, in Chapter 3, I reach the conclusion that a multi-sectoral general equilibrium approach is required.

The remainder of Chapter 3 and Chapter 4 involve a literature review to see what general lessons could be learned from existing empirical general equilibrium models of economic-environmental interaction. In Chapter 3 I focus on the limiting case of environmental input-output (IO) systems. Most of the applications reviewed are concerned with *accounting* for pollution generation in the target economy. Several do consider *changes* in sources of pollution generation (technology and/or energy use). However, the crucial point is that the environmental IO applications that attempt to do this do not attempt to *model* marginal changes in pollution generation variables. Rather historical data are used to adjust environmental IO matrices to account for changes that have actually occurred in production (or consumption) behaviour in the target economy. For example, Weir (1998) looks at the impact on emissions generation of changes in input mixes in all sectors of the Danish economy over the period 1966 to 1988, during which time there was a general shift towards less energy-intensive production methods.

However, several of the applications reviewed in Chapter 3 do attempt to use IO methodology to model the likely impact of marginal changes in exogenous economic variables (e.g. final demand). Therefore in the conclusion to Chapter 3 I make the argument that adopting an environmental IO approach to modelling the impact of changes in economic behaviour might not be appropriate, particularly if the hypothesised disturbance to the system is likely to change relative prices. This would be expected if there are any constraints on supply in the economy. However, conventional IO systems are demand-driven, with the implication that the supply-side of the economy is assumed to be entirely passive. It has been argued (Ghosh, 1958) that it is possible to construct a supply-driven IO system[1]. However, the problem still remains that IO models cannot deal with the simultaneous importance

of supply and demand in determining prices and quantities. Moreover, IO models assume universal fixed proportional (Leontief) technology, which implies zero substitutability among all inputs to production and consumption in response to any change in relative prices.

I make the argument that in these circumstances it would be better to adopt a less rigid CGE approach, which allows greater flexibility in terms of how behavioural relationships are modelled and the supply-side of the economy is represented. Therefore in Chapter 4 I go on to investigate the main issues involved in developing a more flexible computable general equilibrium (CGE) model that incorporates environmental elements such as different types of energy use and pollution generation. A number of existing economic-environmental CGE applications are reviewed with the purpose of identifying how the key environmental issues of energy use and pollution generation can be incorporated in a CGE modelling framework.

The core element of the study is the development of an empirical model of economy-environment interaction that can be used to analyse the impact of policy intervention and other disturbances in a small open regional economy. The first stage in this process is construction of a comprehensive database describing the structure of the target economy in the chosen base year. This is the focus of Chapter 5, where I explain that the core element of a CGE modelling database is a social accounting matrix (SAM) for the target economy. A SAM incorporates a set of input-output accounts describing the production structure of the economy, augmented with information on flows of income between the main institutional transactors (i.e. households, firms, government and the external sector), patterns of consumer expenditure and capital formation in the economy. For economic-environmental modelling the main requirement is that the sectoral breakdown in the SAM should be sufficient to separately identify production and consumption sectors with distinct fuel supply/use and/or pollution generation characteristics.

[1] The plausibility of supply-driven IO models has been severely criticised by Oosterhaven (1988, 1989).

The construction of the economic database for the target economy of Jersey is itself a key element of value-added from this study. Despite Jersey being a developed, self-governing economy, no national accounts have ever been constructed. Therefore, the construction of a CGE model of the Jersey economy has the added benefit of providing a set of national accounts for the base year, by providing a set of IO tables and facilitating the reporting of important economic indicators, such as GDP and GNP[2].

In Chapter 6 I focus on the construction of the environmental component of the model database. This involves reporting data on environmental inputs (e.g. energy, water or other natural resource use) to and outputs (e.g. pollution) from each production and final consumption sector identified in the economic accounts. These accounts are then used to construct technical coefficients for economic-environmental relationships that exist in the target economy.

The construction of the environmental accounts for Jersey is also a key output in its own right. As I explain in Chapter 6 (Section 2.2), while the States of Jersey have engaged in significant attempts to report on environmental factors, this has never before been done in a format that is consistent with standard economic accounting practices. Jersey is not peculiar in this respect; indeed the issue of inconsistency between economic and environmental accounting is a common area of concern both to modellers (see Chapter 3, Section 5.2) and statisticians responsible for producing environmental accounts (see Chapter 5, Section 2.1). In response Eurostat (the statistical office of the European Union) has begun promoting the construction of what are referred to as NAMEA[3] accounts. The idea of NAMEA accounting is to report both environmental variables (such as different types of energy use and pollution generation), in physical terms, and economic variables, in monetary terms, for a consistent sectoral breakdown. While Jersey is not a member of the European Union, the States have expressed a preference for adopting accounting practices that

[2] As noted in Chapter 5 (Section 2), while I was not involved in the (economic) data collection process and only became involved in the construction of the IO accounts at the processing and balancing stage, I had primary responsibility for construction of the SAM for Jersey.
[3] NAMEA stands for National Accounting Matrix including Environmental Accounts – see Chapter 6, Section 2.1.

are common to other European economies, particularly the UK. Therefore the economic-environmental database constructed in the NAMEA format (see Chapter 6, Section 3) is another valuable element in the development of the Jersey national accounts.

Generally, at least in a UK context, the construction and use of a region-specific economic-environmental database is unique and is one of the main elements of value-added produced by this study. As I explain in Chapter 1, there is significant current interest in developing economic-environmental accounting and modelling frameworks at the regional level in the UK as a result of the devolution of a significant degree of responsibility for setting and meeting sustainability objectives. Therefore the value-added from the region-specific database construction stage of this study is not limited to the target economy of Jersey. One of the issues faced by the agencies responsible for investigating the development of appropriate frameworks for analysis of economic-environmental issues at the regional level in the UK[4] is the appropriateness of using region-specific data for accounting and modelling purposes. Given that comprehensive regional accounting (in terms of both the economy and the environment) has been limited in the UK, the example reported here is of significant interest.

In particular, one of the key outputs of this study is the development of Jersey-specific input-pollution and output-, or expenditure-pollution coefficients in Chapter 6 (despite the fact that software constraints have prevented the application of the former in the initial version of the Jersey model – see Section 2 below). In Chapter 6 (Section 5) I undertake an empirical investigation to assess the added precision from constructing region-specific technical coefficients for accounting and modelling economic-environmental relationships. This involves comparing the basic accounting

[4] As noted in Chapter 1, the National Assembly for Wales and English Regional Authorities have engaged in a joint consultation process with the UK Environment Agency on constructing an economic-environmental accounting and modelling framework. The Scottish Executive has set up its own Scottish Environmental Accounts Working Group (SEAWG), which I have been asked to participate in. The SEAWG is currently consulting with local agencies and academics and the Environmental Accounts Branch of the UK's Office for National Statistics on the construction of an empirical economic-environmental framework that will incorporate, where possible, Scotland-specific data.

results that are found using the Jersey-specific coefficients against a set of coefficients constructed for Jersey using data on the average pollution intensities of equivalent activities in the UK. The main finding of this investigation was that differences in polluting technology in the UK and Jersey are such that significant gains in accuracy are achieved by estimating and using the Jersey-specific environmental coefficients. This particular element of the thesis, and its implications for regional accounting and modelling in general are further developed in Turner (2002).

In Chapter 7 I develop a regional environmental IO system based on the Jersey data. While I have argued here that environmental IO *modelling* is of limited usefulness for a supply-constrained economy like Jersey, the construction and application of the environmental IO system is in fact a valuable development. In Chapter 7 I propose that the availability of an environmental IO framework is extremely useful for descriptive analysis of the size and nature of environmental problems in the economy in the base year for which the accounts have been constructed. The environmental IO system constructed here for Jersey is particularly useful for this purpose for two reasons:

1. The accuracy that is gained from the use of region-specific economic and environmental data and technical coefficients.

2. The inclusion of direct emissions generated not only in production but also final consumption activities (tourism and household expenditure). Of particular importance is the estimation of the emissions intensity of final consumption by households in different income bands, which provides the basis for undertaking distributional analysis of environmental policy actions (such as taxes on energy use).

An important element of the work reported in Chapter 7 is the development of IO attribution methodology towards identifying consumption as the driver of pollution

generation. This is an important development, certainly from an environmental or sustainability perspective. Traditional IO attribution techniques implicitly adopt a Keynesian perspective, where exogenous (final) demand drives all activity, and therefore pollution generation in the economy. In Chapter 7 we see that this leads to a large proportion of pollution generation in Jersey being attributable to non-Jersey consumption demand.

This perspective may be appropriate if it is thought that economic activity is driven by external demand factors (e.g. export demand, central government). However, it also means that the pollution content of imports going directly or indirectly to Jersey local final consumption is not attributed at all. Therefore, the approach may be considered misleading, particularly by environmentalists, who would put human consumption (and consumption choices) at the centre of the pollution problem.

In Chapter 7 (Section 2.2.3) I argue that there would huge practical and conceptual problems in attempting to overcome the problem of the pollution content of imports. Therefore, I attempt to improve the concept of attribution by adopting a neo-classical, rather than a Keynesian economic approach. This is the development of neo-classical linear attribution system (NCLAS). In the NCLAS system exports are treated as endogenous, with the implication that region exports only so as to finance its imports through an additional 'trade' sector. The identification of neo-classical output-pollution multipliers then allows all pollution generation in the economy to be attributed to local private (household) and public (government) consumption (both of which are determined, and can therefore be influenced, locally)[5]. However, in the conclusion to Chapter 7 I highlight the fact that this type of accounting exercise, which involves analysis of average behaviour at a given point in time, should not be confused with modelling the likely impacts of marginal changes in behaviour. As I have explained above, an IO system is a very limited economic model due to the assumption of universal Leontief technology and absence of a realistic representation of the supply-side of the economy.

[5] The attribution analyses reported in Chapter 7, including the development of the NCLAS system have been developed in a conference paper of which I am a co-author (McGregor *et al* 2001a).

The implication that "only demand matters" means that conventional IO modelling is often motivated in terms of large unemployment and excess capacity. However, in Chapter 7 I argue that this view of the economy is inconsistent with actual conditions in the Jersey economy, particularly with respect to the labour market, where there is almost zero unemployment and current population policy places significant constraints on the migration of labour into the economy. The latter point is also a problem for the alternative view that IO is applicable to pure demand disturbances in the long-run where free migration of labour and capital accumulation may be expected to relax short- to medium-run restrictions on supply (McGregor *et al*, 1996).

In Appendix 7A I do make an attempt to overcome this problem within the IO framework by choosing a simulation strategy wherein the importance of the binding labour supply constraint is limited by holding total demand for labour constant. However, while this approach allowed the computation of an outcome that could be regarded as realistic for Jersey, in as much as it is within the feasible solution space implied by a long-run constraint on the supply of labour, the results are of limited usefulness to policymakers in Jersey. This is because what is missing is an explanation of *how* the economy adjusts to this new equilibrium. From the simulation questions introduced in Chapter 9 (for the CGE modelling application) it is clear that the States of Jersey, in common with most regional policymakers, are concerned about short run, as well as long run outcomes. Therefore an additional requirement is that it should be possible explicitly to model the adjustment process that takes place in response to any disturbance on a period-by-period basis. This is simply not possible in a standard IO framework.

Therefore in Chapter 8 I go on to develop an economic-environmental CGE modelling framework using the Jersey database constructed in Chapters 5 and 6. The motivation for this development is that a CGE model retains the multi-sectoral and data driven perspective of the IO system, but provides a richer, more theory consistent approach in which all relative prices and quantities are determined

endogenously and supply and demand in all markets are equilibrated simultaneously. In particular, adopting a CGE approach means that I can

- capture any regional competitiveness effects of demand disturbances
- analyse the impacts of supply-side policies
- accommodate relevant econometric analysis where it is available
- conduct full policy evaluation of how the economy adjusts to supply- or demand-side disturbances over distinct time periods

The Jersey economic-environmental CGE model (JEMENVI) is constructed by applying the Jersey-specific database to an existing CGE modelling framework. This is the *n*-sector AMOS framework, developed at the Fraser of Allander Institute and originally calibrated on Scottish data[6]. In Chapter 8, I explain that the main benefit of using the *n*-sector version of AMOS as a template for the new Jersey model is that this means we have a multi-sectoral modelling *framework*, which incorporates a wide range of possible model specifications. This is crucially important in the case of Jersey, where a lack of historical region-specific economic data makes the availability of a facility for comprehensive sensitivity analyses of model specification essential.

In Chapter 9 the new JEMENVI model is used to carry out a number of simulations. These illustrate the fulfilment of my objective in the present study. This objective is stated in Chapter 1 as constructing a model capable of tracking and explaining the movement of chosen environmental, or sustainability indicators in response to the use of policy instruments or other disturbances to the system. Therefore the simulations focus on tracking and explaining the impact on energy consumption and

[6] In fact one other output arising from my thesis, but not reported in depth, is the revision and updating of the Fraser of Allander Institute's Scottish modelling framework. In Chapter 8, I explain that I have updated the Scottish SAM database using 1994 data for the 3-sector and *n*-sector AMOS modelling frameworks. In particular, I have developed the *n*-sector framework by adding an environmental component, based on UK average emissions data, to construct an economic-environmental CGE modelling framework for Scotland, AMOSENVI 94. Illustrative simulations using this framework are reported in a co-authored paper, McGregor *et al* (2001b). I have also developed a Scottish environmental IO system, based on the 1998 Scottish IO tables and the 1998 UK NAMEA tables. Attribution analyses using this system are reported in another co-authored paper, McGregor *et al* (2001c).

pollution indicator variables resulting from several hypothesised disturbances to the Jersey economy. Specifically the scenarios simulated focussed on policy options relating to one of Jersey's key sustainability objectives – sustainable development under the constraint of limited population growth – under different hypotheses about demand conditions in the economy[7].

2. Suggestions For Future Research

I have identified four main areas in this dissertation as requiring further research and development:

1. More comprehensive sensitivity analysis of the JEMENVI model specification.
2. Development of a SAM-based attribution system for a small open regional economy such as Jersey.
3. More flexible modelling of energy-use and pollution generation in the generic AMOS/JEMENVI framework.
4. Incorporation of a wider range of individual and composite indicators in the AMOS/JEMENVI framework.

The first of these developments, the need for more comprehensive sensitivity analysis of the JEMENVI model configuration and specification outlined in Chapters 8, Section 4.1. There I explain that no historical economic data are available for econometric estimation of parameter values or testing of model specifications. Therefore, there is a need for comprehensive sensitivity analysis. Some preliminary sensitivity analyses are reported in Chapter 9, Section 4. These focus on varying parameter values that are important in determining labour demand, and were selected for preliminary sensitivity analysis on the basis that the key factor determining the environmental impacts of all the simulations reported is the effect on the level of real consumer expenditure in Jersey. However, I have explained that, ideally,

[7] In fact the issue of population has become such an important policy question in Jersey that the work I have done with the JEMENVI model in Chapter 9 is already being used to inform the policy debate in Jersey (see Fraser of Allander Institute, 2001b).

requirements for fuller sensitivity analysis should be determined through interaction with policymakers in Jersey once they have interpreted and understood results reported for particular scenarios, such as the population policy simulations discussed in Chapter 9. Such interaction is likely to take place in the near future, and I hope that this will generate further simulations and development of the JEMENVI framework. Early discussions with the States of Jersey have already highlighted incorporation of the local housing market and disaggregation of the labour market to recognise different skills groups as key areas that are likely to impact on the basic simulation results reported here.

The second area where I recommend further research effort is discussed in Sections 2.2.2, 3.2 and 4 of Chapter 7: this is development of a SAM-based attribution system. Section 2.2.2 discussed how it might be desirable to develop more consumption-based measures of pollution generation. For example, a measure of 'Gross National Pollution' for the target economy (pollution generated directly or indirectly by the consumption of the residents of that economy) rather than the 'Gross Domestic Pollution' that can be measure in the environmental IO system (pollution generated by activity located in the economy). Analysis of the full pollution (and resource use) requirements of national consumption would require more information than is available in an environmental IO system. In particular, in Chapter 7, Section 3.2 I draw attention to the very limited treatment of household income and expenditure that is possible in an IO framework. The only element of household income that is recorded in an IO table is income from employment, with the implication that any household expenditure in excess of the value of income from employment must be treated as being determined exogenously. However, in reality we would expect other elements of household income to be determined endogenously, such as profit income from ownership or investment in local businesses or property. IO accounts do not record these types of income flows; however they are standard elements included in a SAM. Given the availability of a SAM (constructed in Chapter 5) and a comprehensive environmental database (Chapter 6) for Jersey in 1998, it should be possible to develop a SAM-based attribution system, and I hope that this can be done in the near future. However, as I have argued in Chapters 3 and 7, if we want to fully

account for the pollution/resource use requirements of local consumption, an inter-regional attribution framework would be required. I have argued that the data requirements render this an infeasible task for Jersey at the present time. However, I do hope to carry out some preliminary research in this area in the near future, most likely using Scottish regional and UK national data.

The third and main area where further development of the work presented here is required is the modelling of energy use and pollution generation in the Jersey CGE modelling framework. In the CGE literature review in Chapter 4 I identify the treatment of energy use as the key factor in modelling environmental problems. In Chapter 4 I report finding no general consensus as to exactly *how* the substitutability between different energy types and between energy and other production inputs/consumption commodities should be modelled. However, I conclude that this lack of consensus is mainly due to the practical difficulties in testing model specification, with the implication that the debate is largely centred on differences in judgement. A consensus does exist over the need to fully investigate the impact of different types of energy use on the environment.

In Chapter 6, where pollution generation in Jersey in the base year of 1998, is measured, I reported the finding that the fuel mix used in different activities is the dominating factor determining emissions of almost all the pollutants identified. This is reflected in the environmental coefficients used in the economic-environmental model for Jersey that is constructed and used in Chapters 8 and 9 respectively. However, as I explain in Chapter 8 (Section 4.1), what is missing from the JEMENVI model is any possibility for substitution between different types of energy and between energy and other inputs. This is because of the constraints of the existing modelling software that was available for the present study and the limited time available to complete it. Within the existing AMOS modelling framework (which provides the template for JEMENVI), multi-level production (and consumption) structures are used for each sector, with choices of CES, Cobb-Douglas or Leontief functions at each level (see Chapter 8, Section 2.1). However, the sparcity of the intermediate matrix in the Jersey database rules out the use of a

multiplicative functional form for the choice between intermediate inputs (including energy inputs). Therefore only constant fixed proportions Leontief technology can be used for this relationship. That is to say different types of energy and energy and non-energy inputs can only be treated as complements in production and consumption.

In Chapter 8 (Section 4.2) I explain that the main implication of this for modelling pollution generation is that it renders the use of the Jersey-specific *input*-pollution coefficients determined in Chapter 6 redundant in the existing JEMENVI framework. This is because if there is a constant proportional relationship in the use of all individual energy and other intermediate inputs there are only limited possibilities for modelling changes in pollution levels due to the 'input substitution' effects defined in Chapter 4, Section 5.2. As I explain in Chapter 6, Section 4, the only possibilities for a change in pollution levels due to 'input substitution' effects under these conditions would be

(a) If CES technology is assumed for the production of gross output and there is substitution away from the composite intermediate good towards value-added (capital and labour).

(b) If there is substitution away from the local supply of energy commodities in favour of imports.

However, both these possibilities would be captured by the use of the output/expenditure-pollution coefficients derived for Jersey in Chapter 6, Section 4, because both involve a reduction in the scale of production in the local energy supply sector(s).

Therefore in Chapter 8, Section 4.2, I conclude that it would be desirable to develop the JEMENVI software and model specification to allow a more sophisticated treatment of energy that would in turn allow effective modelling of input-pollution relationships. Given the general sparcity of the Jersey intermediates matrix, this

would most likely require separating energy commodities from other intermediates to allow substitution between different types of fuel before energy is combined with other intermediates and value-added in the production and consumption structures of the model.

My review of the economic-environmental CGE literature in Chapter 4 offers some suggestions as to how this type of development could be made. For example the specification adopted by Beauséjour *et al* (1994, 1995) involves separately identifying a 'stationary' energy block in the intermediates block of the production and consumption structures (see Figure 4.6 in Chapter 4). Within the stationary energy nest there are possibilities for substitution between what has been referred to in the Jersey case as the 'non-motive' energy types that are used for heating and lighting purposes. The stationary energy composite then combines with other intermediates (including 'motor fuels', referred to here as automotive fuels). Alternatively, models such as Bergman (1990, 1991) and Böhringer & Rutherford (1997) – see Figure 4.4 - model gross output as a combination of a non-energy intermediate composite and a value-added/energy composite wherein the aggregate energy commodity is substitutable with capital. Of course, this decision would require investigation of substitution possibilities in Jersey. In Chapter 8, Section 4.1, I explain that no historical data are available for econometric estimation of parameter values in the Jersey economic model constructed here. However, my discussions with fuel suppliers in Jersey (for the environmental database construction in Chapter 6) suggest that some information may be available on historical uses of different types of heating systems and fuels that may permit estimation of substitution possibilities for domestic and commercial non-motive/stationary energy use.

I believe that one development that should be made for input-pollution modelling in JEMENVI is to disaggregate the 'Oil & Fuel Distribution' sector to separately identify the 6 individual fuel types that this sector supplies – automotive fuel, kerosene SGK, kerosene LSK, gas oil, light fuel oil and coal. (The seventh oil-based fuel identified in the environmental database construction – Chapter 6 - is heavy fuel oil, which is directly imported by the electricity sector and exclusively used in

electricity generation.) In Chapter 4 (Section 4.2), I explain that the most common breakdown of energy types is to identify oil, gas, coal (the three basic fossil fuel types) and electricity. However, it is also clear that, depending mainly on the purpose for which the model is being built (e.g. the impact of energy price changes, pollution generation etc) and on the specific patterns of energy supply and consumption in the target economy, there may be further disaggregation of energy types. In the case of Jersey and modelling pollution generation, I report (in Chapter 6, Section 3) that each of the 7 individual oil-based fuels have significantly different pollution characteristics, which depend both on the type of fuel used and the technology used to combust it.

Therefore one of my main recommendations is that the JEMENVI model be developed to separately identify coal, automotive fuel, kerosene SGK, kerosene LSK, gas oil, light fuel oil, heavy fuel oil, along with the existing gas and electricity sectors[8]. Moreover, I recommend that this development be accompanied by further research on how the model software and specification should be developed to incorporate a more sophisticated treatment of energy use. Software development will also be required to allow pollution generation to be modelled using equations (6.1) and (6.2) from Chapter 6, which contain the environmental coefficients necessary to model both input- and output-pollution relationships. This would allow me to model changes in pollution generation in Jersey due to the 'composition', 'technology', 'input substitution' and 'scale' effects identified in Chapter 4 (Section 5.2).

Implementing this type of development is likely to be important if an economic-environmental CGE model is to be used for analysing the potential impacts of environmental policy instruments. This is particularly important if policy is aimed at inducing substitution away from the use of certain types of inputs that are thought to have environmentally harmful properties. For example, carbon taxes are aimed at inducing substitution away from fuels with high carbon contents because there is a

[8] In the present configuration of the Jersey environmental IO and CGE models an aggregate 'Gas, Oil & Fuel Distribution' sector is identified. However, as I explain in Chapter 5 (Section 3.3) separate 'Gas' and 'Oil & Fuel Distribution' sectors are identified in the 28-sector economic and environmental databases.

direct relationship between carbon content and CO_2 emissions (that is largely independent of combustion technology).

Similar types of development have been proposed elsewhere for the Scottish economic-environmental (AMOSENVI) framework, to allow modelling of policy instruments aimed at improving resource (particularly energy) efficiency and the UK's proposed Climate Change Levy[9]. The Climate Change Levy is an example of the use of carbon taxes to reduce emissions of CO_2, the greenhouse gas with the highest emissions levels in the UK.

One other area of the proposed development of the Scottish modelling framework coincides with the fourth and final recommendation for future research identified at the start of this section. This is the incorporation of a wide range of sustainability indicators, including a measure of Green GNP. At the end of Chapter 2 (Section 8.2) I explain that I hope to develop the economic-environmental framework constructed here to incorporate a 'quality of life' indicator, such as an Index of Sustainable Economic Welfare (ISEW). One requirement for modelling this type of indicator is obviously as detailed and flexible a treatment as possible of energy use and pollution generation in the economy in order to maximise the usefulness and accuracy of the model outputs that may contribute to the measurement of the index. However, the main problem that I identify in Chapter 2 is the issue of determining what components should included in a quality of life indicator, or social welfare function, and what weight should be attached to each component. I argue that the composition of such an index should reflect the preferences of the people whose quality of life is being measured. This implies adopting some type of revealed preference approach. Therefore one potential area of further research is the possible use of the ongoing survey and consultation process in Jersey to investigate the formulation of a local quality of life or welfare indicator based on local preferences. If such an indicator could be incorporated in the JEMENVI framework it would be possible not only to

[9] An ESRC-funded research programme on making these developments to the Scottish economic-environmental modelling framework is began in April 2002. This research is based in part on developing the work in this thesis and I have been appointed the research fellow on the project.

track and explain movements in the value of the index, but also to assess the implications of adjustments in its composition.

The model developments and recommendations for further research that I have made here focus empirically on the Jersey and Scottish economies. However, as I have argued throughout this thesis, all of these are relevant to any small open regional economy that is concerned with modelling economy-environment interaction for the purpose of analysing the types of policy options associated with the general objective of sustainable development. Ultimately, then a potential area of research is to apply the lessons learned here to other regional economies. In particular, I hope that my research will prove useful to the sustainability policy debate currently taking place at the regional level in the UK.

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Appendix 5A. Sample Questionnaire Used In The IO Primary Data Collection Process

The following is the general questionnaire used to gather data for the construction of the IO table in the interview part of the survey process. Specifically tailored variants were used for several sectors (the finance sectors, 'Agriculture & Fishing' and 'Wholesale & Retail Trade'). For the postal component of the survey process a more straightforward version was used.

JERSEY INDUSTRIAL SURVEY QUESTIONNAIRE (FOR INFORMATION PENDING INTERVIEW)

Note: The information given in this questionnaire will be available only to members of the study team and will be treated as strictly confidential. Results will be presented in such a way as to preclude the identification of any individual firm in your sector. As far as possible, information should refer to the calendar year 1998 and only to establishments located in Jersey. In the absence of complete data, estimates or informed guesses are perfectly acceptable.

This return should relate to the calendar year 1998. If it does not relate to this period, please state period covered: .....

SECTION 1 – GENERAL INFORMATION

Note: In answering questions 1.3 and 1.4 below, please select from the following list of activities:

1. Quarrying (including sand and gravel extraction)
2. Manufacturing (including crafts and furniture-making, food processing and textiles, etc.)
3. Water collection, treatment and distribution
4. Electricity generation and distribution
5. Gas/LPG Distribution
6. Heating Oil Distribution
7. Petrol/Derv Distribution
8. Aviation fuel Distribution
9. Coal Distribution
10. Construction
11. Land Transport (Includes buses, coaches, road hauliers and taxis)
12. Sea and Air Transport
13. Transport Support (e.g. warehousing, harbour operation, travel agents) and Post
14. Telecommunications
15. Computer Services
16. Legal Activities
17. Accountancy
18. Other Business Services (estate agents, vehicle hire, management consultants etc.)
19. Public Administration and Defence
20. Education
21. Health and Social Work
22. Sewage and Refuse Disposal
23. Recreation, Culture and Sport
24. Other Service Activities (Sector includes laundries, undertakers, hairdressers, etc.)

1.1 Please give your name and telephone number in case of any queries arising from your return.

Name: ..... Tel. No. .....

1.2 Name of firm: .....

1.3 Principal activity of your firm: .....

1.4 Using the list of activities set out above please estimate the contribution of the principal and other activities to total turnover. Please specify all the other activities.

Activity	% contribution to total turnover
(1) principal activity:	
Other: (2)	
(3)	
(4)	
(5)	
(6)	
Total	100%

1.5 Please give an estimate of the total rateable value of all of the non-residential properties you occupy in Jersey (including both land and buildings): £.....

1.5a Please give total rates paid in 1998: £.....

1.6 Of the total use of non-residential buildings and other properties, what is the percentage share of the properties that are owned by your firm (in %)? .....

SECTION 2 – EMPLOYMENT

Note: Do not take account of short-term distortions caused by industrial disputes, etc. Part-time workers are defined as those not normally working for more than twenty-five hours per week. If you are unable to calculate the average employment during the year then please provide an estimate for a single month, e.g., June 1998.

2.1 Please give the average Jersey based employment in 1998 for the following types of staff:

Type of employment	(a) full-time	(b) part-time
(1) working proprietors/partners (excluding salaried directors)		
(2) other self-employed (including salaried directors)		
(3) non-seasonal employees		
(4) seasonal employees		

2.2 What was the average length of time in months that seasonal employees were employed for during the year? .....(months)

SECTION 3 – SALES, WORK DONE AND SERVICES RENDERED

Note: The turnover figure should include all sales made in the year of the survey whether or not the goods were produced in the year, plus work done and services rendered (such as repairs, installation and hiring out). The figure should be net of trade discounts, agents commissions and allowances on returned goods. If goods and services are sold outside Jersey, then give the Free On Board (FOB) value. The definition of tourists include all visitors, including business and conference visitors, from outside of the island. Please exclude sales of capital items, i.e. land and buildings, vehicles and plant machinery.

3.1 Please give the total value of turnover and the main destinations of your sales during the year indicated.

(1) Total value of sales (£ 000)	**Estimated percentage of sales direct to:**							**Total**
	(2) Jersey businesses	**(3) Jersey households**	**(4) Jersey government departments**	**(5) Tourists**	**(6) UK**	**(7) Rest of EU**	**(8) Rest of World**	
								100%

SECTION 4 – PURCHASES FOR RESALE AND STOCKS

Note: Purchases for resale are those purchases that are made for the sole purpose of reselling to customers without any processing work by your firm involved.

4.1 Please give the value of total purchases of goods for resale to customers:

(1) Total Value of Purchases (£ 000)	Estimated percentage of purchases direct from:						Total
	(2) Jersey Manufacturers	(3) Jersey Retailers	(4) Jersey Wholesalers	(5) UK	(6) Rest of EU	(7) Rest of World	
							100%

4.2 Please give the value of stocks of goods at cost price:

at beginning of year: £..... at end of year: £.....

4.3 What is your estimate of the average percentage change in the price of stocks from the beginning of the year to the end of the year (in %): .....

SECTION 5 –OPERATING EXPENDITURE

5.1 Please estimate the value of your purchases of goods and services (e.g., interest charges and leasing costs, etc.) and the proportions purchased from different sources.

Item Purchased	(a) Value £ 000	Estimated percentage purchased from:				Total
		(b) Jersey Suppliers	(c) UK	(d) Rest of EU	(e) Rest of World	
Utilities/Energy						
(1) Electricity						100%
(2) Gas/LPG						100%
(3) Coal						100%
(4) Petrol & Derv						100%
(5) Heating Oil						100%
(6) Aviation Fuel						100%
(7) Water						100%
Materials						
(8) Printed Materials						100%
(9) Agricultural Produce						100%
Dairy Produce						100%
Arable Produce						100%
Horticultural Produce						100%
(10) Fish Products						100%
(11) Quarry Products (sand, gravel etc.)						100%
(12) Other Materials						100%
Business & Financial Services						
(13) Banking Services						100%
(14) Insurance Services						100%
(15) Investment Trusts Services						100%
(16) Fund Management Services						100%
(17) Estate Agents Services						100%
(18) Legal Services						100%
(19) Accountancy Services						100%
(20) Computer Services						100%
(21) Business Services (e.g. Architects & Advertising)						100%
(22) Postal Services						100%
(23) Telecommunications Services						100%
Other Services						
(24) Repair and Maintenance						100%
(25) Renting of Machinery						100%
(26) Hotel & Catering Services						100%
(27) Renting of Property						100%
(28) Vehicle repair and maintenance.		100%				100%
(29) Hired Transport (Land)						100%
(30) Hired Transport (Sea & Air)						100%
(31) Transport Support Services						100%
(32) Construction Work						100%
Waste Disposal						
(33) Green Waste disposal						100%
(34) Sanitation disposal						100%
Others (specify)						100%
Total						

5.2 For waste disposal please provide an estimate, in tonnes, for each of the following categories:

Waste Disposal	Tonnes
(1) Green Waste	
(2) Sanitation	
(3) Other (please specify)	

5.3 Please give total direct labour costs of all persons (including working proprietors and seasonal workers) for your firm. Please include overtime payments, bonuses as well as employers' social security and occupational pension contributions. £.....

5.4. Of the above total labour costs, how much would you estimate was paid to the seasonal employees (in %)? .....

SECTION 6 – CAPITAL EXPENDITURE & VEHICLE USE.

6.1 Please estimate both the value of all capital purchases made in 1998 and the proportions purchased from different sources.

	(a) Value of Purchases (£ 000)	**Estimated percentage purchased from:**					**Total**
		(b) Own firm	**(c) Other Jersey Firms**	**(d) UK**	**(e) Rest of EU**	**(f) Rest of World**	
(1) Construction/refurbishment of buildings							100%
(2) Purchase of Vehicles/machinery							100%
(3) IT Hardware							100%
(4) IT Software							100%
Others (please specify)							100%
Total Capital Expenditure							

6.2 Please give the number of vehicles owned (or leased) by the company in 1998, of the following types:

Type of Vehicle	Number
(1) Cars	
(2) Vans	
(3) Lorries	
(4) Other (please specify)	

SECTION 7 – OTHER INFORMATION

Note: This section asks for various sources and uses of your current income. Although some information required in this section has already been asked above (e.g., rent and interest charges), the information required here is more detailed. Please note that in identifying the sources of your income, your trading profit, if any, is not required in the item "Other sources of income". However, the item "Uses of income" should include the allocation of your trading profit.

The major sources of income that are required here include:

- Rent;
- Receipts of interests and dividends, and other non-trading income;
- Property income from abroad (net of taxes paid outside Jersey).

The major uses of income that are required here include:

- Payments of interests and dividends;
- Jersey taxes on income;
- Profits due abroad (net of Jersey taxes);
- Payments of royalties and licence fees;
- Current transfers to charities;
- Other transfers.

7.1 Other sources of income:

Income sources	**Value (£ 000)**	**Estimated <u>percentage</u> of income received from:**						Total
		(a) Jersey businesses	**(b) Jersey households**	**(c) Jersey government departments**	**(d) UK**	**(e) Rest of EU**	**(f) Rest of world**	
(1) Rent received								100%
(2) Gross dividend and interest receipts								100%
(3) Other income received (e.g., property income from abroad. Please specify)								100%

7.2 Uses of income:

Income allocation	**Value (£ 000)**	**Estimated <u>percentage</u> of income allocated to:**						Total
		(a) Jersey businesses	**(b) Jersey households**	**(c) Jersey government departments**	**(d) UK**	**(e) Rest of EU**	**(f) Rest of world**	
(1) Rent paid								100%
(2) Gross dividend and interest payments								100%
(3) Jersey taxes on income								100%
(4) Other payments (please specify)								100%

7.3 Of your total trading profits, how much would you estimate was transferred to the UK (in %)? .....

7.4 Of your total trading profits, how much would you estimate was transferred to the rest of the EU (in %)? .....

7.5 Of your total trading profits, how much would you estimate was transferred to the rest of the world (excluding the EU, in %)? .....

Thank you very much for your co-operation in assisting with the completion of this questionnaire. If you have any further queries please contact:

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Appendix 6A. Emissions Of Eight Individual Air Pollutants In Jersey (1998) By Polluter Group And Source

In the tables contained in this Appendix I provide a summary of the emissions of each of the eight individual air pollutants identified in this study and estimated in Section 3 of Chapter 6. There are eight tables, one for each pollutant:

6A.1 CO_2 (carbon dioxide) as carbon
6A.2 CH_4 (methane)
6A.3 SO_2 (sulphur dioxide)
6A.4 NO_X (nitrous oxides)
6A.5 NMVOCs (non-methane volatile organic compounds)
6A.6 CO (carbon monoxide)
6A.7 N_2O (nitrogen dioxide)
6A.8 Black smoke

In each table I break emissions generation down both by the production or final demand sector where generation occurs and by each of the different types of polluting process (source) that I identify in the accounting process described in Section 3.

Table 6A.1 Emissions Of CO_2 (Carbon Dioxide) As Carbon By Polluting Sector (rows) And Source (columns) - kilograms

	FUEL-USE/COMBUSTION RELATED EMISSIONS							NON-COMBUSTION RELATED EMISSIONS		TOTAL DIRECT EMISSIONS OF CO2 AS CARBON BY SECTOR
	Non-stationary		Stationary							
	Petrol/derv use	Aircraft movements	Gas use	Heating oil use	Coal use	Oil use in electricity generation	Waste incineration	Process emissions - solvent use	Emissions from animal and/or human waste	
Agriculture & Fishing	3388181		0	11488771						14876951
Quarrying	623911		10066	354067						988044
Total Manufacturing	2306830		124435	3401775						5833040
Electricity	454917		0	0		60737545				61192462
Water	160447		0	0						160447
Gas	130440		0	0						130440
Jersey Telecommunications	221169		1585	5794						228548
Construction	5760394		4467	300450						6065311
Oil & Fuel Distribution	782433		0	0						782433
Total Wholesale & Retail Trade	7582288		111626	907704						8601617
Hotels, Restaurants & Catering	1725342		2096349	5933721	34486					9789897
Total Land Transport	1210730		0	70069						1280799
SATTS	704897	17443500	0	1330490						19478887
Post	168533		0	90437						258970
Banks & Building Societies	6616		11001	72000						89617
Total Insurance Companies	81883		0	0						81883
Investment Trusts & Fund Managers	876819		49081	191110						1117011
Total Computer Services	248062		0	3036						251098
Total Legal Activities	251363		25905	0						277268
Accountancy	53837		0	0						53837
Other Business Activities	958203		0	0						958203
Other Services Activities	1527207		1707	358040						1886954
Total Recreation, Culture & Sport	393097		610355	597358						1600810
Education	128299		562449	569765	195					1260709
Health & Social Work & Housing	258403		2349305	1147547			13832000			3755255
Public Services	36016		1069495	159943						15097454
Public Admin & Defence	5781		322268	25671						353719
Household 1	5910632		424765	2150388	521332					9007117
Household 2	15628114		435784	3390450	611831					20066179
Household 3	18818959		540655	3173993	1196090					23729696
Household 4	24015008		1185448	4519552	879533					30599540
Household 5	28810767		918772	11926412	453161					42109111
Tourists	9101875				0					9101875
Total Emissions by Source	132331449	17443500	10855519	52168542	3696627	60737545	13832000	0	0	291065182

Table 6A.2 Emissions Of CH_4 (Methane) By Polluting Sector (rows) And Source (columns) - kilograms

	FUEL-USE/COMBUSTION RELATED EMISSIONS							PROCESS/NON-COMBUSTION RELATED EMISSIONS		TOTAL DIRECT EMISSIONS OF METHANE BY SECTOR
	Non-stationary		Stationary							
	Petrol/derv use	Aircraft movements	Gas use	Heating oil use	Coal use	Oil use in electricity generation	Waste incineration	Process emissions - solvent use	Emissions from animal and/or human waste	
Agriculture & Fishing	522.39		0.00	10.96					794674.00	795207.35
Quarrying	85.79		0.06	0.36						86.21
Total Manufacturing	330.22		0.71	3.32						334.25
Electricity	107.75		0.00	0.00		62.73				170.48
Water	31.97		0.00	0.00						31.97
Gas	26.15		0.00	0.00						26.15
Jersey Telecommunications	23.41		0.01	0.01						23.43
Construction	180.69		0.03	0.31						181.02
Oil & Fuel Distribution	114.16		0.00	0.00						114.16
Total Wholesale & Retail Trade	1658.40		0.63	0.93						1659.96
Hotels, Restaurants & Catering	418.86		11.88	6.06	6.37					443.17
Total Land Transport	248.11		0.00	0.07						248.18
SATTS	130.46	1305.00	0.00	1.36						1436.82
Post	6.24		0.00	0.09						6.33
Banks & Building Societies	2.86		0.06	0.07						2.99
Total Insurance Companies	35.62		0.00	0.00						35.62
Investment Trusts & Fund Managers	381.47		0.28	0.20						381.94
Total Computer Services	94.57		0.00	0.00						94.58
Total Legal Activities	58.49		0.15	0.00						58.64
Accountancy	23.42		0.00	0.00						23.42
Other Business Activities	179.48		0.00	0.00						179.48
Other Services Activities	286.07		0.01	0.32						286.39
Total Recreation, Culture & Sport	58.84		3.46	0.61						62.91
Education	4.02		3.19	0.58	0.04					7.83
Health & Social Work & Housing	8.11		13.32	1.17						22.59
Public Services	1.13		6.06	0.16			3402.00			3409.36
Public Admin & Defence	0.18		1.83	0.03						2.03
Household 1	3228.87		2.41	2.19	96.26				18315.01	21644.74
Household 2	8537.36		2.47	3.45	112.97				18315.01	26971.26
Household 3	10280.46		3.06	3.23	220.84				18315.01	28822.61
Household 4	13118.97		6.72	4.60	162.40				18315.01	31607.70
Household 5	15738.81		5.21	12.15	83.67				18315.01	34154.84
Tourists	4972.19								8551.18	13523.38
Total Emissions by Source	60895.53	1305.00	61.53	52.24	682.54	62.73	3402.00	0.00	894800.22	961261.78

Table 6A.3 Emissions Of SO_2 (Sulphur Dioxide) By Polluting Sector (rows) And Source (columns) - kilograms

	FUEL-USE/COMBUSTION RELATED EMISSIONS							PROCESS/NON-COMBUSTION RELATED EMISSIONS		TOTAL DIRECT EMISSIONS OF SO2 BY SECTOR
	Non-stationary		Stationary							
	Petrol/derv use	Aircraft movements	Gas use	Heating oil use	Coal use	Oil use in electricity generation	Waste incineration	Process emissions - solvent use	Emissions from animal and/or human waste	
Agriculture & Fishing				307605						307605
Quarrying				1735						1735
Total Manufacturing				66503						66503
Electricity				0		443513				443513
Water				0						0
Gas				0						0
Jersey Telecommunications				28						28
Construction				1472						1472
Oil & Fuel Distribution				0						0
Total Wholesale & Retail Trade				4448						4448
Hotels, Restaurants & Catering				29080	1060					30140
Total Land Transport				343						343
SATTS		11745		6520						18265
Post				443						443
Banks & Building Societies				353						353
Total Insurance Companies				0						0
Investment Trusts & Fund Managers				937						937
Total Computer Services				15						15
Total Legal Activities				0						0
Accountancy				0						0
Other Business Activities				0						0
Other Services Activities				18365						18365
Total Recreation, Culture & Sport				2928						2928
Education				2792	6					2798
Health & Social Work & Housing				5624						5624
Public Services				784						784
Public Admin & Defence				126						126
Household 1				501	16017					16518
Household 2				789	18798					19587
Household 3				739	36748					37487
Household 4				1052	27023					28075
Household 5				2777	13923					16700
Tourists										0
Total Emissions by Source	0	11745	0	455962	113574	443513	0	0	0	1024795

Table 6A.4 Emissions Of NO_X (Nitrous Oxides) By Polluting Sector (rows) And Source (columns) - kilograms

	FUEL-USE/COMBUSTION RELATED EMISSIONS							PROCESS/NON-COMBUSTION RELATED EMISSIONS		TOTAL DIRECT EMISSIONS OF NOX BY SECTOR
	Non-stationary		Stationary							
	Petrol/derv use	Aircraft movements	Gas use	Heating oil use	Coal use	Oil use in electricity generation	Waste incineration	Process emissions - solvent use	Emissions from animal and/or human waste	
Agriculture & Fishing	50715		0	76656						127371
Quarrying	7070		28	1859						8957
Total Manufacturing	12154		351	21573						34079
Electricity	1917		0	0		806291				808207
Water	783		0	0						783
Gas	502		0	0						502
Jersey Telecommunications	691		4	30						726
Construction	12955		13	1578						14546
Oil & Fuel Distribution	6197		0	0						6197
Total Wholesale & Retail Trade	53593		315	4766						58675
Hotels, Restaurants & Catering	10427		5919	31157	76					47580
Total Land Transport	7619		0	368						7987
SATTS	6885	343650	0	6986						357521
Post	427		0	475						902
Banks & Building Societies	35		31	378						444
Total Insurance Companies	439		0	0						439
Investment Trusts & Fund Managers	4696		139	1003						5839
Total Computer Services	1226		0	16						1242
Total Legal Activities	955		73	0						1028
Accountancy	288		0	0						288
Other Business Activities	3453		0	0						3453
Other Services Activities	5504		5	3117						8626
Total Recreation, Culture & Sport	1242		1723	3137						6102
Education	289		1588	2992	0					4869
Health & Social Work & Housing	581		6633	6026						13240
Public Services	81		3020	840			91000			94941
Public Admin & Defence	13		910	135						1058
Household 1	29515		1199	5257	1155					37127
Household 2	78040		1230	8289	1356					88915
Household 3	93974		1527	7759	2650					105910
Household 4	119921		3347	11049	1949					136266
Household 5	143869		2594	29157	1004					176623
Tourists	45451									45451
Total Emissions by Source	701508	343650	30651	224603	8190	806291	91000	0	0	2205893

Table 6A.5 Emissions Of NMVOCs By Polluting Sector (rows) And Source (columns) - kilograms

	FUEL-USE/COMBUSTION RELATED EMISSIONS							PROCESS/NON-COMBUSTION RELATED EMISSIONS		TOTAL DIRECT EMISSIONS OF NMVOC BY SECTOR
	Non-stationary		Stationary							
	Petrol/derv use	Aircraft movements	Gas use	Heating oil use	Coal use	Oil use in electricity generation	Waste incineration	Process emissions - solvent use	Emissions from animal and/or human waste	
Agriculture & Fishing	14225		0	864						15089
Quarrying	2856		4	29						2889
Total Manufacturing	11948		55	262				59		12325
Electricity	3946		0	0		7126				11072
Water	1160		0	0						1160
Gas	961		0	0						961
Jersey Telecommunications	875		1	0						876
Construction	7426		2	24						7453
Oil & Fuel Distribution	3996		0	0						3996
Total Wholesale & Retail Trade	59320		50	73						59443
Hotels, Restaurants & Catering	15134		935	478	503					17050
Total Land Transport	8925		0	6						8931
SATTS	4498	95700	0	107						100305
Post	249		0	7						256
Banks & Building Societies	104		5	6						115
Total Insurance Companies	1298		0	0						1298
Investment Trusts & Fund Managers	13896		22	15						13933
Total Computer Services	3450		0	0						3450
Total Legal Activities	2149		12	0						2161
Accountancy	853		0	0						853
Other Business Activities	6615		0	0						6615
Other Services Activities	10543		1	25				8		10577
Total Recreation, Culture & Sport	2184		272	48						2504
Education	165		251	46	3					465
Health & Social Work & Housing	333		1048	92						1473
Public Services	46		477	13			275800			276336
Public Admin & Defence	7		144	2						153
Household 1	103133		189	173	7608					111103
Household 2	272690		194	272	8929					282086
Household 3	328366		241	255	17455					346318
Household 4	419030		529	363	12836					432758
Household 5	502710		410	958	6613					510691
Tourists	158816									158816
Total Emissions by Source	1961910	95700	4841	4118	53948	7126	275800	68	0	2403511

Table 6A.6 Emissions Of CO (Carbon Monoxide) By Polluting Sector (rows) And Source (columns) - kilograms

	FUEL-USE/COMBUSTION RELATED EMISSIONS							PROCESS/NON-COMBUSTION RELATED EMISSIONS		TOTAL DIRECT EMISSIONS OF CO BY SECTOR
	Non-stationary		Stationary							
	Petrol/derv use	Aircraft movements	Gas use	Heating oil use	Coal use	Oil use in electricity generation	Waste incineration	Process emissions - solvent use	Emissions from animal and/or human waste	
Agriculture & Fishing	60950		0	4826						65776
Quarrying	14016		5	99						14120
Total Manufacturing	65439		57	1284						66780
Electricity	23977		0	0		19821				43798
Water	6829		0	0						6829
Gas	5717		0	0						5717
Jersey Telecommunications	4552		1	2						4554
Construction	14383		2	84						14469
Oil & Fuel Distribution	21202		0	0						21202
Total Wholesale & Retail Trade	348940		52	254						349246
Hotels, Restaurants & Catering	91165		967	1662	2292					96087
Total Land Transport	52233		0	20						52253
SATTS	24870	269700	0	373						294942
Post	624		0	25						649
Banks & Building Societies	667		5	20						692
Total Insurance Companies	8327		0	0						8327
Investment Trusts & Fund Managers	89164		23	54						89240
Total Computer Services	21945		0	1						21946
Total Legal Activities	13063		12	0						13075
Accountancy	5475		0	0						5475
Other Business Activities	39000		0	0						39000
Other Services Activities	62159		1	211						62370
Total Recreation, Culture & Sport	12409		282	167						12858
Education	320		260	160	13					752
Health & Social Work & Housing	645		1084	321						2051
Public Services	90		494	45			1110900			1111528
Public Admin & Defence	14		149	7						170
Household 1	613894		196	401	34653					649143
Household 2	1623177		201	632	40668					1664678
Household 3	1954587		250	591	79504					2034931
Household 4	2494262		547	842	58462					2554113
Household 5	2992362		424	2221	30121					3025129
Tourists	945345									945345
Total Emissions by Source	11611801	269700	5010	14300	245714	19821	1110900	0	0	13277245

Table 6A.7 Emissions Of N_2O (Nitrogen Dioxide) By Polluting Sector (rows) And Source (columns) - kilograms

	FUEL-USE/COMBUSTION RELATED EMISSIONS							PROCESS/NON-COMBUSTION RELATED EMISSIONS		TOTAL DIRECT EMISSIONS OF N2O BY SECTOR
	Non-stationary		Stationary							
	Petrol/dery use	Aircraft movements	Gas use	Heating oil use	Coal use	Oil use in electricity generation	Waste incineration	Process emissions - solvent use	Emissions from animal and/or human waste	
Agriculture & Fishing	80.07									80.07
Quarrying	14.35									14.35
Total Manufacturing	50.63									50.63
Electricity	8.55									8.55
Water	3.23									3.23
Gas	2.60									2.60
Jersey Telecommunications	5.05									5.05
Construction	144.55									144.55
Oil & Fuel Distribution	17.40									17.40
Total Wholesale & Retail Trade	150.03									150.03
Hotels, Restaurants & Catering	32.55									32.55
Total Land Transport	24.35									24.35
SATTS	15.00									15.00
Post	4.21									4.21
Banks & Building Societies	0.08									0.08
Total Insurance Companies	1.03									1.03
Investment Trusts & Fund Managers	11.06									11.06
Total Computer Services	3.54									3.54
Total Legal Activities	4.74									4.74
Accountancy	0.68									0.68
Other Business Activities	19.45									19.45
Other Services Activities	30.99									30.99
Total Recreation, Culture & Sport	8.43									8.43
Education	3.22									3.22
Health & Social Work & Housing	6.48									6.48
Public Services	0.90									0.90
Public Admin & Defence	0.15									0.15
Household 1	74.54									74.54
Household 2	197.08									197.08
Household 3	237.31									237.31
Household 4	302.84									302.84
Household 5	363.31									363.31
Tourists	114.78									114.78
Total Emissions by Source	1933.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1933.18

Table 6A.8 Emissions Of Black Smoke By Polluting Sector (rows) And Source (columns) - kilograms

	FUEL-USE/COMBUSTION RELATED EMISSIONS							PROCESS/NON-COMBUSTION RELATED EMISSIONS		TOTAL DIRECT EMISSIONS OF BLACK SMOKE BY SECTOR
	Non-stationary		Stationary							
	Petrol/derv use	Aircraft movements	Gas use	Heating oil use	Coal use	Oil use in electricity generation	Waste incineration	Process emissions - solvent use	Emissions from animal and/or human waste	
Agriculture & Fishing										0
Quarrying										0
Total Manufacturing										0
Electricity						53852				53852
Water										0
Gas										0
Jersey Telecommunications										0
Construction										0
Oil & Fuel Distribution										0
Total Wholesale & Retail Trade										0
Hotels, Restaurants & Catering										0
Total Land Transport										0
SATTS		19575								19575
Post										0
Banks & Building Societies										0
Total Insurance Companies										0
Investment Trusts & Fund Managers										0
Total Computer Services										0
Total Legal Activities										0
Accountancy										0
Other Business Activities										0
Other Services Activities										0
Total Recreation, Culture & Sport										0
Education										0
Health & Social Work & Housing										0
Public Services										0
Public Admin & Defence										0
Household 1										0
Household 2										0
Household 3										0
Household 4										0
Household 5										0
Tourists										0
Total Emissions by Source	0	19575	0	0	0	53852	0	0	0	73427

Appendix 6B. Identifying And Adapting A Set Of UK Direct Emissions Coefficients As A Potential Proxy For Jersey-Specific Coefficients

1. Identifying A Set Of UK Direct Emissions Coefficients For The Base-Year 1998

In Section 2.1 of the main text (Chapter 6) I explain that the Environmental Accounts Branch of Office for National Statistics (ONS) has constructed a 'trial NAMEA table' to report economic and environmental variables at a consistent 76-sector breakdown of the UK economy. The data included in the 76-sector trial NAMEA tables for the UK are organised over a time series for the years 1990 to 1998. For each year data are given on sectoral emissions of 18 individual pollutants, 3 composite pollutants, and several types of fuel use, all in physical terms for each of the 76 sectors and 2 domestic (household) categories, 'travel' and 'non-travel'. In the main tables for each year, corresponding sectoral economic data are given on employment, value-added, intermediate consumption and gross sectoral output are given for each of the 76 production sectors. In the NAMEA table itself, the latter three variables are given in constant 1995 prices for the entire time series. This does not pose any serious difficulty though, since the raw current price data for each year are given in an appending sheet where the process of deflation to 1995 prices is carried out. I am able to take current price data straight from the 123-sector UK IO supply-use tables for each year. Thus, by a simple process of aggregating the sectoral output data to the 76-sector breakdown I have all the components required for the derivation of a set of sectoral output-pollution coefficients by the method described in equation (6.3) in the text. If I restate equation (6.3a) for the national case, for each sector, i, of the UK economy across each pollutant, k, the result is a KxI matrix $\mathbf{M_i}^{UK}$ with elements

(6B.1) $m_{k,i}^{UK} = P_{k,i}^{UK}/X_i^{UK}, \forall\, i = 1,\ldots,I, \forall\, k = 1,\ldots,K$

Similarly, I define the matrix of final demand expenditure-pollution coefficients, $\mathbf{M_z}^{UK}$, with elements:

(6B.2) $m_{k,z}^{UK} = P_{k,z}^{UK} / C_z^{UK}, \forall z = 1,\ldots,Z, \forall k = 1,\ldots,K$

The UK NAMEA data only record emissions data for one final demand sector. Therefore all elements in $\mathbf{M_z}^{UK}$ will be equal to zero, except where z = households. Therefore effectively $\mathbf{M_z}^{UK}$ collapses to an 18x1 vector of household pollution coefficients, $\mathbf{m_h}^{UK}$. Note that one piece of information not included in the economic accounts of the trial NAMEA dataset is total consumer expenditure, c_h, for me to derive direct emissions coefficients for households of the form shown for final demand sectors in equation (6.4). As I note above, household emissions are recorded under two categories, 'domestic - travel' and 'domestic – non-travel'; however corresponding figures for expenditure are not given. In order to produce a vector of household direct emissions (expenditure-pollution) coefficients, I must therefore aggregate the two emissions categories to give total emissions by households for each pollutant, and take the value of total consumer expenditure directly from UK IO tables for 1998.

Since direct emissions data are not given for any other category of final demand (e.g. tourist consumption), I am only able to derive UK direct emissions coefficients for one category of final consumption, the aggregate household sector[1]. This has the implication that if any other final demand sectors are responsible for direct emissions generation at the regional level, these will be ignored in any estimates using adjusted UK coefficients. In the case of Jersey, I identify tourists as important direct users of automotive fuels and generators of a number of traffic-related pollutants. Therefore, in Section 5 of the main text, I argue that this omission alone has serious implications for the accuracy of any

[1] Note, however, that direct emissions by tourists may be included in the domestic emissions figures that are reported in the NAMEA dataset and used here to determine the household expenditure-pollution coefficients. However, if this is the case it is not clear how these would be distinguished and separated from the emissions attributable to local consumers/households.

accounting and or modelling that could be done using UK-adjusted pollution coefficients.

By quantifying equations (6B.1) and (6B.2) using data from the UK trial NAMEA tables I derive a set of (1998) UK direct emissions coefficients. This is composed of an 18x76 matrix of output-pollution coefficients, $\mathbf{M_i}^{UK}$, for the generation of 18 individual air pollutants in each of the 76 production sectors and an 18x1 vector, $\mathbf{m_h}^{UK}$, of household final demand-expenditure pollution coefficients.

2. Adapting The UK Average Direct Emissions Intensities To Proxy For Jersey-Specific Coefficients

The key advantage of the UK set of coefficients is the high level of sectoral disaggregation in the matrix $\mathbf{M_i}^{UK}$ of output-pollution coefficients. In Table 6B.1 I show how the 76-sector classification of the UK NAMEA tables maps to the 123-sector SIC classifications used to identify the 123 UK IO sectors and the 91 sectors identified in the UKENA environmental accounts. The UK (1992) SIC codes are consistent with the 1995 SIC listings published by the States of Jersey (JSIC), that I use to identify sectors in the standard Jersey IO tables for 1998. Therefore it is a relatively straightforward task to match the 76 NAMEA coded UK coefficients to the 25 Jersey sectors. I report the results of this process in Table 6B.2.

To use the UK coefficients at the regional level I do not simply apply matrix $\mathbf{M_i}^{UK}$ without adjustment. It must be adapted to reflect the composition of output in the regional economy. This involves the following steps:

1. I attach a weight of zero to the column vector of output-pollution coefficients for any sectors that are present in the UK economy but not in the Jersey economy.

Table 6B.1 UK (NAMEA) Mapping System For Integrating Environmental (EA) And Economic (IO) Accounts

NAMEA code	EA code	IO code	SIC(92), JSIC (95) code	Industry/activity description
1	1	1	1	Agriculture, hunting and related service activities
2	2	2	2	Forestry, logging and related service activities
3	3	3	5	Fishing, operation of fish hatcheries and fish farms
4	4	4	10	Mining of coal, lignite and peat
5	5	5	11	Extraction of crude petroleum and natural gas
6	6	6	13	Mining of metal ores
7	7	7	14	Other mining and quarrying
8	8	8-19	15	Manufacture of food products and beverages
9	9	20	16	Manufacture of tobacco products
10	10	21-27	17	Textiles
11	11	28	18	Manufacture of wearing apparel; dressing and dyeing of fur
12	12	29-30	19	Leather tanning, luggage and footwear
13	13	31	20	Timber, wood products excl. furniture; cork and straw
14	14	32	21	Pulp, paper and paperproducts
15	15	33-34	22	Publishing, printing and production of recorded material
16	16-18	35	23	Coke oven products, refined petroleum products, processing of nuclear fuel
17	19	36	24.11, 24.12	Industrial gases, dyes, pigments
18	20	37	24.13	Other inorganic chemicals
19	21	38	24.14	Other organic basic chemicals
20	22	39	24.15	Fertilisers and nitrogen compounds
21	23	40	24.16, 24.17	Plastics, synthetic rubber, primary form
22	24	41	24.2	Pesticides, agro-chemicals
23	25	42	24.3	Paints, varnishes, printing ink etc
24	26	43	24.4	Pharmaceuticals and botanical products
25	27	44	24.5	Soap and detergents, cleaning and toilet preparations
26	28	45	24.6	Chemical products nes
27	29	46	24.7	Man-made fibres
28	30	47	25.1	Rubber products
29	31	48	25.2	Plastic products
30	32	49	26.1	Glass and glass products
31	33	50	26.2, 26.3	Ceramic goods
32	34	51	26.4	Structural clay products
33	35	52	26.5	Cement, lime and plaster
34	36	53	26.6-26.8	Articles of concrete, stone, other non-metallic mineral products
35	37	54	27.1-27.3	Iron and steel
36	38-39	55	27.4	Non-ferrous metals incl aluminium
37	40	56	27.5	Casting of metals
38	41	57-61	28	Fabricated metal products, except machinery
39	42	62-68	29	Machinery and equipment
40	43	69	30	Office machinery and computers
41	44	70-72	31	Electrical machinery and apparatus
42	45	73-75	32	Radio, television and comms
43	46	76	33	Medical, precision and optical instruments, watches and clocks
44	47	77	34	Motor vehicles, trailers and semi-trailers
45	48	78-80	35	Other transport equipment
46	49-50	81-84	36, 37	Manufacture of furniture, toys, sports equipment, other products and recycling
47	51-55	85	40.1	Electricity production
48	56	86	40.2, 40.3	Gas distribution; steam and hot water supply
49	57	87	41	Water supply
50	58	88	45	Construction
51	59	89	50	Garages, car showrooms
52	60	90	51	Wholesaler trade and commission trade except motor vehicles
53	61	91	52	Retail and repair trade, except motor vehicles
54	62	92	55	Hotels and restaurants
55	63	93	60.1	Railways
56	64-68	94	60.2,60.3	Road transport (buses, coaches, tubes, trams, taxis, freight by road, pipelines)
57	69	95	61	Water transport
58	70	96	62	Air transport
59	71	97	63	Supporting and auxiliary transport activities, travel agencies
60	72	98-99	64	Post and telecommunications
61	73	100	65	Financial intermediation, except insurance and pension funds
62	74	101	66	Insurance and pensions
63	75	102	67	Activities auxiliary to financial intermediation
64	76	103-105	70	Real estate activities
65	77	106	71	Renting of machinery
66	78	107	72	Computer and related actvities
67	79	108	73	Research and development
68	80	109-114	74	Other business actvities
69	81-82	115	75	Public administration
70	83	116	80	Education
71	84	117-118	85	Health and veterinary services, social work
72	85-87	119	90	Waste services
73	88	120	91	Activities of membership organisations
74	89	121	92	Recreational, cultural and sporting actvities
75	90	122	93	Other service activities; dry cleaning, hair dressing, funeral parlours
76	91	123	95	Private households with employed persons

Table 6B.2 - SIC, EA and NAMEA Codings Used In Construction Of The Jersey 25-Sector Environmental IO Syst

Jersey IO sector	Description	SIC classification	NAMEA code (UK output-pollution coefficients)
1	Agriculture & fishing	01,05	1,3
2	Quarrying & Construction	14,45	7,50
3	Total Manufacturing	15-18, 20, 22, 25-26, 28-31, 33, 35, 37	8-11,13,15,29,31,34,38-41,43,45,46
4	Electricity	40.1	47
5	Water	41	49
6	Gas and Oil & Fuel Distribution	40.2,50.50,52.48	48,51,53
7	JerseyTelecommunications	64.2	60
8	Wholesale & retail trade	50-52	51,52,53
9	Hotels, restaurants & catering	55	54
10	Land transport	60.2, 60.3	56
11	Sea & AirTransport & Trans. Supp.	61,62,63	57,58,59
12	Post	64.1	60
13	Banks and building societies	65.121,65.21,65.22,65.233,65.234,65.235 & 65.236	61
14	Insurance Companies	66	62
15	Investment Trusts & Fund Managers	65.231, 65.232, 67	61,63
16	Computer services	72	66
17	Legal Activities	74.11	68
18	Accountancy	74.12	68
19	Other business activities	70, 71, & 74.13 to 74.8	64,65,68
20	Other service activities	91,93	73,75
21	Recreation, culture, sport	92	74
22	Education	80	70
23	Health, social work & housing	85	71
24	Public Services	90	72
25	Public administration and defence	75	69

Table 6B.3 Weights Applied In Adapting UK Output-Pollution Coefficients To The (25-sector) Jersey Environmental IO System

Sector	Description	NAMEA code	Weighting code *	Weight applied
1	Agriculture & fishing	1 (Agriculture - SIC 1)	B	0.940
		3 (Fishing - SIC 5)		0.060
2	Quarrying & Construction	7 (Other mining and quarrying - SIC 14)	A	0.055
		50 (Construction - SIC 45)		0.945
3	Total Manufacturing	8 (Mfr of food products & beverages - SIC 15)	B	0.449
		9 (Tobacco products - SIC 16)		0.009
		10 (Textiles - SIC 17)		0.021
		11 (Wearing apparel, dressing & dying of fur - SIC 18)		0.004
		13 (Wood & wood products, except furniture - SIC 20)		0.005
		15 (Publishing, printing & prod recorded material - SIC 22)		0.273
		29 (Plastic products - SIC 25.2)		0.036
		31 (Ceramic goods - SIC 26.25)		0.001
		34 (Articles of concrete, stone, other non-metallic metal products - SIC 26.6, 26.7)		0.060
		38 (Fabricated metal products, except machinery - SIC 28)		0.043
		39 (Machinery & Equipment - SIC 29)		0.009
		40 (Office machinery - SIC 30)		0.002
		41 (Electrical machinery and apparatus - SIC 31)		0.005
		43 (Medical, precision & optical instruments, watches & clocks - SIC 33)		0.001
		45 (Other transport equipment - SIC 35)		0.036
		46 (Mfr of furniture, toys, sports equip, other products & recycling - SIC 36, 37)		0.048
4	Electricity	47 (Electricity production)	U	1.000
5	Water	49 (Water: collection, purification and distribution of - SIC 41	U	1.000
6	Gas, Oil & Fuel Distribution	48 (Gas: distribution of gaseous fuels through mains - SIC 40.2)	A	0.341
		51 (Oil & fuel distribution - SIC 50.50, 52.48)		0.659
7	JerseyTelecommunications	60 (Telecommunications - SIC 64.2)	U	1.000
8	Wholesale & retail trade	52 (Wholesaler trade and commission trade, except of motor vehicles - SIC 51)	B	0.448
		53 (Retail and repair trade, except of motor vehicles - SIC 52)		0.552
9	Hotels, restaurants & catering	54 (Hotels and restaurants - SIC 55)	U	1.000
10	Land transport	56 (Road Transport SIC 60.2, 60.3)	U	1.000
11	Sea & AirTransport & Trans. Supp.	57 (Water transport - SIC 61.1, 61.2)	B	0.207
		58 (Air transport - SIC 62)		0.283
		59 (Supporting and auxiliary transport activities; activities of travel agents - SIC 63)		0.510
12	Post	60 (Post - SIC 64.1)	U	1.000
13	Banks and building societies	61 (Financial intermediation, except insurance and pension funding - SIC 65.121, 65.21, 65.22, 65.233, 65.234, 65.235, 65.236)	U	1.000
14	Insurance Companies	62 (Insurance and pension funding, except compulsory social security - SIC 66	U	1.000
15	Investment Trusts & Fund Managers	61 (Investment trusts - SIC 65.231, 65.232)	A	0.809
		63 (Fund managers - activities auxiliary to financial intermediation - SIC 65)		0.191
16	Computer services	66 (Computer and related activities - SIC 72)	U	1.000
17	Legal Activities	68 (Legal activities - SIC 74.11)	U	1.000
18	Accountancy	68 (Accountancy - SIC 74.12)	U	1.000
19	Other business activities	64 (Real estate activities - SIC 70)	B	0.414
		65 (Renting of machinery - SIC 71)		0.078
		68 (All other ther business activities - SIC 74.13-74.8)		0.507
20	Other service activities	73 (Activities of other memb. orgs not elsewhere classified - SIC 91	B	0.149
		75 (All other service activities - SIC 93)		0.851
21	Recreation, culture, sport	74 (Recreational, cultural and sporting activities - SIC 92)	U	1.000
22	Education	70 (Education - SIC 80)	U	1.000
23	Health, social work & housing	71 (Health & vetinary services - SIC 85)	U	1.000
24	Public Services	72 (Waste services - SIC 90)	U	1.000
25	Public administration and defence	69 (Public admininstration - SIC 75)	U	1.000

* Weighting of EA output-pollution coefficients according to:

A Shares in output (as calculated in Jersey IO tables)

B Shares in employment (using Jersey Manpower Database and UK labour intensity data)

C Unofficial output share estimates from States of Jersey

U Unweighted UK coefficients

2. I then aggregate the remaining sectors that are present in both economies to the sectoral breakdown identified in the Jersey IO tables (see Table 6B.2).

3. Finally, for each Jersey NAMEA sector, I weight the column vectors from matrix $\mathbf{M_i}^{UK}$ according to the contribution of each component activity to the total output of the *Jersey* sector (see Table 6B.3).

The second and third steps are crucially important because the composition of output for each sector in the 25-sector breakdown identified for Jersey will differ from the equivalent sector if the UK tables were aggregated in the same way. While the pollution intensities are UK-specific, they are adjusted using region-specific output weights for Jersey. For example, suppose the 'quarrying' and 'construction' sectors in the UK 76-sector tables were aggregated to give a 'quarrying & construction' sector, as they are in the 25-sector Jersey tables. The shares in the output of this new composite sector from each of the two component sectors are not the same as in the Jersey case, which in turn means that the output-pollution coefficient for the composite sector will not be the same. This is made clearer if we consider each of the stages followed to determine the adapted output-polllution coefficients for Jersey:

(a) For both Jersey and the UK the 'quarrying' sector is defined as SIC sector 14 - 'Other mining and quarrying' - with NAMEA code 7; the 'construction' sector is defined as SIC sector 45, with NAMEA code 50

(b) The gross outputs of these two sectors, and the composite sector in Jersey (from the 1998 IO table) are
   - 'Quarrying' - £12.58million
   - 'Construction' - £216.12million
   - 'Quarrying & construction' - £228.70million

For the UK (current price gross sectoral outputs from the NAMEA dataset[2])

- 'Quarrying' - £3,564million
- 'Construction' - £102,274million
- 'Quarrying & construction' - £105,838million

(c) This means that the shares in the output of the composite sector, 'quarrying & construction', of each of the component sectors, 'quarrying' and 'construction' are

- For Jersey: 'quarrying' – 0.055, 'construction' - 0.945
- For the UK: 'quarrying' – 0.034, 'construction' - 0.966

(d) These output shares are then used as weights in applying the UK estimated output-pollution coefficients to the new composite sector. Take for example the coefficient for CO_2:

- The 'quarrying' sector, with NAMEA code 7, has an output-CO_2 coefficient (kilograms per £million output) of 472,139
- The 'construction' sector, with NAMEA code 50, has an output-CO_2 coefficient (kilograms per £million output) of 41,187

(e) Applying the economy- or region-specific output weights determined in (c) and the UK pollution intensities from matrix M_i^{UK}, this means that:

- The Jersey 'quarrying & construction' sector has the output-pollution coefficient/direct emissions intensity of 64,885 (kilograms of CO2 per £1million output)
- The UK 'quarrying & construction' sector has the output-pollution coefficient/direct emissions intensity of 55,839 (kilograms of CO2 per £1million output)

[2] The UK NAMEA dataset does not report the complete UK IO tables for the time series, 1991-1998, reported, instead giving just the key sectoral figures for intermediate demands, value-added and gross outputs.

Note that because the more CO_2-intensive 'quarrying' activity has a larger output share in the composition of Jersey's 'quarrying & construction' output than in the UK, not only are the UK-adjusted output-CO_2 coefficients different in the two economies, but the Jersey sector is also more CO_2-intensive.

By going through the process outlined in stages 1-3 above, I derive a kxi (18x25) matrix, $\mathbf{M_i}^{UK(\vartheta)}$ of UK-adjusted output-pollution coefficients for Jersey (1998). As noted above, it is only possible to derive a single column vector of final demand expenditure-pollution coefficients, the vector m_h^{UK} of (aggregate) household coefficients. This enters the UK-adjusted matrix $\mathbf{M_z}^{UK(\vartheta)}$ unweighted; all other elements of $\mathbf{M_z}^{UK(\vartheta)}$ are equal to zero because the UK does report direct emissions by any other final demand sector.

However, as I explain in more detail in Section 5 of the main text, it is important to be aware of the assumptions that are implicitly imposed by the adoption of adjusted national coefficients at the regional level:

1. *Identical fuel use patterns* – i.e. the physical amount fuel used per £1 million output/expenditure by an equivalent sector (in terms of composition of output) is the same whether activity is located in the UK or Jersey.

2. *Identical technology* – i.e. the emissions factors stating how much pollution results from burning this fuel are the same in Jersey as would be found in the UK. Also non-combustion related emissions (from production processes that do not involve burning fuel) are the same whether activity is located in the UK or Jersey.

The results of the process of adapting UK set of direct emissions coefficients to the Jersey case are an 18x25 matrix of output-pollution coefficients, $\mathbf{M_i}^{UK(\vartheta)}$, for the 76 production sectors identified across 18 individual pollutants and a 18x1 vector, $\mathbf{m_h}^{UK(\vartheta)}$, of household expenditure-pollution coefficients. I report a sub-set of this set of coefficients in Table 6B.4 (below). Here I show K = 7 pollutants, a sub-set selected on

the grounds that these pollutants are common to the Jersey-specific set of coefficients derived in Section 4 of the main text (and reported in Table 6.15).

Table 6B.4 Direct Emissions (kilograms) Per £1million Domestic Gross Output/Expenditure By Production Sector/Final Demand Group In Jersey 1998 - UK-Adjusted Pollution Coefficients

Sectors / Pollutants	Agriculture & Fishing	Quarrying & Construction	Manufacturing	Electricity	Water	Gas, Oil & Fuel Dist.	Jersey Telecom.	Wholesale & Retail Trade	Hotels, Rest. & Catering	Land Transport	Sea & Air Trans. & Trans Supp	Jersey Post	Banks & Building Soc.	Insurance Companies
Carbon dioxide (CO2) as carbon	299031.563	64885.109	125113.947	5419242.979	140999.450	82994.230	41178.590	64632.604	46813.553	905824.766	1076320.322	41178.590	31671.015	31876.938
Methane (CH4)	45639.383	10.041	7.950	677.470	10.193	9698.616	4.208	6.818	4.337	69.610	140.943	4.208	3.308	3.486
Sulphur dioxide (SO2)	461.228	45.152	179.098	38787.263	46.511	7.631	7.872	11.317	3.254	206.218	5142.681	7.872	5.387	4.715
Nitrous oxides (NOx)	2535.910	577.388	315.548	13239.631	611.910	263.610	169.199	337.049	106.858	6969.053	10293.171	169.199	93.258	101.043
Non-methane volatile organic compounds (NMVOC)	798.969	661.961	1535.914	277.689	710.354	2302.703	83.278	147.837	60.953	1527.275	1719.145	83.278	62.661	69.926
Carbon monoxide (CO)	3633.160	2831.311	174.179	2987.617	2492.157	921.681	530.921	862.976	461.007	5310.513	4028.012	530.921	492.910	551.903
Nitrogen dioxide (N20)	4430.079	16.264	2.270	235.550	14.717	2.983	1.889	3.325	1.426	33.340	47.130	1.889	1.477	1.644

Sectors / Pollutants	Inv. Trusts & Fund Mgrs	Computer Services	Legal Activities	Accountancy	Other Bus. Activities	Other Service Activities	Recreation, Culture & Sport	Education	Health, Social Work & Housing	Public Services	Public Admin. & Defence	Aggregate Households
Carbon dioxide (CO2) as carbon	29969.652	47955.810	30879.925	30879.925	33783.401	61805.817	42837.287	106543.696	48756.649	112325.472	130654.306	272303.887
Methane (CH4)	3.027	5.958	2.983	2.983	3.721	6.428	3.030	6.621	2.766	110683.646	6.315	91.375
Sulphur dioxide (SO2)	5.366	10.792	7.091	7.091	7.161	13.838	48.140	85.308	116.872	53.658	213.638	116.445
Nitrous oxides (NOx)	83.207	196.874	81.083	81.083	122.813	248.557	82.737	165.138	65.955	1250.808	580.108	900.204
Non-methane volatile organic compounds (NMVOC)	54.561	220.666	51.284	51.284	78.971	761.146	35.682	66.316	31.488	1324.955	34.330	1049.625
Carbon monoxide (CO)	428.086	1139.362	399.883	399.883	596.989	908.261	261.922	502.896	93.620	723.431	187.550	5500.410
Nitrogen dioxide (N20)	1.289	3.387	1.217	1.217	1.846	3.094	1.097	2.037	0.549	76.850	2.732	18.210

Table 6B.5 Total Direct Emissions (kilograms) in Jersey, 1998, Generated in The Production Of Sectoral And Total Output, And During Final Consumption By Households - Estimated Using UK-Adjusted Pollution Coefficients

Sectors / Pollutants	Agriculture & Fishing	Quarrying & Construction	Manufacturing	Electricity	Water	Gas, Oil & Fuel Dist.	Jersey Telecom.	Wholesale & Retail Trade	Hotels, Rest. & Catering	Land Transport	Sea & Air Trans. & Trans Supp	Jersey Post	Banks & Building Soc.	Insurance Companies
Carbon dioxide (CO2) as carbon	16971954	14839160	12567841	252990054	1758567	1234340	1751889	22740591	10485879	18418971	75372719	763168	35541036	955516
Methane (CH4)	2590327	2296	799	31627	127	144244	179	2399	971	1415	9870	78	3712	104
Sulphur dioxide (SO2)	26178	10326	17991	1810731	580	113	335	3982	729	4193	360132	146	6045	141
Nitrous oxides (NOx)	143929	132048	31697	618074	7632	3921	7198	118589	23935	141708	720812	3136	104654	3029
Non-methane volatile organic compounds (NMVOC)	45347	151390	154284	12964	8860	34247	3543	52015	13653	31055	120389	1543	70318	2096
Carbon monoxide (CO)	206205	647518	17496	139473	31083	13708	22587	303633	103262	107984	282074	9840	553141	16543
Nitrogen dioxide (N20)	251435	3720	228	10996	184	44	80	1170	319	678	3300	35	1658	49

Sectors / Pollutants	Inv. Trusts & Fund Mgrs	Computer Services	Legal Activities	Accountancy	Other Bus. Activities	Other Service Activities	Recreation, Culture & Sport	Education	Health, Social Work & Housing	Public Services	Public Admin. & Defence
Carbon dioxide (CO2) as carbon	8965657	850825	2641981	2625204	3038943	1571918	1831989	6562346	7714829	2985445	7453780
Methane (CH4)	906	106	255	254	335	163	130	408	438	2941808	360
Sulphur dioxide (SO2)	1605	191	607	603	644	352	2059	5254	18493	1426	12188
Nitrous oxides (NOx)	24892	3493	6937	6893	11047	6322	3538	10171	10436	33245	33095
Non-methane volatile organic compounds (NMVOC)	16322	3915	4388	4360	7104	19358	1526	4085	4982	35215	1959
Carbon monoxide (CO)	128065	20214	34213	33995	53701	23100	11201	30975	14814	19228	10700
Nitrogen dioxide (N20)	386	60	104	103	166	79	47	125	87	2043	156

Pollutants	Aggregate Households
Carbon dioxide (CO2) as carbon	288424897
Methane (CH4)	96784
Sulphur dioxide (SO2)	123339
Nitrous oxides (NOx)	953499
Non-methane volatile organic compounds (NMVOC)	1111765
Carbon monoxide (CO)	5826047
Nitrogen dioxide (N20)	19289

Pollutants	Total Emissions (kg)
Carbon dioxide (CO2) as carbon	801059498
Methane (CH4)	5830095
Sulphur dioxide (SO2)	2408385
Nitrous oxides (NOx)	3163930
Non-methane volatile organic compounds (NMVOC)	1916683
Carbon monoxide (CO)	8660800
Nitrogen dioxide (N20)	296542

Appendix 7A. Impact Simulations Using the Environmental IO System For Jersey

1. Use Of The Environmental IO Model For Jersey

In this appendix I elaborate on a couple of "what if" type impact simulations by undertaking some illustrative case studies using the Jersey environmental IO model constructed in Chapters 6 and 7. Specifically, I consider two examples of using the environmental IO model to simulate the impact of demand-side disturbances on sectorally disaggregated output, employment, value-added (GDP) and pollution generation following an external shock to one or more of the final demand sectors. As I explain in Chapter 7, Section 1, however, when interpreting the results of such simulations it should be borne in mind that the IO analyses are subject to severe restrictions:

1. IO models cannot capture price-induced substitution effects because all functional relationships are of the Leontief (constant proportions) form.

2. Because of the assumptions of a passive supply-side, a conventional IO system is not suitable for modelling situations where there may be supply constraints or where supply-side disturbances (including policies) may be important.

It has been argued by McGregor et al (1996) that, particularly in a small open economy context where medium- to long-run inter-regional factor mobility is likely, IO can be regarded as providing the ultimate solutions for a range of more complex regional/small open economy models. McGregor et al (1996) demonstrate that in a wide range of regional economic models, I-O accurately describes the long-run response of activity to a permanent change in aggregate final demand. They explain that many regional models do not operate as IO systems in the short-run, but may do so in the long run. This is particularly likely where there is only one non-produced primary input, labour, whose long-run supply is rendered perfectly elastic, through migration, and where the region is perfectly integrated into the national financial

markets. (By this reasoning the classical general equilibrium model, with a fixed set of factors, may be the opposite limiting case – i.e. a short-run model.)

However if the labour supply is not perfectly elastic in the long-run I-O results will not be produced. This point is crucially important in the case of Jersey, where there are quite severe constraints on the operation of the local labour market. With virtually zero unemployment, and more unfilled vacancies than unemployment, Jersey typically operates at (or indeed above) 'full-employment'. This implies that the economy certainly operates under a binding labour supply constraint in the short-run. However, unlike most regional economies, this constraint is unlikely to ease significantly in the long run, at least under the current policy consensus. McGregor *et al*'s (1996) argument regarding the long-run interpretation of IO results is most likely to hold where the labour supply is effectively rendered perfectly elastic in the long run through migration. However the current policy consensus in Jersey is that migration should be restricted in order to pursue the objective of keeping the resident population to the same level, or less than, it was in 1995[1]. This implies that the economy operates under a binding labour supply constraint in the long run as well as the short run.

Therefore I would argue that there are crucial limitations in attempting to model any demand stimulus to the Jersey economy using IO techniques, primarily because labour market conditions in Jersey are simply not consistent with the IO view of perfectly elastic supply, even in the long-run. However, for the purpose of illustrating the type of impact analysis that is possible in the IO framework, I can choose a simulation strategy under which the importance of the binding labour supply constraint in Jersey is limited by holding total demand for labour constant.

2. Simulation Strategy And Impact Analyses

I undertake three illustrative simulations:

[1] In 1995 the population of Jersey was around 85,000; in 1998 this figure had grown to around 89,000.

Simulation 1: a 10% reduction in export demand for the output of the 'Banks and Building Societies' sector of the Jersey economy.

Simulation 2: a 10% increase in tourist demand for local output.

Simulation 3: an (adjusted) combination of simulations 1 and 2, assuming the objective of maintaining stable total employment on the Island.

In the first simulation, the direct impact of the shock is confined to the sector in question only. On the other hand, in the second simulation, the demand shock directly affects every sector that sells to tourists will be affected directly. I should point out that although the percentage changes of the external shocks are the same in both simulations, the implied absolute changes to final demand are very different. Therefore, the scales of the impact will also differ across these simulations.

2.1 Simulation 1: Contraction In Export Demand For 'Banks & Building Societies' Output

2.1.1 Economic Impacts

In Simulation 1, since the 'Banks & Building Societies' sector exports a total of £1,035.642million worth of output in the 1998 I-O table (Table 5.3 in Chapter 5), a 10% reduction in export demand means a £103.564million reduction in demand for this sector's output. (I assume that the shock is distributed equally over the three export destinations, RUK, REU and ROW). Since the majority of 'Banks & Building Societies' output (92%) is in fact produced to meet export demand, this also equates to a 9.2% reduction in total demand for the sector's output.

The direct employment effect is also confined to the 'Banks & Building Societies' sector. The 10% reduction in export demand corresponds to a 9.2% reduction in output and therefore a proportionate reduction in this sector's employment. 'Banks & Building Societies' employment falls from 5757 to 5226 FTE employees, meaning

that the sector requires 531 (9.2%) less employees required to produce its output. This equates to a 1.13% reduction in total employment on the Island.

However, in addition to these direct impacts concentrated in the 'Banks & Building Societies' sector, there are further indirect and induced impacts that ripple through the wider economy as a result of reduced production of output and employment in the 'Banks & Building Societies' sector.

First of all, as 'Banks & Building Societies' reduces its level of output, it reduces its demand for the intermediate inputs it purchases from other sectors of the local economy, which, in turn, causes those sectors to contract their production of outputs. These *indirect* output effects of the demand disturbance are quantified using the Type I output multiplier for 'Banks & Building Societies', which is the column total for this sector in the Type I Leontief inverse in Table 7.2 of the main text. The value of this multiplier is 1.012 (to 3 decimal places). By multiplying this by the value of the initial disturbance, £103.564million I find that the direct plus indirect impact of the demand shock is a reduction in aggregate production of £104.86million. More generally, the (Ix1) vector of the Type I output effect, $\Delta \mathbf{X}^1$, is determined by the relationship

(7A.1) $\Delta \mathbf{X}^1 = [\mathbf{I}-\mathbf{A}]^{-1}\Delta \mathbf{C}_{i(z)}$

Where $\Delta \mathbf{C}_{i(z)}$ is an Ix1 (25x1) vector representing the initial change in total final demand, C_i, here limited to the change in demand from sector z = total export demand for the output of the 'Banks & Building Societies' sector. $[\mathbf{I}-\mathbf{A}]^{-1}$ is the IxI (25x25) Type I Leontief inverse. $\Delta \mathbf{X}^1$ is the resulting ix1 (25x1) vector showing the Type I output effect, i.e. the total change in output (including direct and indirect effects) across all 25 sectors.

Table 7A.1 Impact On Sectoral Output And Employment From A 10% Contraction In Export Demand To The Banks and Building Societies Sector in Jersey, 1998

Sector	Output effects (£million)			Employment effects (FTE employees)		
	Direct impact	Direct + indirect impact	Direct + indirect + induced impact	Direct impact	Direct + indirect impact	Direct + indirect + induced impact
Agriculture & Fishing	0.000	-0.018	-0.169	0.0	-0.6	-6.1
Quarrying & Construction	0.000	-0.103	-1.033	0.0	-2.1	-21.4
Manufacturing	0.000	-0.148	-0.703	0.0	-3.1	-14.9
Electricity	0.000	-0.036	-0.695	0.0	-0.3	-6.3
Water	0.000	-0.002	-0.142	0.0	0.0	-1.3
Gas, oil & fuel distribution	0.000	-0.002	-0.229	0.0	0.0	-3.2
Jersey Telecommunications	0.000	-0.109	-0.811	0.0	-1.1	-8.5
Wholesale & Retail Trade	0.000	-0.021	-3.340	0.0	-0.4	-71.1
Hotels, Restaurants & Catering	0.000	-0.019	-1.195	0.0	-0.5	-32.1
Land Transport	0.000	-0.001	-0.064	0.0	0.0	-1.3
Sea & Air Transport & Transport Support	0.000	-0.036	-0.538	0.0	-0.5	-7.0
Jersey Post	0.000	-0.141	-0.281	0.0	-2.8	-5.5
Banks & Building Societies	-103.564	-103.577	-104.787	-531.3	-531.4	-537.6
Insurance Companies	0.000	-0.006	-0.461	0.0	-0.1	-6.6
Investment Trusts & Fund Managers	0.000	-0.001	-0.006	0.0	0.0	0.0
Computer Services	0.000	-0.045	-0.090	0.0	-0.9	-1.8
Legal Activities	0.000	-0.351	-1.320	0.0	-5.1	-19.2
Accountancy	0.000	-0.037	-0.105	0.0	-0.5	-1.4
Other Business Activities	0.000	-0.184	-0.765	0.0	-4.5	-18.5
Other Services Activities	0.000	-0.012	-0.428	0.0	-0.4	-14.8
Recreation, Culture & Sport	0.000	0.000	-0.604	0.0	0.0	-12.5
Education	0.000	0.000	-0.491	0.0	0.0	-12.0
Health, Social Work & Housing	0.000	0.000	-1.784	0.0	0.0	-37.7
Public Services	0.000	0.000	-0.003	0.0	0.0	-0.1
Public Adminstration & Defence	0.000	-0.006	-0.163	0.0	-0.2	-4.4
Total	-103.564	-104.856	-120.207	-531.3	-554.7	-845.4

In the second column of Table 7A.1 I report how the Type I output effect of this shock is distributed across the 25 production sectors (the first column shows the direct output effect is concentrated in the 'Banks & Building Societies' sector itself).

As implied by the low output multiplier value given by the column total of the Type I Leontief inverse in Table 7.2 (main text), the indirect impacts of the reduction in demand for 'Banks & Building Societies' output are relatively small (only accounting for 1.23% of the total Type I effect). This is because the 'Banks and Building Societies' sector does not have strong backward linkages with the rest of the Jersey economy (in fact, note from the bottom row of Table 7.2 that it has the smallest Type I output multiplier of all the 25 sectors of the Jersey economy).

However more significant effects are observed in the Type II case. As I explain in the main text of Chapter 7, as well as the direct and indirect effects discussed above, Type II analysis also incorporates consumption and income effects from changes in employment. That is to say, Type II analysis of the disturbance will also take into account the further *induced* impacts resulting from any change in income from employment paid to local households (used to finance household consumption expenditure in the economy). Using the Type II output multiplier for 'Banks and Building Societies' in the bottom row of Table 7.4, with value 1.378, I find that that the full reduction in output in the economy resulting from the initial £103.564million drop in 'Banks and Building Societies' export demand is equal to £142.703million. (£120.207million of this is the value of the reduced output of the 25 production sectors, and the remaining £22.496million is reduced income from employment).

I determine the distribution of the Type II output effect across the 25 production sectors by the same method as is in the Type I case. However, this time I estimate equation (7A.1) using the 26x26 version of the Leontief inverse, $[\mathbf{I}-\mathbf{A}^*]^{-1}$ (Table 7.4 main text), where household expenditure is determined endogenously. I report the results of this calculation, the ((I+1)x1) vector, $\Delta\mathbf{X}^2$, of the Type II output effect, in the third column of Table 7A.1.

I find that the sectors that experience the largest induced effects (the difference between columns 2 and 3 of Table 7A.1) are also the sectors shown to have the highest levels of consumer expenditure in the IO table (Table 5.3). These are 'Wholesale & Retail Trade', 'Health Social Work & Housing', 'Hotels, Restaurants & Catering' and 'Banks & Building Societies' itself.

It is also possible to quantify the indirect and induced employment effects of the shock. I do this using the Ix1 (25x1) vector of employment-output coefficients, λ, with elements for each sector, i:

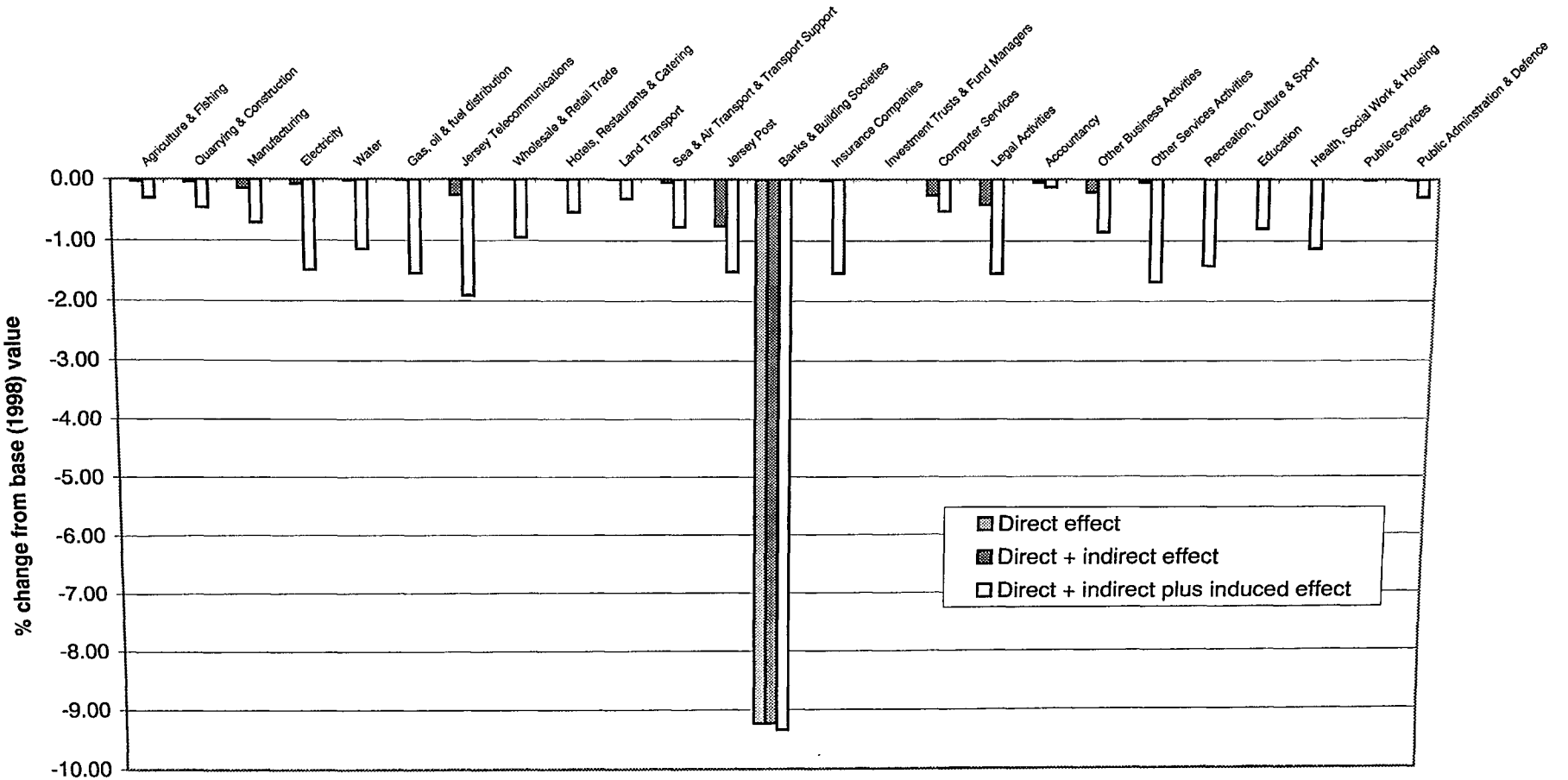
(7A.2) $\lambda_i = \Lambda_i / x_i$

Where Λ_i is the number of (full time equivalent, FTE) workers employed in sector i and x_i is the output of sector $_i$ (in £million); λ_i tells us the number of workers required to produce one unit of output in sector i. The Type I employment effect, $\Delta\Lambda^1$, for each sector, i, is determined by multiplying that sector's employment-output coefficient, λ_i, by the Type I output effect, $\Delta\mathbf{X}^1$:

(7A.3) $\Delta\Lambda^1 = \lambda.\Delta\mathbf{X}^1$

Thus I can determine the direct plus indirect impact on employment resulting from the reduced output levels in the 'Banks & Building Societies' sector itself *and* in the sectors it has backward linkages with. I report the Type I, direct plus indirect employment effects of the shock in the fifth column of Table 7A.1. Note, again, that the bulk of the Type I effect is concentrated in the 'Banks & Building Societies' sector. This reflects the finding reported above that the indirect effects of this shock are small, due to the fact that 'Banks & Building Societies' does not have strong backward linkages within the local economy. Thus, other local sectors do not have to reduce their employment by much to meet the reduction in intermediate demand from 'Banks & Building Societies'.

Figure 7A.1 Percentage Change In Sectoral Outputs, Employment And Value-Added In Response To A 10% Reduction In Export Demand To The Banks & Building Societies Sector in Jersey, 1998



Similarly, I estimate the Type II employment effects - i.e. the reduction in total employment resulting from the direct plus indirect plus induced output effects - by substituting the Type II output effect, $\Delta \mathbf{X}^2$, into (7A.3). At the economy-wide level the full employment impact of the shock is 1.8% drop from the base figure of 47,111 FTE's to 46,266, with 64% of these jobs lost in 'Banks & Building Societies', but with reductions in employment in all sectors. In the final column of Table 7A.1 I show how the full employment effect is distributed across the sectors. Again notice that the largest induced employment effects can be found in the sectors with the highest level of consumer expenditure.

Notice that the actual drop in employment resulting from the shock is relatively small given the absolute size of the demand shock. This is because of the relatively high level of output per employee in the 'Banks & Building Societies' sector. The relatively level of average wages paid in this sector is what generates the large induced impacts observed here. What this means is that significant income and consumption effects could be expected to result from a fairly modest reduction in employment when activity in a high wage sector like 'Banks & Building Societies' contracts.

I summarise the results of this first simulation in terms of percentage changes from base in Figure 7A.1. These results also include the impacts on value-added. I calculate the value-added effects using an Ix1 vector of value-added-output coefficients, ϖ, that is determined in the same manner as the employment-output coefficients in (7A.2), but with total value added for each sector i, ς_i, from the IO table (Table 5.3) in place of sectoral employment, Λ_i.

Note that in Figure 7A.1 the proportionate change in each variable at the sectoral level is the same. This is due to the assumption of universal Leontief (constant proportions) technology in the IO model.

Also note from Figure 7A.1 that while the inclusion of induced effects in the measurement of the total impact on all sectors *does* mean that the that the shock has

significant effects across the whole economy, the bulk of the effects are concentrated in the 'Banks & Building Societies' sector itself. The other sectors that are most affected tend to be those with high levels of consumer expenditure. This is because of the significant consumption and income effects that result from a shock such as this one, which is directly targeted at a sector where wage payments are high relative to its domestic intermediate demands.

2.1.2 Environmental Impacts

Above I have used the vector of employment-output coefficients, λ, and the vector of value-added-output coefficients, ϖ, to estimate the impacts on sectoral employment levels and value-added that result from the contraction in export demand to the 'Banks & Building Societies' sector. Similarly, I can use the output-pollution coefficients that constitute the environmental component of the Jersey IO system to estimate the environmental effects of the shock.

In Chapter 6 (Section 5), I explain that total pollution generation can be estimated using the matrices of direct emissions intensities for the 8 individual and one composite pollutants (K=9) identified across the 25 production sectors, $\mathbf{M_i}$, and final household and tourist demand sectors, $\mathbf{M_z}$, as follows:

$$\text{(7A.4)}\quad \mathbf{P} = \mathbf{P_i} + \mathbf{P_z} = \mathbf{M_i}.\mathbf{X} + \mathbf{M_z}.\mathbf{C}^{\mathbf{T}}$$

where $\mathbf{P}$ is a (Kx1) vector of total emissions of each of the K pollutants identified. Therefore the change in pollution generation resulting from changes in sectoral outputs is determined as:

$$\text{(7A.5)}\quad \Delta\mathbf{P} = \Delta\mathbf{P_i} + \Delta\mathbf{P_z} = \mathbf{M_i}\Delta\mathbf{X} + \mathbf{M_z}\Delta\mathbf{C}^{\mathbf{T}}$$

Where $\Delta\mathbf{X}$ will be the direct output effect (the initial change in final demand) – i.e. $\Delta\mathbf{X}^{\mathbf{1}}$, as determined in (7A.1), in the Type I case or $\Delta\mathbf{X}^{\mathbf{2}}$ in the Type II case. The last element of (7A.5) – the change in direct emissions generation by exogenous final

demand sectors - will apply only where the shock is targeted in a final demand sector that is responsible for direct emissions generation. See, for example, the tourist demand shock in Simulation 2 below. In Chapter 6 I explain that households are directly responsible for pollution generation. However, unless the shock involves an exogenous change in household expenditure, any changes in direct emissions generation by households will be limited to the Type II case, where household expenditure is treated as being endogenously driven by wage income from the production sectors. In Section 3.2 of the main text of Chapter 6 I explain that in the Type II case the KxI (9x25) matrix $\mathbf{M_i}$ of output-pollution coefficients is replaced with a Kx(I+1) (9x26) matrix that includes a vector of household output-(wage income)-pollution coefficients, $\mathbf{m_h}$.

There is an equivalent method of estimating $\Delta\mathbf{P}$: by substituting equation (7A.1) into (7A.5) for $\Delta\mathbf{X} = \Delta\mathbf{X^1}$ in the Type I case (or $\Delta\mathbf{X} = \Delta\mathbf{X^2}$ in the Type II case), we have

(7A.6) $$\Delta\mathbf{P} = \Delta\mathbf{P_i} + \Delta\mathbf{P_z} = \mathbf{M_i}[\mathbf{I}-\mathbf{A}]^{-1}\Delta\mathbf{C_i} + \mathbf{M_z}\Delta\mathbf{C}^{T}$$

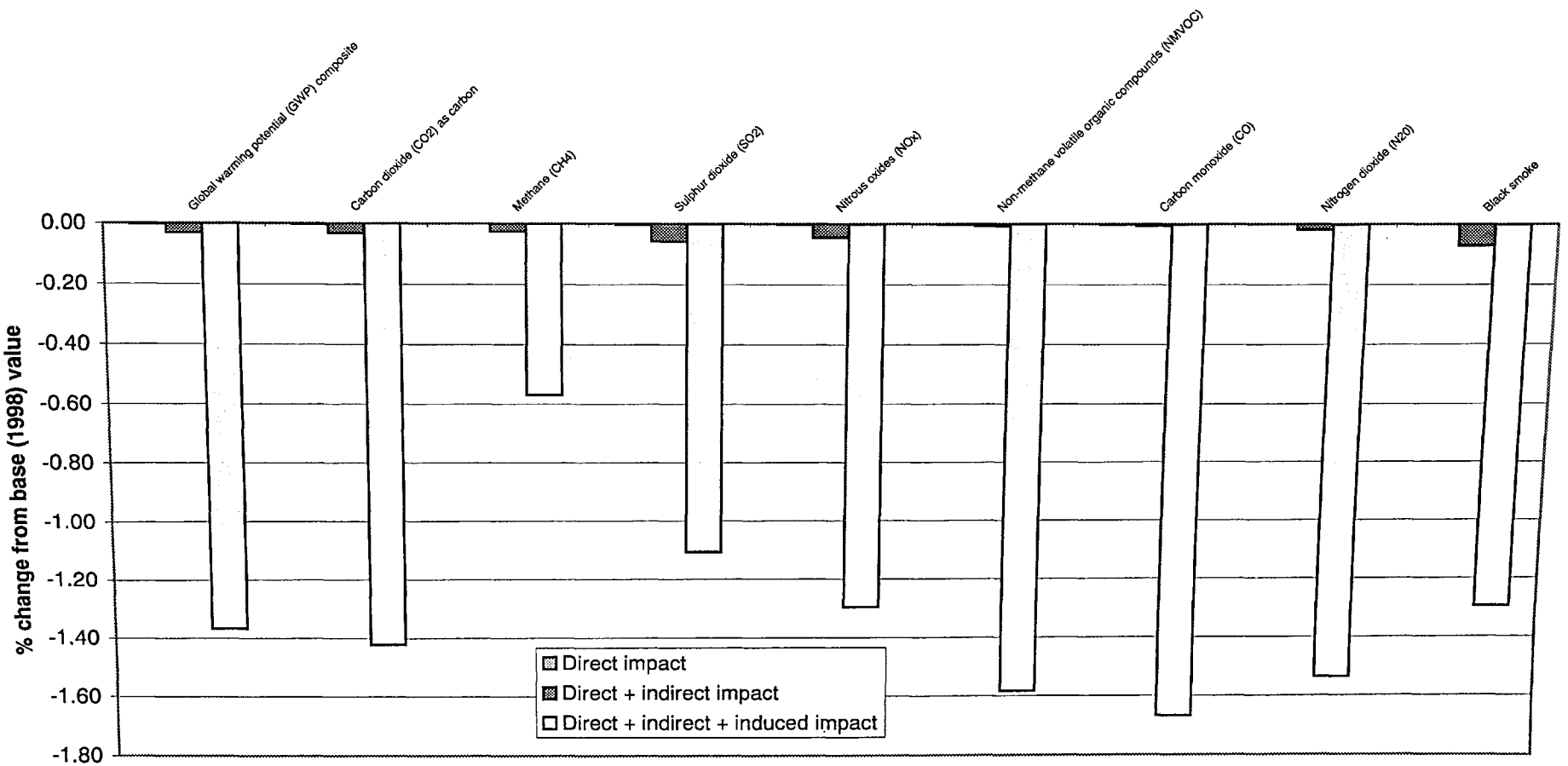
In Chapter 7, section 3.2 I explain that the KxI (or Kx(I+1)) matrix of Type I (Type II) output-pollution multipliers, $\mathbf{M_{i1}}$ ($\mathbf{M_{i2}}$), takes the form $\mathbf{M_i}[\mathbf{I}-\mathbf{A}]^{-1}$ ($\mathbf{M_i}[\mathbf{I}-\mathbf{A^*}]^{-1}$). Therefore it is also possible to determine $\Delta\mathbf{P}$ by applying the matrix of output-pollution multipliers, $\mathbf{M_{i1}}$ (or $\mathbf{M_{i2}}$), to the initial shock to final demand, $\Delta c_{i(z)}$:

(7A.7a) $$\Delta\mathbf{P} = \Delta\mathbf{P_i} + \Delta\mathbf{P_z} = \mathbf{M_{i1}}\Delta\mathbf{C_i} + \mathbf{M_z}\Delta\mathbf{C}^{T}$$

(7A.7b) $$\Delta\mathbf{P} = \Delta\mathbf{P_i} + \Delta\mathbf{P_z} = \mathbf{M_{i2}}\Delta\mathbf{C_i} + \mathbf{M_z}\Delta\mathbf{C}^{T}$$

I illustrate the impact on each of the environmental indicator (pollutant) variables of the changes in sectoral activity levels that result from the 10% contraction in export demand for 'Banks & Building Societies' output in Figure 7A.2.

Figure 7A.2 Impact On 8 Individual And 1 Composite Environmental Indicators Of A 10% Reduction in Export Demand To The Banks & Building Societies Sector In Jersey, 1998



The interesting thing to note here is that induced pollution effects almost entirely account for the change in each of the environmental indicators that occur in response to this shock. The direct pollution impact comes solely from the 'Banks & Building Societies' sector, which is one of the least directly pollution intensive sector in the Jersey economy (across all the pollutants identified here). Moreover, because the 'Banks & Building Societies' sector does not have strong backward intermediate linkages in the local economy, the Type I (direct plus indirect) pollution impacts of the shock are extremely small (the largest impact is on emissions of black smoke, which fall by only 0.07%).

However the induced reductions in emissions in response to this shock are much more significant, ranging from a 0.57% reduction in total methane emissions to a 1.67% fall in total carbon monoxide emissions in the Jersey economy. I report above that sectors with high levels of consumer expenditure show the biggest Type II output effects in response to a change in the level of activity in the 'Banks & Building Societies' sector. Consequently the pollution generation associated with the production of output in these sectors also falls in response to the shock. However, because households are themselves direct polluters, and indeed are directly responsible for a large share of total emissions of most of the pollutants identified here, the main factor driving the environmental results reported in Figure 7A.2 is changes in wage-driven energy consumption in the household sector.

2.2 Simulation 2: Increase In Tourist Demand For Local Outputs

2.2.1 Economic Impacts

In Simulation 1 the direct impact of the shock is confined to the sector the demand disturbance was focussed in. In this second simulation the shock is delivered across the board in line with the initial distribution of tourist expenditure in the economy: every sector that sells output to tourist demand will be directly affected. The direct output effect of the 10% increase in tourist expenditure on locally produced outputs is an increase of £20.242million distributed across the eleven sectors that directly

serve tourist demand according to the initial allocation of tourist expenditure (see the first column of Table 7A.2 below). The direct employment effect (reported in the fourth column of Table 7A.2) is the number of additional employees required to produce these additional sectoral outputs. This is determined using equation (7A.3), and corresponds to a 1.09% increase in total employment in Jersey.

In order to meet this increase in final demand from tourists, the eleven sectors directly affected by the shock have to increase their input purchases from other sectors of the Jersey economy. This starts a ripple effect throughout the economy from the initial stimulus to tourist expenditure, as all sectors increase their input demand in order to increase their output to meet the additional intermediate and final demands. The result is a Type I output multiplier effect that affects 23 out of the 25 production sectors in the economy, taking the actual increase in output, including direct and indirect effects, to £26.314million. I report the sectoral composition of the direct and indirect output effect and the additional employment required to produce this output in the second and fifth columns of Table 7A.2. The Type I employment effect equates to a 1.3% increase in total employment on the Island, the bulk of which, 66%, occurs in 'Hotels, Restaurants & Catering', the sector where the largest share of the direct impact was felt.

There are also significant *induced* impacts from the tourism shock. However, the factors underlying the induced effects here are somewhat different to those driving the impact of the 'Banks & Building Societies' export demand shock in Simulation 1.

First of all note that, while the percentage changes of the external shocks in the two simulations are the same, the implied absolute changes to final demand are very different. 10% of 'Banks & Building Societies' export demand (£103.6million) is more than 5 times greater than 10% of total tourist expenditure on local outputs (£20.4million). However, if we compare the total employment results in Tables 7A.1 and 7A.2, note that the magnitude of the changes in employment resulting from the two shocks is quite similar in both cases. This is because the sectors that serve tourist

demand tend to be much more labour intensive ones – i.e. a similar size employment effect results from a smaller absolute change in tourist demand than from a much bigger change in demand for 'Banks & Building Societies' output. The observed induced effects in this second simulation are driven more by the additional numbers employed than the level of wages paid to each worker. 'Hotels, Restaurants & Catering actually pays the lowest average sectoral wage in the Jersey economy, and therefore there will be a relatively low employment multiplier.

I report the Type II output and employment effects in the third and sixth columns of Table 7A.2. The full increase in output in the economy resulting from the £20.242million tourist demand shock is £44.966million (£33.879million of this is the additional output by the 25 production sectors, and the remaining £11.086million is the increase in income from employment). This means that the 10% tourist demand shock has an output multiplier of 2.22, the full output effect being more than double the size of the initial stimulus. The Type II employment effect resulting from the direct, indirect and induced changes in output equates to a 1.6% increase in total employment on the Island.

In Figure 7A.3 I summarise the output, employment and value-added effects in terms of percentage changes from the base values for 1998 (again, the effect on each variable is the same in percentage terms, which is due to the assumption of universal Leontief technology). Note that, while the effects of the tourist demand shock are spread more widely across the economy than was the case with the shock in Simulation 1, which was directed at just one sector, the bulk of the impact does hit in two sectors in particular. These are 'Hotels, Restaurants & Catering' and 'Wholesale & Retail': together these two sectors account for just over 90% of tourist demand for locally produced outputs. However, both of these sectors also have stronger backward linkages with the local economy than is the case with 'Banks & Building Societies', which leads to more significant indirect effects than are observed in the first simulation.

Table 7A.2 **Impact On Sectoral Output And Employment From A 10% Increase In Tourist Demand For Local Outputs in Jersey, 1998**

Sector	Output effects (£million)			Employment effects (FTE employees)		
	Direct impact	Direct + indirect impact	Direct + indirect + induced impact	Direct impact	Direct + indirect impact	Direct + indirect + induced impact
Agriculture & Fishing	0.002	0.552	0.626	0.1	19.8	22.5
Quarrying & Construction	0.000	0.462	0.920	0.0	9.6	19.1
Manufacturing	0.480	0.772	1.045	10.2	16.4	22.2
Electricity	0.000	0.413	0.738	0.0	3.8	6.7
Water	0.000	0.077	0.146	0.0	0.7	1.4
Gas, oil & fuel distribution	0.044	0.156	0.268	0.6	2.2	3.7
Jersey Telecommunications	0.000	0.175	0.521	0.0	1.8	5.4
Wholesale & Retail Trade	3.453	3.659	5.294	73.5	77.9	112.7
Hotels, Restaurants & Catering	14.871	14.898	15.477	399.9	400.7	416.2
Land Transport	0.850	0.871	0.902	17.1	17.5	18.2
Sea & Air Transport & Transport Support	0.083	0.215	0.462	1.1	2.8	6.0
Jersey Post	0.019	0.200	0.269	0.4	3.9	5.3
Banks & Building Societies	0.000	1.630	2.226	0.0	8.4	11.4
Insurance Companies	0.000	0.105	0.329	0.0	1.5	4.7
Investment Trusts & Fund Managers	0.000	0.009	0.011	0.0	0.1	0.1
Computer Services	0.000	0.065	0.087	0.0	1.3	1.7
Legal Activities	0.000	0.646	1.124	0.0	9.4	16.4
Accountancy	0.000	0.108	0.142	0.0	1.5	2.0
Other Business Activities	0.000	0.715	1.001	0.0	17.3	24.2
Other Services Activities	0.019	0.142	0.346	0.7	4.9	12.0
Recreation, Culture & Sport	0.378	0.379	0.677	7.8	7.9	14.0
Education	0.000	0.000	0.242	0.0	0.0	5.9
Health, Social Work & Housing	0.043	0.043	0.922	0.9	0.9	19.5
Public Services	0.000	0.000	0.001	0.0	0.0	0.0
Public Adminstration & Defence	0.000	0.024	0.101	0.0	0.6	2.7
Total	20.242	26.314	33.879	512.3	610.8	754.1

Figure A7.3 Percentage Change In Sectoral Outputs, Employment And Value-Added In Response To A 10% Increase In Tourist Demand for Local Outputs in Jersey, 1998

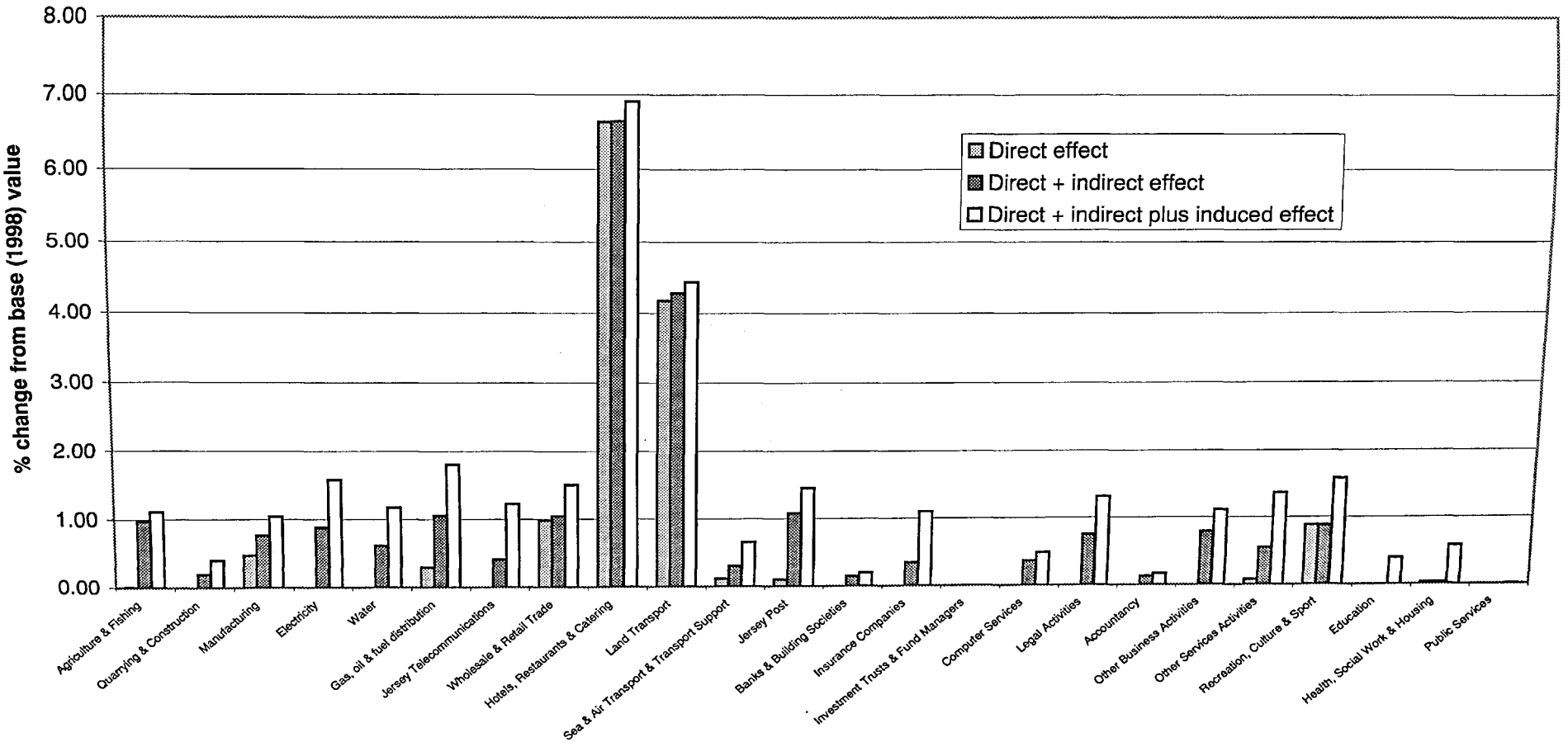
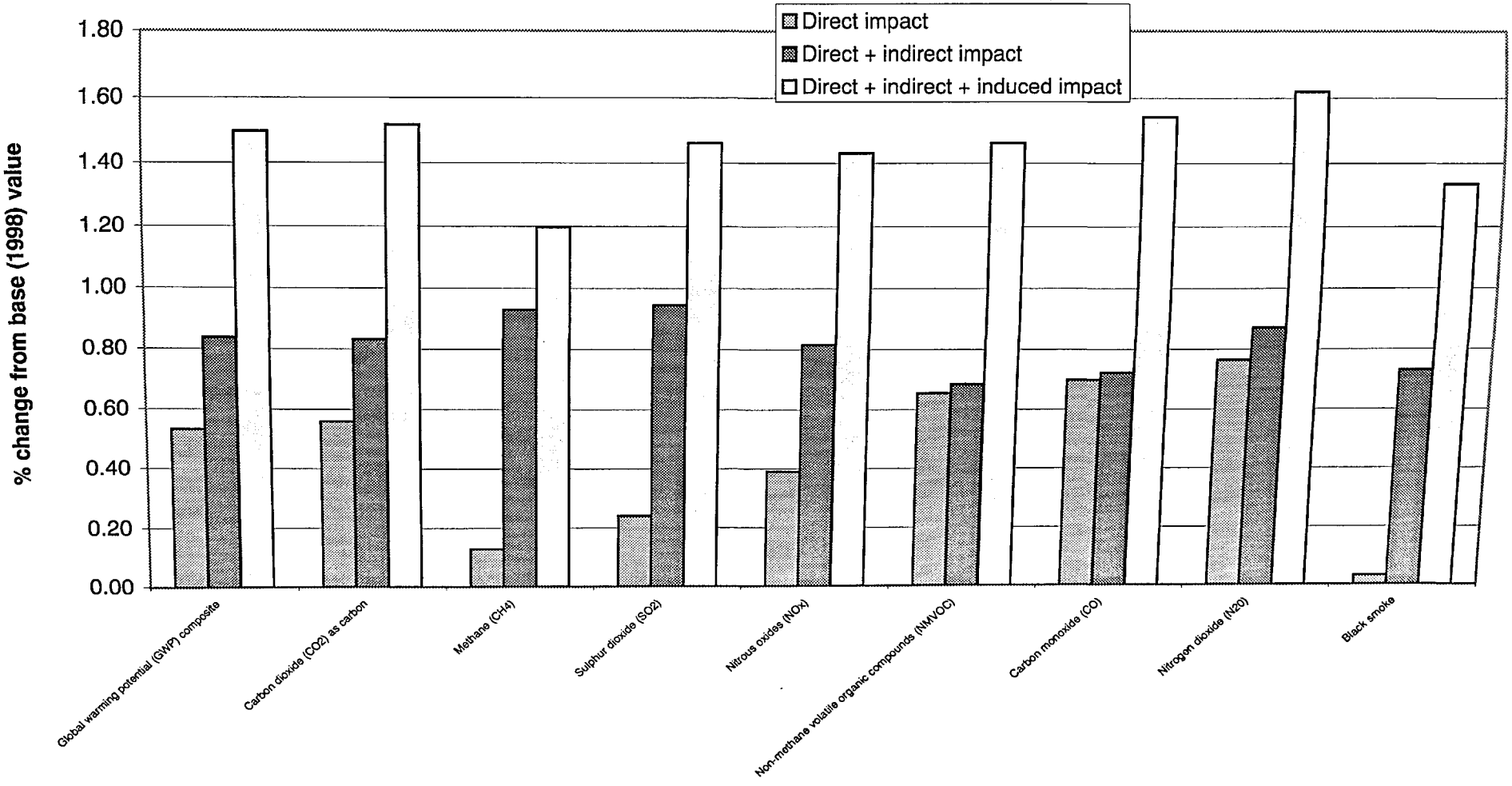


Figure 7A.4 Impact On 8 Individual And 1 Composite Environmental Indicators Of A 10% Increase In Tourist Demand For Local Outputs In Jersey, 1998



2.2.2 Environmental Impacts

In Figure 7A.4 I illustrate the environmental impacts of the tourist demand shock. As in the case of the 'Banks & Building Societies' demand shock, induced effects make up a large proportion of the total environmental impact across most of the pollutants. This is because of the large increase in employment required to support the increase in tourist demand. However, in contrast to the first simulation, there are also significant direct and indirect pollution effects. One important factor is that tourists themselves are directly responsible for emissions generation, through their (human) waste generation and use of automotive fuels in driving private or hire cars during their visit to Jersey. For all pollutants except SO_2 and black smoke, which tourists do not directly generate, direct emissions for tourists account for between 45% (NO_X) and 93% (methane) of the total direct effects of the shock (and between 9% and 39% of the total (Type II) effects of the shock). The other factor influencing the size of the direct effect is that the main sectors which directly serve tourism, for example 'Hotels, Restaurants & Catering', are important direct polluters (unlike 'Banks & Building Societies' in the first simulation). The indirect effects of the tourist demand shock are also significant because the sectors that directly serve tourist demand tend to have strong backward linkages in the local economy and relatively high Type I output-pollution multipliers.

2.3 Simulation 3: Using A Tourist Demand Stimulus To Offset The Negative Employment Effects Of A Contraction In 'Banks & Building Societies Export Demand

I make the observation above that the magnitude of the changes in employment in the first two simulations is similar, despite the huge difference in the values of the shocks applied. This highlights another potential use for the IO model: looking at the *net* impact of simultaneous changes in demand, which is particularly useful if it is considered desirable to target one or more of the key economic variables.

Suppose for example, that there is a policy objective to keep total employment on the Island constant. It is possible to adjust the percentage value of the tourist expenditure shock in simulation 1 so that the full (Type II) positive employment effect of this stimulus exactly offsets the negative effect of the 10% reduction in export demand to 'Banks & Building Societies. This illustrates a useful type of policy analysis exercise that the IO model can be used for. If, for some reason, policymakers expect a fall in demand in one sector, the model can be used to explore options to offset the negative effects of such a shock, so as to maintain constant employment.

At the start of this Appendix I question the use of IO modelling techniques for a supply-constrained economy like Jersey because the inherent IO assumption of an entirely passive supply-side is inconsistent with actual conditions in the economy, particularly with respect to the labour market. However, if total employment can be held constant the labour supply constraint will not be violated. Thus, when the IO model is used in this way the results are likely to be more useful to policymakers in a supply-constrained economy. (Nonetheless, the problems of fixed technology, the elasticity of supply in other markets, and more general supply-side issues such as the absence of any price-induced effects remain relevant).

Therefore in this third simulation I adjust the value of the tourist demand stimulus so that it just offsets the total (Type II) change in employment found for the 10% 'Banks & Building Societies' export demand shock in Simulation 1 (meaning a change in tourist demand for local outputs of 11.2%[2]). The two shocks are then applied simultaneously.

2.3.1 Economic Impacts

In Table 7A.3 (below) I summarise the absolute values of the full (Type II) output, employment and value-added (GDP) effects resulting from the two demand disturbances across the 25 sectors of the Jersey economy. In the final three columns

[2] This new value is calculated using the difference in the size of the Type II employment effects found in the first two simulations given the size of the initial tourist demand shock: (854.4/745.1)*10 = 11.2.

Notice that while the total employment effect of the two shocks nets out to zero change from base, there are negative net impacts on the level of output produced in the economy and on GDP because of the different composition and absolute value of the two shocks.

It is interesting to look at the composition of all three types of effect. First, consider the composition of the employment effect. The net impact is no change in the level of total employment, with the 845 (FTE) jobs lost as a result of the 'Banks & Building Societies' demand shock being offset by 845 jobs gained as a result of the stimulus to tourist demand. However, there is an important redistribution of employment among the 25 production sectors, particularly away from 'Banks & Building Societies' and towards the 'Hotels, Restaurants & Catering' and 'Wholesale & Retail Trade' sectors. In the first simulation I find that employment in 'Hotels, Restaurants & Catering' and 'Wholesale & Retail Trade' is negatively affected by the 'Banks & Building Societies' demand shock because of the drop in consumer demand that results from reduced income from employment paid to households (the induced effect of the shock). However, here this local consumer demand effect is more than offset by the increase in non-local consumer (tourist) demand – i.e. the direct effects of the tourist shock (the induced effects of the 'Banks & Building Societies' shock still outweigh those of the tourist demand stimulus).

This reallocation of employment has important implications for Jersey GDP. Not only is labour productivity in sectors like 'Hotels, Restaurants & Catering' and 'Wholesale & Retail' lower in terms of the value of output per (FTE) employee, but each additional job in these sectors produces much less total value-added than each job lost in the 'Banks & Building Societies' sector. Therefore the reallocation of jobs resulting from the attempt to compensate for the decline in total employment from export demand shock to 'Banks & Building Societies' by stimulating tourist demand results in a negative net impact on total GDP (a net reduction of 1.01%).

[2] This new value is calculated using the difference in the size of the Type II employment effects found

Of course, this third simulation could also be carried out with the aim of keeping one of the other key economic indicator variables constant. For example, if the objective is a zero net impact on GDP, rather than employment, the size of the tourism shock can be adjusted accordingly. However, in this particular case, maintaining a constant level of GDP in the presence of a 10% reduction in export demand to 'Banks & Building Societies', we would require a 46.2% increase in tourist demand[3]. Moreover, this would mean a net increase in employment of 5.6%, with 2638 new FTE jobs created on the Island, 1891 of which would be in the 'Hotels, Restaurants & Catering' sector, where employment would increase by 31.4%. Thus, the problem of using IO to analyse the impact of disturbances in a supply-constrained economy applies once again.

In Figure 7A.5 I summarise the sectoral output, employment and value-added effects of Simulation 3 in terms of percentage changes from the base values for 1998.

2.3.2 Environmental Impacts

In Figure 7A.6 (below) I report the net environmental impacts, in terms of the percentage change in emissions of the 8 individual and one composite pollutants, of the simultaneous disturbances in tourist and 'Banks & Building Societies' export demand. The first thing to note is that the magnitude of all the environmental impacts is much less than is observed in either of the first two simulations. This is because the presence of a negative and positive demand shocks together leads to the negative and positive environmental effects cancelling each other out to some extent. In terms of the *direct* environmental impact, the change in all the individual pollutant indicators and the GWP composite is very small, but with the all the net impacts being positive. In Simulation 1 I found that the direct pollution effects of the reduction in demand to 'Banks & Building Societies' were extremely small due to the low emissions intensities of producing output in this sector. The tourist demand shock, on the other hand, while having a smaller total direct output effect, has much

in the first two simulations given the size of the initial tourist demand shock: (854.4/745.1)*10 = 11.2.

[3] Again, the size of the required shock is calculated using the difference in the value-added effects of the two shocks, given the size of variable shock – (110.808/26.892)*11.2 = 46.2.

more significant direct output-pollution effects because of the pollution intensity of activities directly associated with tourist expenditure.

When I take indirect effects into account the positive impacts on the environmental indicators is larger. This happens because the negative Type I output effects from the export demand shock to 'Banks & Building Societies' are not enough to outweigh those from the tourist demand stimulus. I have explained that 'Banks & Building Societies' does not have strong backward linkages to the local economy. This has the implication that the Type I environmental effects from the 'Banks & Building Societies' shock are also relatively small (ranging from 0.01% to 0.07% change from base), and only slightly counteract the Type I environmental effects of the tourism shock.

However the net impact on all environmental indicators is reduced when induced effects are taken into account. This is particularly true in the case of three pollutants, NMVOC, carbon monoxide (CO) and N_2O, whose generation (in Jersey) is mainly associated with automotive fuel consumption by local households. This reflects the fact that, despite total employment remaining unchanged, the higher wages paid in the jobs lost in the 'Banks & Building Societies' shock relative to those gained elsewhere from the tourist demand shock mean that the former has much larger income and consumption effects.

Generally, however, the results I report in Figure 7A.6 suggest that, in the long run, the total environmental impact of attempting to stimulate tourist demand in order to compensate for the employment effects of the 'Banks & Building Societies' export demand shock is likely be a net increase in pollution generation. This is because of the direct, indirect and induced pollution intensity of tourist expenditure, both in terms of the production activities that serve tourist demand, and of tourists' own energy consumption activities during their stay in Jersey. My analysis of the economic impacts of the joint shock also suggests that the detrimental effect on the environment is likely to be accompanied by negative effects on aggregate production and GDP.

Table 7A.3 Total (Direct Plus Indirect Plus Induced) Impacts On Sectoral Output, Employment and Value-Added (GDP) Of A Demand Shift Between 'Banks & Building Societies' Export Demand And Tousist Demand For Local Outputs in Jersey, 1998

	Simulation 3(a) 10% Contraction in Export Demand to 'Banks & Building Societies'			Simulation 3(b) 11.21% Increase In Tourist Demand For Local Outputs			NET EFFECTS ON JERSEY ECONOMY		
Sector	Output effect £million	Employment Effect FTEs	Change in GDP £million	Output effect £million	Employment Effect FTEs	Change in GDP £million	Output effect £million	Employment Effect FTEs	Change in GDP £million
Agriculture & Fishing	-0.169	-6.1	-0.102	0.702	25.2	0.425	0.533	19.2	0.323
Quarrying & Construction	-1.033	-21.4	-0.797	1.032	21.4	0.796	-0.001	0.0	-0.001
Manufacturing	-0.703	-14.9	-0.306	1.172	24.9	0.510	0.469	10.0	0.204
Electricity	-0.695	-6.3	-0.426	0.827	7.5	0.507	0.132	1.2	0.081
Water	-0.142	-1.3	-0.069	0.164	1.5	0.080	0.022	0.2	0.011
Gas, oil & fuel distribution	-0.229	-3.2	-0.096	0.301	4.2	0.126	0.071	1.0	0.030
Jersey Telecommunications	-0.811	-8.5	-0.486	0.584	6.1	0.349	-0.228	-2.4	-0.136
Wholesale & Retail Trade	-3.340	-71.1	-2.448	5.935	126.3	4.352	2.596	55.2	1.903
Hotels, Restaurants & Catering	-1.195	-32.1	-0.795	17.351	466.6	11.542	16.156	434.5	10.747
Land Transport	-0.064	-1.3	-0.046	1.011	20.4	0.720	0.947	19.1	0.675
Sea & Air Transport & Transport Support	-0.538	-7.0	-0.424	0.518	6.7	0.408	-0.020	-0.3	-0.016
Jersey Post	-0.281	-5.5	-0.222	0.302	5.9	0.238	0.021	0.4	0.016
Banks & Building Societies	-104.787	-537.6	-99.661	2.495	12.8	2.373	-102.292	-524.8	-97.287
Insurance Companies	-0.461	-6.6	-0.346	0.368	5.3	0.276	-0.093	-1.3	-0.070
Investment Trusts & Fund Managers	-0.006	0.0	-0.005	0.013	0.1	0.010	0.006	0.0	0.005
Computer Services	-0.090	-1.8	-0.067	0.098	2.0	0.073	0.007	0.1	0.005
Legal Activities	-1.320	-19.2	-1.177	1.260	18.4	1.123	-0.060	-0.9	-0.054
Accountancy	-0.105	-1.4	-0.089	0.159	2.2	0.135	0.054	0.7	0.046
Other Business Activities	-0.765	-18.5	-0.646	1.122	27.1	0.948	0.358	8.7	0.302
Other Services Activities	-0.428	-14.8	-0.387	0.388	13.5	0.351	-0.039	-1.4	-0.036
Recreation, Culture & Sport	-0.604	-12.5	-0.383	0.758	15.7	0.481	0.154	3.2	0.098
Education	-0.491	-12.0	-0.363	0.271	6.6	0.201	-0.220	-5.4	-0.163
Health, Social Work & Housing	-1.784	-37.7	-1.338	1.034	21.8	0.776	-0.750	-15.8	-0.563
Public Services	-0.003	-0.1	-0.001	0.002	0.0	0.001	-0.001	0.0	-0.001
Public Adminstration & Defence	-0.163	-4.4	-0.127	0.114	3.0	0.088	-0.049	-1.3	-0.038
ABSOLUTE VALUE OF TOTAL CHANGE	-120.207	-845	-110.808	37.981	845	26.892	-82.226	0	-83.916
PERCENTAGE CHANGE	-3.66	-1.79	-4.17	1.15	1.79	1.01	-2.50	0.00	-3.16

Figure 7A.5 Net Impact on Sectoral Output, Employment And Value-Added Of A 10% Contraction In Banks & Building Societies Export Demand And An 11.2% Stimulus to Tourist Demand For Local Outputs in Jersey, 1998

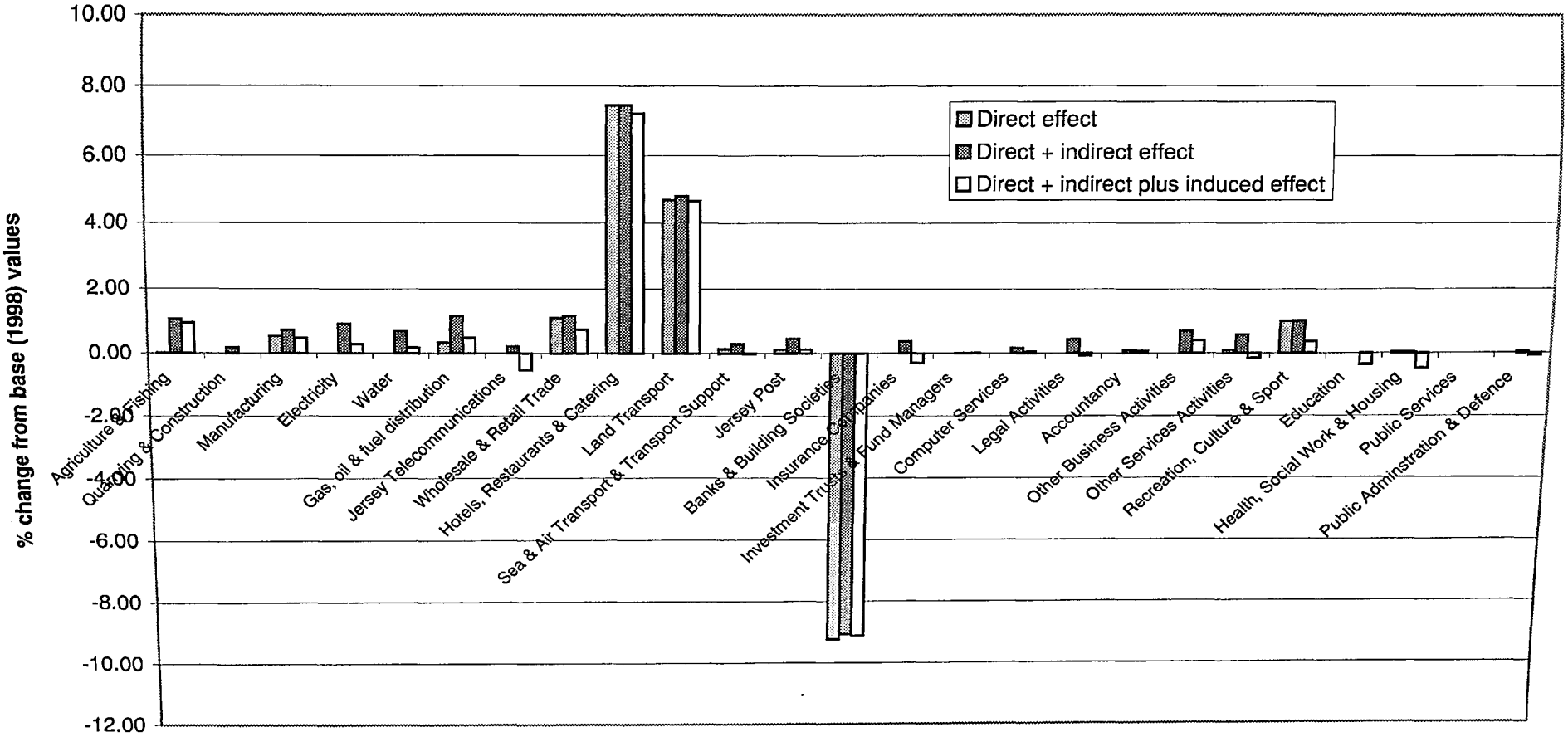
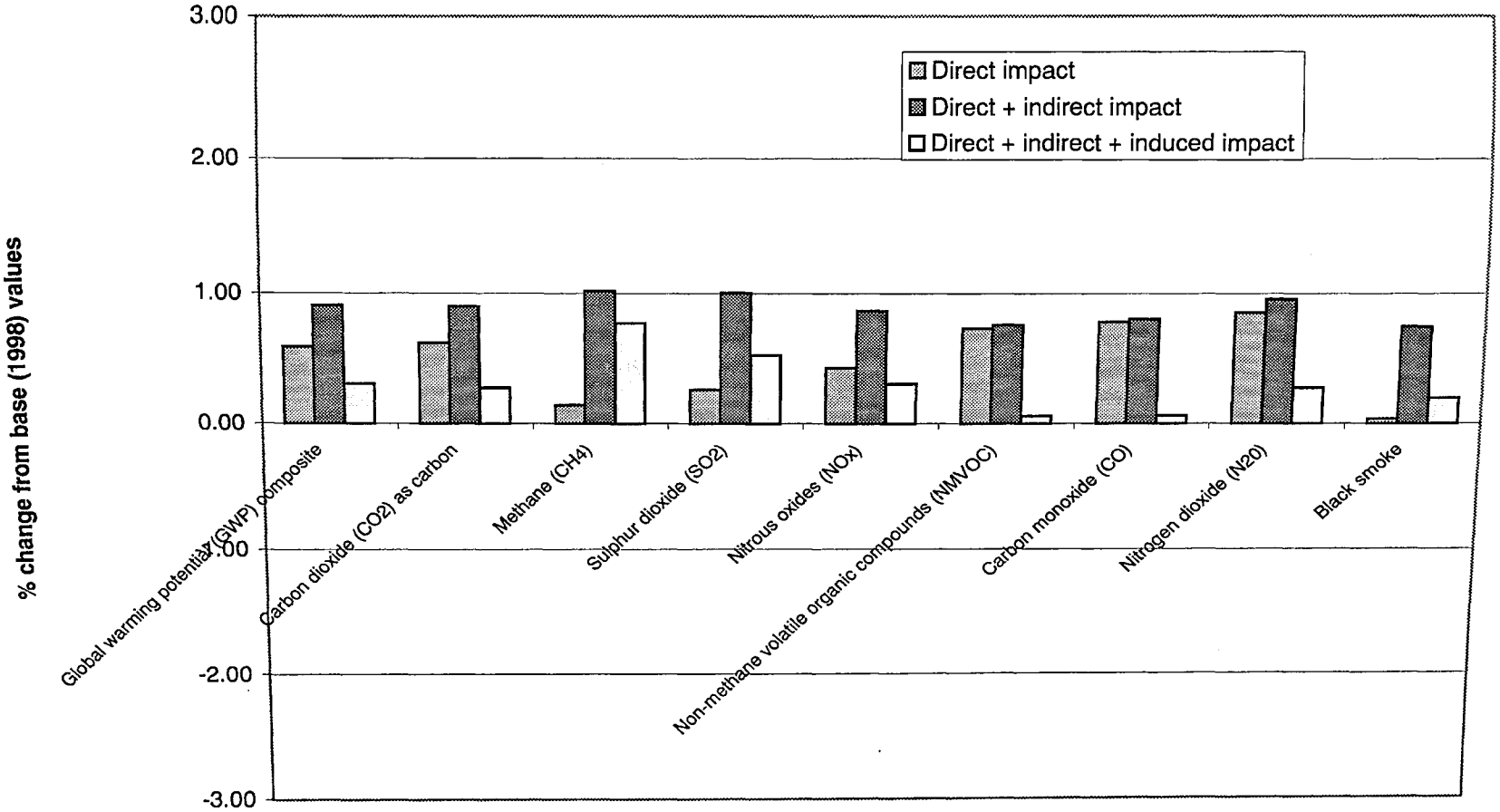


Figure 7A.6 - **Net Impact On 8 Individual And 1 Composite Environmental Indicators Of A 10% Contraction In 'Banks & Building Societies' Export Demand And An 11.2% Stimulus To Tourist Demand For Local Outputs in Jersey, 1998**



Appendix 7B. Attribution Of Pollution Generation In Jersey (1998) With UK-Adjusted Coefficients

In Section 5 of Chapter 6 I consider the added precision gained from estimating and using the region-specific matrices $\mathbf{M_i}$ (also referred to as $\mathbf{M_i^{\theta}}$) and $\mathbf{M_z}$ ($\mathbf{M_z^{\theta}}$) of output-pollution and final demand expenditure-pollution coefficients for Jersey as compared to the adjusted-national (UK) matrices $\mathbf{M_i^{UK(\theta)}}$ and $\mathbf{M_z^{UK(\theta)}}$. I construct the Jersey-specific matrices using the sectoral emissions estimates that are derived from base year (1998) data on fuel use and polluting technologies employed by each production and final demand sector in Jersey (see Chapter 6, Sections 3 and 4). I construct the UK-adjusted matrices by estimating a set of UK direct pollution coefficients from data on sectoral outputs and emissions generation in the UK in 1998, but adapt these using weights that reflect the composition of output at the aggregate and sectoral level in Jersey (see Appendix 6B).

My basic finding in Section 5 of Chapter 6 is that there are very significant differences in the sectoral emissions intensities across all pollutants given by the Jersey-specific matrices, $\mathbf{M_i}$ and $\mathbf{M_z}$, and the UK-adjusted ones, $\mathbf{M_i^{UK(\theta)}}$ and $\mathbf{M_z^{UK(\theta)}}$, both in terms of the absolute size of individual coefficients, and in terms of the relative intensities of different activities. The one definite explanatory factor I identify for this is that one of the assumptions necessary for using the UK-adjusted coefficients in Jersey – that equivalent production and final demand sectors in Jersey and the UK have identical fuel use intensities – is shown to be violated in the base year data.

I find that the differences in the Jersey-specific and UK-adjusted pollution coefficients lead to dramatic differences both in terms of estimates of total pollution generated at the sectoral and aggregate levels, and in the direct contribution of different production and final demand sectors to total emissions. However, I also argue that any errors in the absolute and relative emissions intensities could be expected to carry through to estimates of the *indirect* contribution of different activities to the pollution problem in Jersey (1998). In the main text of Chapter 7 I

conduct attribution analyses using the Jersey-specific environmental IO system in order to determine the indirect and induced contributions of different production and final consumption activities to total emissions generation in Jersey. My objective in this Appendix is to demonstrate that there would be significant differences in these results if the analyses are dependent on the UK-adjusted matrices, $\mathbf{M_i}^{UK(\theta)}$ and $\mathbf{M_z}^{UK(\theta)}$, of pollution coefficients.

In Section 3.2 of Chapter 7 I use the matrices of Jersey-specific pollution coefficients and the Type I Leontief inverse to derive a set of Type I output-pollution multipliers, which give the direct plus indirect emissions intensity of each sector's production to meet final demand. The KxI (9x25) matrix of UK-adjusted Type I output-pollution multipliers, which I refer to as $\mathbf{M_{i1}}^{UK(\theta)}$, is defined in the same way as is shown for the Jersey-specific case in equation (7.13) (Section 3.2), but substituting the UK-adjusted matrix, $\mathbf{M_i}^{UK(\theta)}$, of output-pollution coefficients for the Jersey-specific matrix $\mathbf{M_i}$:

$$\textbf{(7B.1)} \qquad \mathbf{M_{i1}}^{UK(\theta)} = \mathbf{M_i}^{UK(\theta)}[\mathbf{I-A}]^{-1}$$

Where $[\mathbf{I-A}]^{-1}$ is the Jersey-specific (IxI) Type I Leontief inverse. The UK-adjusted (Kx(I+1)) matrix $\mathbf{M_{i2}}^{UK(\theta)}$ of UK-adjusted Type II output-pollution multipliers is defined in the same way, but using the (I+1)x(I+1) Type II Leontief inverse where household expenditure is endogenised, defined in Section 3.2 as $[\mathbf{I-A^*}]^{-1}$, and the (Kx(I+1)) matrix $\mathbf{M_{i(+h)}}^{UK(\theta)}$, which includes a vector of household output-(income) pollution coefficients.

I show the UK-adjusted matrices $\mathbf{M_{i1}}^{UK(\theta)}$ and $\mathbf{M_{i2}}^{UK(\theta)}$ of output-pollution multipliers in Tables 7B.1 and 7B.2 (note that in Table 7B.2 I do not show the vector of household multipliers because there is no final demand for household production). If these two matrices are compared with the Jersey-specific ones shown in Tables 7.3 and 7.5 of the main text, it is clear that there are once again significant differences both in terms of the absolute size of the multipliers, and in terms of the relative intensities across sectors.

Table 7B.1 Direct Plus Indirect Emissions Intensities (kg) Per £1million Final Demand For The Outputs Of Local Production Sectors - With All Final Demands Determined Exogenously (UK-Adjusted Type I Output-Pollution Multipliers)

Sectors / Pollutants	Agriculture & Fishing	Quarrying & Construction	Manufacturing	Electricity	Water	Gas, Oil & Fuel Dist.	Jersey Telecom.	Wholesale & Retail Trade	Hotels, Rest. & Catering	Land Transport	Sea & Air Trans. & Trans Supp	Jersey Post	Banks & Building Soc.
Carbon dioxide (CO2) as carbon	469493.334	96086.289	334776.944	5426977.508	404202.982	119113.064	122855.549	170264.780	195376.311	951568.711	1265891.586	135287.063	34567.901
Methane (CH4)	46268.160	73.519	5190.730	698.552	86.176	9788.943	139.637	116.537	1560.897	169.997	182.677	116.284	11.630
Sulphur dioxide (SO2)	1519.825	200.606	1376.335	38819.318	1808.958	195.850	466.167	693.126	904.173	452.115	6478.108	518.874	21.057
Nitrous oxides (NOx)	3020.547	693.779	1142.325	13279.195	1296.577	393.687	444.835	660.717	604.699	7128.934	10773.092	745.921	104.178
Non-methane volatile organic compounds (NMVOC)	931.190	727.016	1729.952	296.241	793.586	2389.907	190.594	206.306	185.050	1593.318	1757.524	213.587	67.197
Carbon monoxide (CO)	4093.411	3054.647	897.614	3040.427	2961.103	1183.890	886.264	1073.857	882.188	5485.415	4230.686	859.395	503.980
Nitrogen dioxide (N20)	4486.510	22.423	506.958	237.491	30.118	11.527	17.665	16.053	151.030	41.549	56.190	15.111	2.365

Sectors / Pollutants	Insurance Companies	Inv. Trusts & Fund Mgrs	Computer Services	Legal Activities	Accountancy	Other Bus. Activities	Other Service Activities	Recreation, Culture & Sport	Education	Health, Social Work & Housing	Public Services	Public Admin. & Defence
Carbon dioxide (CO2) as carbon	64913.491	55715.900	89085.398	71660.628	69774.101	65427.696	111826.107	195790.945	178220.621	152296.811	357851.782	162813.660
Methane (CH4)	69.523	103.491	60.782	84.777	46.604	72.375	78.277	1039.681	88.361	210.954	110940.174	44.011
Sulphur dioxide (SO2)	170.116	135.693	265.421	253.511	223.023	181.549	327.018	1020.220	516.577	750.911	1526.874	421.346
Nitrous oxides (NOx)	216.871	182.580	327.403	202.473	206.953	216.231	440.752	547.289	397.026	386.663	2054.652	674.231
Non-methane volatile organic compounds (NMVOC)	118.393	102.804	251.729	93.557	91.595	116.746	802.320	153.432	142.999	123.617	1565.274	64.815
Carbon monoxide (CO)	720.924	527.164	1238.424	508.172	556.100	713.899	1003.973	670.111	797.410	383.927	1567.118	294.870
Nitrogen dioxide (N20)	9.029	11.505	9.333	10.140	6.669	8.940	8.810	99.154	8.257	17.139	92.808	5.097

Table 7B.2 Direct Plus Indirect Plus Induced Emissions Intensities (kg) Per £1million Final Demand For The Outputs Of Local Production Sectors - With Wage-Related Household Expenditure Determined Endogenously (UK-Adjusted Type II

Sectors / Pollutants	Agriculture & Fishing	Quarrying & Construction	Manufacturing	Electricity	Water	Gas, Oil & Fuel Dist.	Jersey Telecom.	Wholesale & Retail Trade	Hotels, Rest. & Catering	Land Transport	Sea & Air Trans. & Trans Supp	Jersey Post	Banks & Building Soc.
Carbon dioxide (CO2) as carbon	892889.642	372243.148	670495.650	5624129.928	663275.018	396033.047	373936.526	445764.223	461282.594	1230799.463	1508133.772	557257.217	142040.904
Methane (CH4)	46726.884	372.718	5554.460	912.155	366.865	10088.969	411.668	415.024	1848.990	472.526	445.132	573.463	128.070
Sulphur dioxide (SO2)	2713.515	979.181	2322.833	39375.154	2539.365	976.576	1174.045	1469.848	1653.848	1239.356	7161.066	1708.543	324.057
Nitrous oxides (NOx)	4465.261	1636.082	2287.865	13951.919	2180.583	1338.594	1301.574	1600.777	1512.025	8081.726	11599.672	2185.769	470.898
Non-methane volatile organic compounds (NMVOC)	2005.861	1427.962	2582.078	796.656	1451.166	3092.789	827.891	905.583	859.978	2302.065	2372.387	1284.638	339.987
Carbon monoxide (CO)	9357.947	6488.399	5071.962	5491.833	6182.421	4627.130	4008.221	4499.434	4188.483	8957.388	7242.740	6106.198	1840.306
Nitrogen dioxide (N20)	4536.092	54.762	546.272	260.578	60.457	43.955	47.067	48.315	182.168	74.248	84.558	64.526	14.951

Sectors / Pollutants	Insurance Companies	Inv. Trusts & Fund Mgrs	Computer Services	Legal Activities	Accountancy	Other Bus. Activities	Other Service Activities	Recreation, Culture & Sport	Education	Health, Social Work & Housing	Public Services	Public Admin. & Defence
Carbon dioxide (CO2) as carbon	478874.567	288908.432	355197.998	387980.685	403286.656	458792.077	474950.922	504022.927	670422.764	541896.266	780202.817	692874.828
Methane (CH4)	518.025	356.141	349.098	427.491	407.944	498.561	471.700	1373.632	621.632	633.062	111397.765	618.300
Sulphur dioxide (SO2)	1337.205	793.138	1015.678	1145.318	1163.302	1290.569	1350.783	1889.225	1904.252	1849.316	2717.617	1915.758
Nitrous oxides (NOx)	1629.390	978.280	1235.433	1281.821	1344.966	1558.469	1679.808	1599.039	2076.519	1716.055	3495.799	2482.907
Non-methane volatile organic compounds (NMVOC)	1169.115	694.696	927.180	896.445	938.122	1115.189	1724.009	935.791	1392.314	1112.504	2637.291	1410.224
Carbon monoxide (CO)	5868.142	3426.695	4547.285	4441.315	4703.016	5605.016	5519.089	4502.686	6917.482	5228.231	6818.657	6885.683
Nitrogen dioxide (N20)	57.505	38.813	40.496	47.182	45.725	55.005	51.333	135.249	65.897	62.763	142.268	67.170

Figure 7B.1 Type I Pollution (NOx) Multipliers - Estimated Using Jersey-Specific And UK-Ajusted Output-Pollution Coefficients

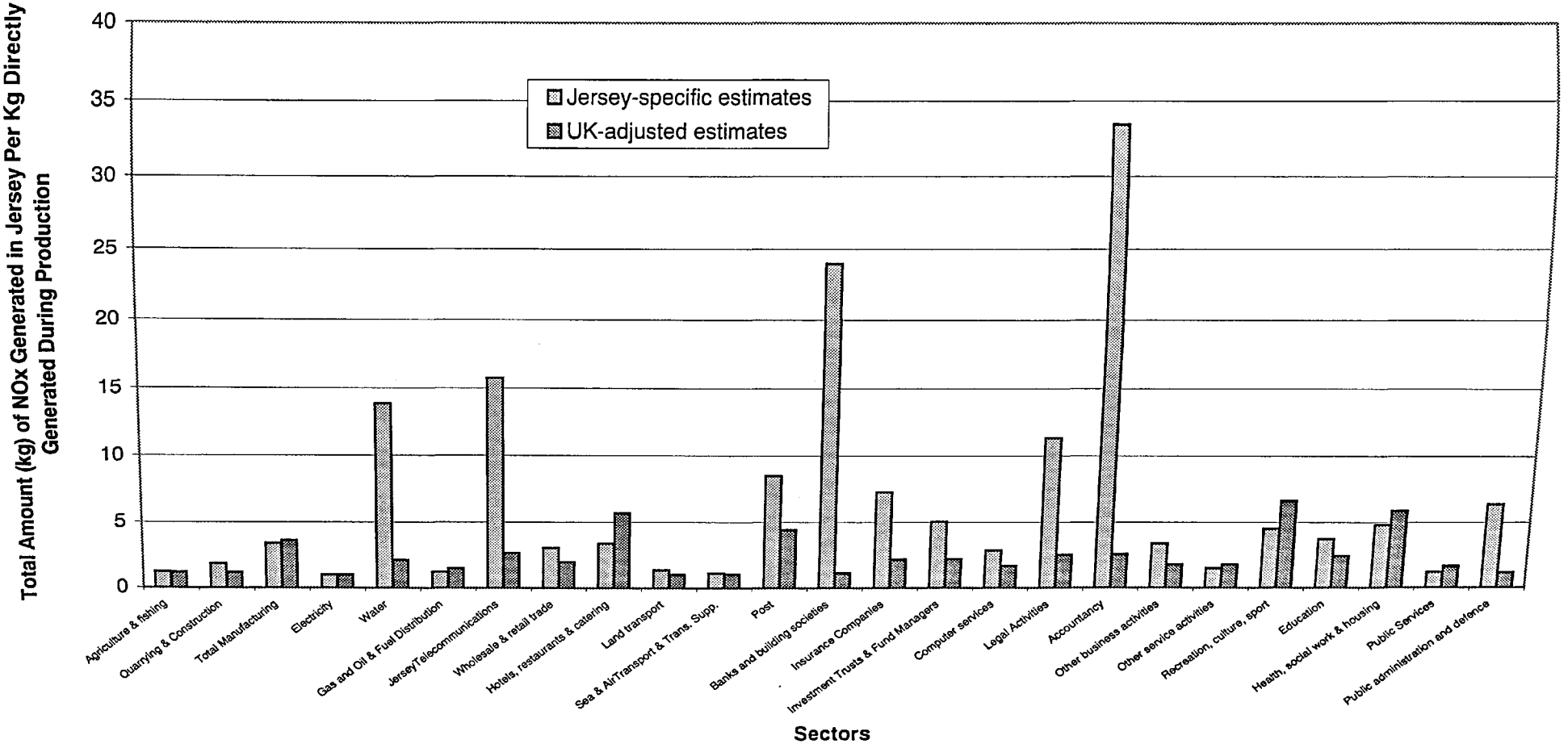
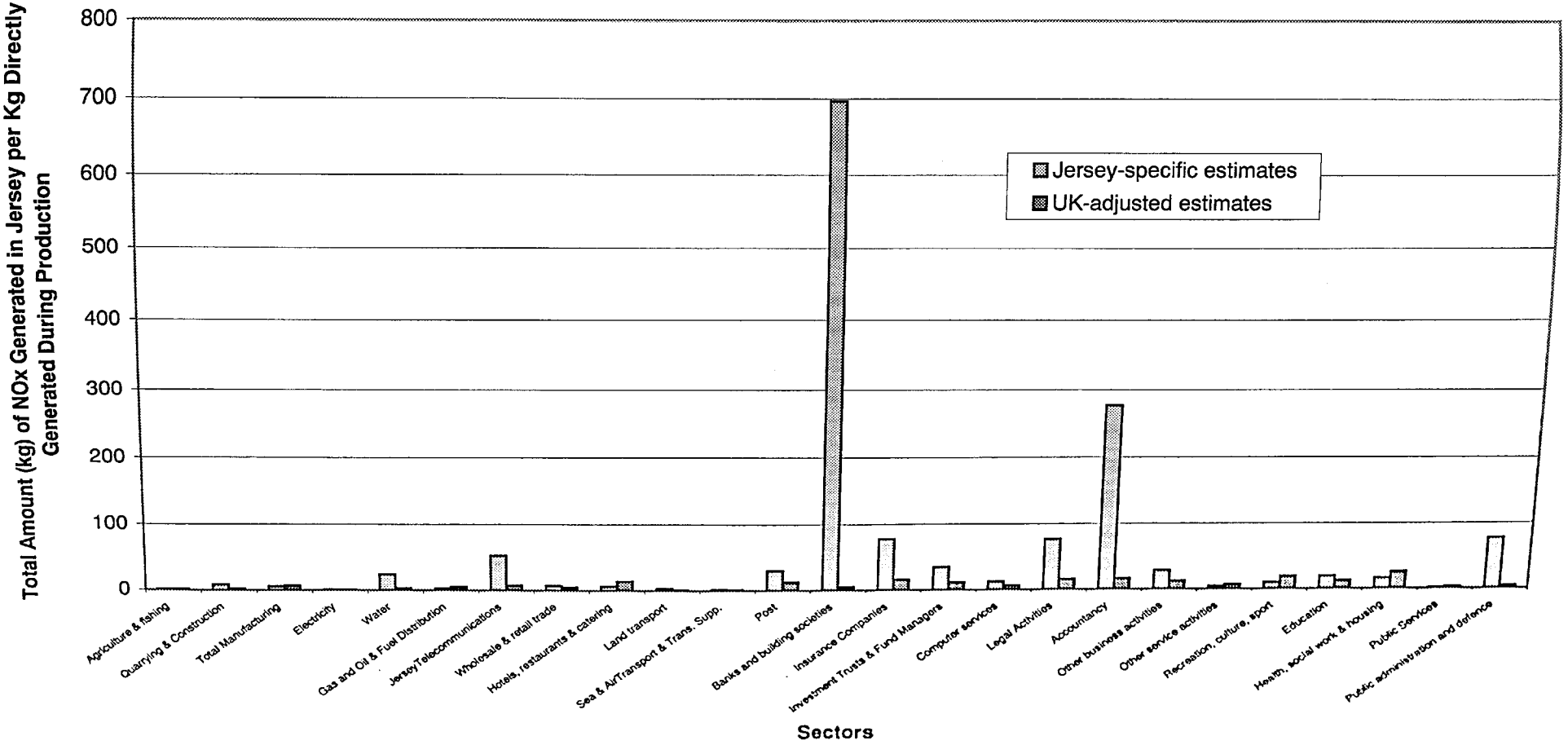


Figure 7B.2 Type II Pollution (NOx) Multipliers - Estimated Using Jersey-Specific And UK-Adjusted Output-Pollution Coefficients



In Figures 7B.1 and 7B.2 I illustrate the extent of the differences between the UK-adjusted and Jersey-specific measures for the Type I and Type II cases respectively for the individual pollutant NO_X.

Note that I do not the output-pollution multipliers themselves in Figures 7B.1 and 7B.2. The output-pollution multipliers state the amount (in kilograms) of pollution generated in the economy per £1million of final demand for sectoral outputs. Instead I report the 'pollution multipliers', which show the amount (in kilograms) of total pollution generated in the economy for each kilogram of pollution directly generated by each sector i (similar to employment or income multipliers). These are defined as $\mathbf{M_{i1}/M_i}$ in the Type I case and $\mathbf{M_{i2}/M_i}$ in the Type II case, and give us an idea of the importance of direct generation relative to the total pollution intensity of each sector.

For example, according to the Jersey-specific measure a sector like 'Banks & Building Societies', which has a relatively low direct NO_X-intensity, has relatively large NO_X pollution multipliers. What the pollution multiplier value tells us is how much of the total amount of NO_X generated to the sector in the base year (1998) is generated by the sector itself or elsewhere in the economy (whether that total is high or low). For example, in the Type I case, Figure 7A.1 tells us for every 24kg of NO_X generated by 'Banks & Building Societies', only 1kg of this is directly generated in the sector itself. The rest is NO_X embodied in goods and services that it buys from other local sectors for use as inputs as to production. This is according to the Jersey-specific measure; however, according to the UK measure, the value of the NO_X multiplier is only 1.18, suggesting that almost all the NO_X generated by 'Banks & Building Societies' is directly generated within the sector itself. In the Type II case (Figure 7A.2) the problem is even more pronounced, with the Jersey-specific measure showing an NO_X multiplier of 696 kilograms of total NO_X emissions being generated by 'Banks & Building Societies' for every 1 kilogram directly generated, while the UK-adjusted figure is only 5.05.

I find that this type of divergence for a number of the sectors, particularly those that belong, along with 'Banks & Building Societies', to the broad 'finance and related

activities' sector of the Jersey economy – 'Insurance Companies', 'Investment Trusts and Fund Managers', 'Legal Activities' and 'Accountancy'. Generally, what Figures 7B.1 and 7B.2 tell us is that the importance attached to direct, indirect and induced effects respectively in explaining the amount of pollution generated in the economy by individual sectors varies markedly depending on whether the Jersey-specific or UK-adjusted measures are used. However, given the importance of financial and related activities in Jersey, I would argue that it is of particular concern that the most significant errors using the UK-adjusted set are found in this area.

In Sections 3.3-3.4 of Chapter 7 I use the Jersey-specific output-pollution multipliers to attribute total pollution in the economy to final demand by commodity (defined by the production sector that sells the commodity to final demand) and by category (defined by the final demand sector that consumes locally produced commodities). Here I report the results of repeating this exercise using the UK-adjusted output-pollution multipliers in place of the Jersey-specific ones.

In Section 3.3 I explain how total emissions attributable to each production sector (or to the commodity it sells to final demand) are estimated by multiplying each sector's vector of (Type I or Type II) output-pollution multipliers by the scalar of total exogenous final demands for its outputs. Using the UK-adjusted output pollution multipliers, equations (7.16) and (7.17) in the main text (Jersey-specific case) are re-expressed to give the estimated amount of pollution attributable to each sector, i, in the Type I and Type II cases respectively:

(7B.2a) $$\mathbf{p_{i1}}^{UK(\vartheta)} = \mathbf{m_{i1}}^{UK(\vartheta)}.c_i$$

(7B.2b) $$\mathbf{p_{i2}}^{UK(\vartheta)} = \mathbf{m_{i2}}^{UK(\vartheta)}.c_{i(-h)}$$

To express the estimated amount of emissions of each pollutant, k, attributable to each sector as a share of total emissions of that pollutant, I divide the results of quantifying (7B.2) for each sector by the estimated vector of total emissions in the

economy, $\mathbf{P}^{UK(\vartheta)}$. (I estimate total emissions using the UK-adjusted measures, $\mathbf{P}^{UK(\vartheta)}$, by equation (6.10) in Section 5 of Chapter 6).

Just as I find in comparing the direct contribution of individual sectors estimated using the UK-adjusted and Jersey-specific measures in Section 5 of Chapter 6 (see Figure 6.2), there are significant differences in results for the Type I and Type II attributions to production sectors/commodities. Taking NO_X as an example once again, note from Figures 7B.3 and 7B.4 that while roughly the same sectors are identified as the main contributors in both cases using the two alternative measures, there are significant variations in the *size* of individual contributions. This is particularly apparent in the Type II case (Figure 7B.4). Both the Jersey-specific and UK-adjusted measures identify 'Banks & Building Societies' as the biggest contributor to total NO_X emissions generated in Jersey when direct, indirect and induced effects are taken into account. However using Jersey-specific measures, 'Banks & Building Societies' is attributed with a share of just under 13%, while the UK-adjusted figure is around 15.5%. Similarly with second biggest contributor, 'Sea & Air Transport and Transport Support', for which the Jersey-specific estimate is 12.1% and the UK-adjusted one is 15.5%.

I find more significant divergences in other key sectors. For example, under the UK-adjusted measure the 'Land Transport' sector is attributed with a share of 4%, while the Jersey-specific figure is only 0.87% (I note Chapter 6, Section 5 that the automotive fuel intensity of the Jersey 'Land Transport' is much lower the UK average). 'Public Services' is attributed with a share of 2.9% using the UK-adjusted measure, but one more than twice as big, 6.4% under the Jersey-specific measure.

On the other hand, in the case of the finance related sectors, with the exception of 'Banks & Building Societies', the shares of total NO_X emissions attributable to production to meet final demand in the Type I and II cases under the two measures are broadly similar. However, the problem is how these shares break down into direct, indirect and induced effects, which, as I explain above, varies radically between the Jersey-specific and UK-adjusted measures.

Figure 7B.3 Type I Attribution To Final Demand By Commodity Using Jersey-Specific and UK-Adjusted Output- And Expenditure-Pollution Coefficients

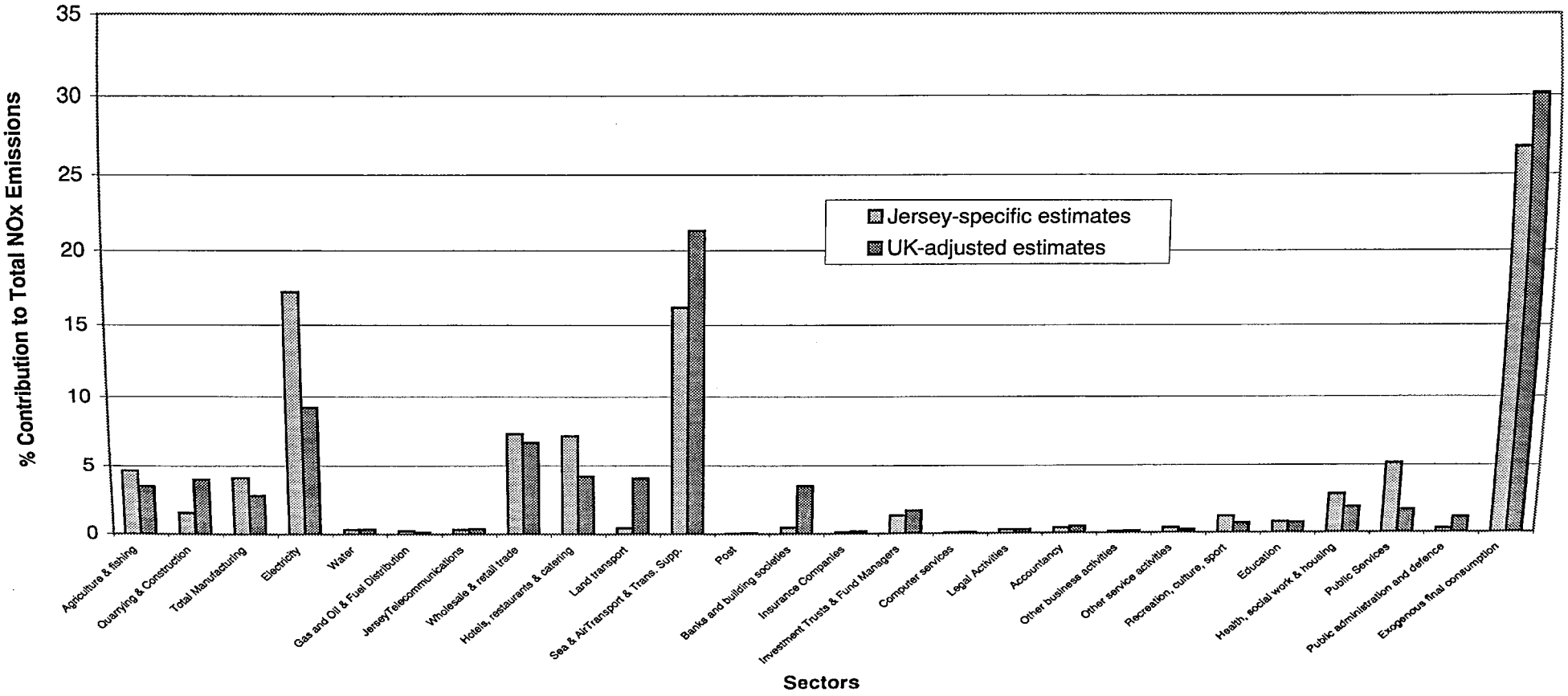
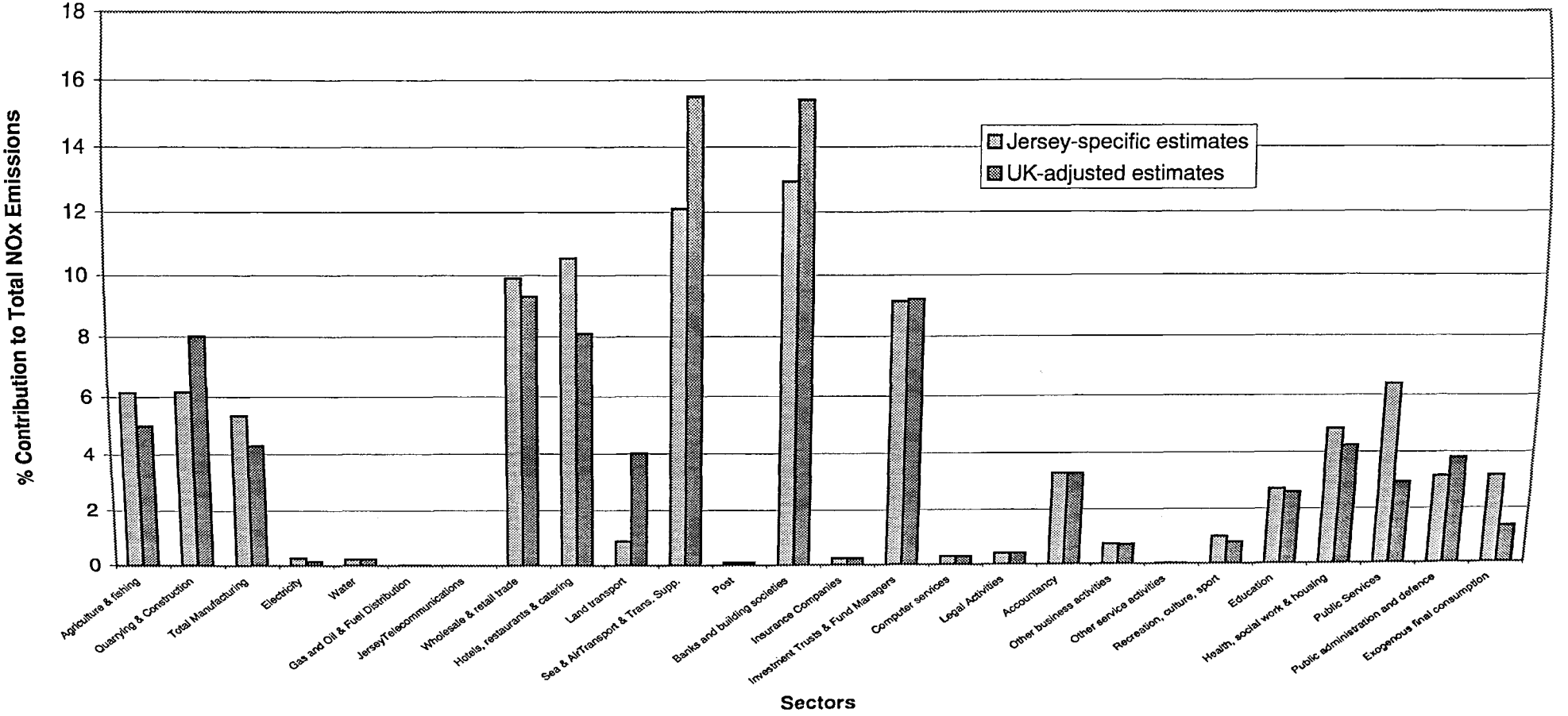


Figure 7B.4 Type II Attribution To Final Demand By Commodity Using Jersey-Specific And UK-Adjusted Output- And Expenditure-Pollution Coefficients



The second type of attribution exercise that I conduct in Chapter 7 (Section 3.4) is attribution of pollution generation to final demand by category, i.e. to the different types of final consumers rather than to the commodities they consume. Using the UK-adjusted output-pollution multipliers, I re-express equations (7.19) and (7.20) from Section 3.4 as

$$\textbf{(7B.3a)} \qquad \mathbf{p_{z1}}^{\mathbf{UK(J)}} = \mathbf{M_{i1}}^{\mathbf{UK(J)}}.(\mathbf{C_i})_z + \mathbf{m_z}^{\mathbf{UK(J)}}.\mathbf{C_z}$$

$$\textbf{(7B.3b)} \qquad \mathbf{p_{z2}}^{\mathbf{UK(J)}} = \mathbf{M_{i2}}^{\mathbf{UK(J)}}.(\mathbf{C_i})_z + \mathbf{m_z}^{\mathbf{UK(J)}}.\mathbf{C_z}$$

Again, I can express the results of estimating equation (7B.3) for each final demand sector in terms of the percentage contribution to total estimated emissions in Jersey, $\mathbf{p}^{\mathbf{UK(J)}}$. I report the estimated contribution of each sector for the pollutant NO_X in the Type I and Type II cases in Figures 7B.5 and 7B.6 respectively. Again there are some fairly significant differences in the share attributable to each final demand sector, part of which relates to the fact that tourists are not attributed with any direct emissions generation under the UK-adjusted measure. For example, when I use the Jersey-specific measures, the share attributable to tourist expenditure is 8.5% in the Type I case and 14.6% in the Type II case, but if I use the UK-adjusted measures these figures are 6% and 11.9% respectively. On the other hand, the share attributable to total (non-tourist) exports is 23.9% in the Type I case and 57.8% in the Type II case under the Jersey-specific measures, compared to 29.7% and 62.3% under the UK-adjusted measure.

Generally, however, the differences here do appear less significant than I find in the attribution to final demand by commodity. However the danger is that the problems that I identify above with respect to *how* emissions are attributable to individual sectors may not be apparent if we were to simply look at final results of the type presented in Figures 7B.5 and 7B.6. That is to say, these results (which are the type commonly presented in reporting this type of analysis) do not reflect the extent of direct relative to indirect and induced pollution generation embodied in the commodities that are consumed by these final demand sectors.

Figure 7B.5 Type I Attribution to Final Demand by Category Using Jersey-Specific And UK-Adjusted Output- and Expenditure-Pollution Coefficients

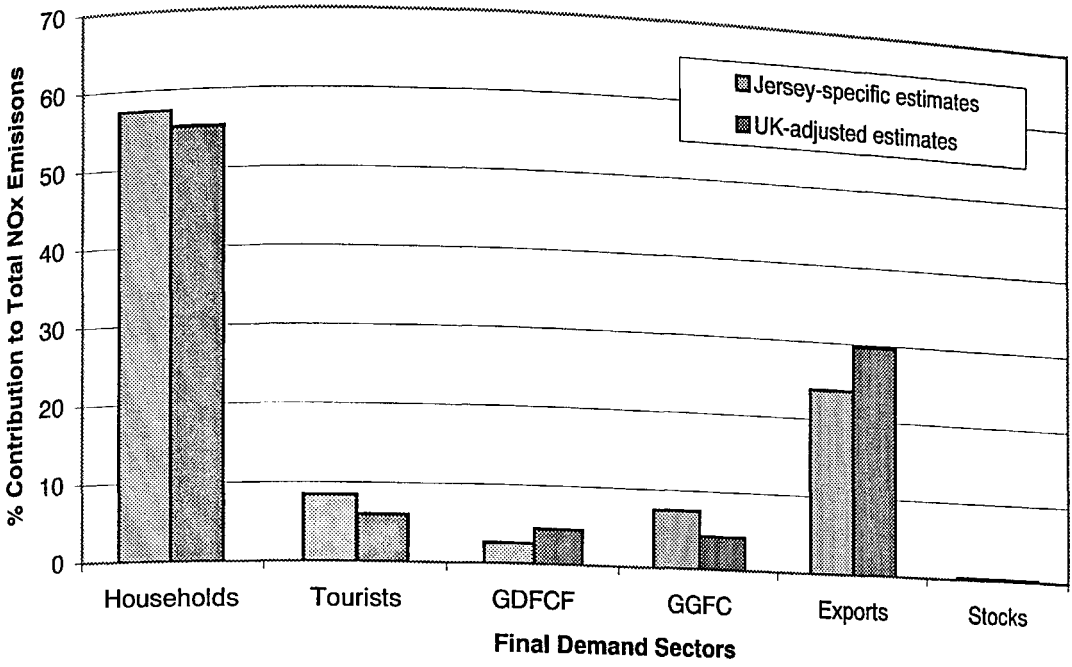
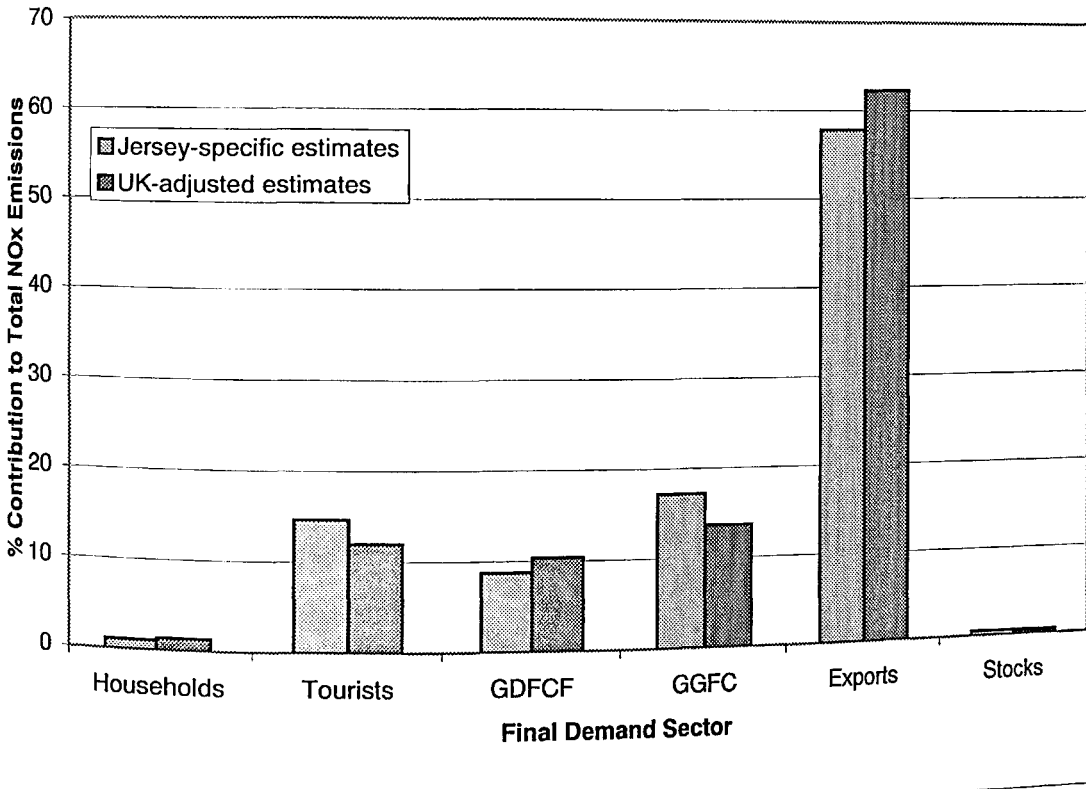


Figure 7B.6 Type II Attribution To Final Demand By Category Using Jersey-Specific and UK-Adjusted Output- And Expenditure-Pollution Coefficients



APPENDIX 8A. SECTORS (ACTIVITIES/COMMODITIES) IDENTIFIED IN JEMENVI

No	Sector	Jersey/UK Standard Industrial Classification (JSIC 1995, UK SIC 1992)
1	Agriculture & Fishing	01, 05
2	Quarrying & Construction	14, 45
3	Manufacturing	15 – 18, 20, 22, 25-26, 28-31, 33,35, 37
4	Electricity	40.1
5	Water	41
6	Gas, Oil and Fuel Distribution	40.2,50.50,52.48
7	Telecommunications	64.2
8	Wholesale and Retail Distribution	50 – 52
9	Hotels & Restaurants	55
10	Land Transport	60.2, 60.3
11	Sea & Air Transport and Transport Support	61, 62, 63
12	Post	64.1
13	Banks & Building Societies	65.121, 65.121, 65.21, 65.22, 65.233, 65.234, 65.235 & 65.236
14	Insurance Companies	66
15	Investment Trusts & Fund Managers	65.231, 65.232, 67
16	Computer Services	72
17	Legal Activities	74.11
18	Accountancy	74.12
19	Other Business Activities	70, 71, 73, 74.13 - 74.8
20	Other Service Activities	91, 93
21	Recreation, Culture & Sport	92
22	Education	80
23	Health, Social Work & Housing	85
24	Public Services (Sewage & Refuge Disposal)	90
25	Public Admin. & Defence	75

APPENDIX 9A. Aggregate Sectors Identified for General Population Policy Modelling for the States of Jersey

AGGREGATE SECTORS	JEMENVI SECTORS
AgricFish	Agriculture & Fishing
Construction	Quarrying & Construction
Manufactures	Total Manufacturing
Services	Electricity Water Gas, Oil & Fuel Distribution Jersey Telecommunications Wholesale & Retail Trade Land Transport Sea & Air Transport & Transport Support Post Other Services Activities Recreation, Culture & Sport
Tourism	Hotels Restaurants & Catering
Finance ('Financial and Other Business Services')	Banks & Building Societies Insurance Companies Investment Trusts & Fund Managers Computer Services Legal Activities Accountancy Other Business Activities
GovSec	Education Health & Social Work & Housing Public Services Public Administration & Defence