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Report to the Scottish Environment Protection Agency (SEPA)

The evaluation of National Accounting with Environmental Accounts (NAMEA) as a methodology for carrying out a sustainability assessment of the Scottish food and drink sector

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Executive Summary

This report introduces environmental input-output (IO) accounts for Scotland as an example of a NAMEA framework. It provides an introduction to the use of basic IO multiplier methodology, which can be applied to examine pollution/waste generation and/or resource use under production and consumption accounting principles. The report illustrates how environmental IO multiplier allows us to do several things:

1. Identify 'hot spots' in the supply chain for each Scottish production sector. A 25 sector illustrative analysis using experimental data and focusing on key food and drink production sectors suggests this may be the key feature in terms of sustainability assessment of the food and drink sector (given that it may not be possible/desirable to change overall consumption levels)

2. To further investigate the structure of pollution/resource use problems in the accounting year the NAMEA applies to, by attributing total emissions/use to final consumption by types of commodity and/or consumer. This is the basis for footprint analysis under consumption accounting principles

3. To generate a range of multipliers that may be use to communicate key elements of pollution generation and/or resource use problems. For example production output-pollution multipliers, final expenditure-pollution multipliers.

4. To use multipliers for impact analysis/'what if scenarios'. However, caution is advised as very restrictive assumptions are required to use IO for this type of analysis may lead to overestimation of impacts of any disturbance.

The concluding message in the report is the need to use and further develop the current Scottish environmental IO framework which is a necessary requirement for sectoral sustainability assessments for Scotland. Scotland has a strong foundation in the type of data required, with regular publication of analytical IO tables describing the structure of the economy in any given year,

and with data forthcoming to augment this accounting framework for environmental analysis. In this respect, Scotland is well-placed to play a leading role in the UK in developing a sustainability assessment framework based on IO methods. Indeed, given the level of interdependence of the UK regional and national economies, in terms of policy and economic activity and also statistical capacity, it is important that Scotland plays such a role, rather than using its strengths to take a distinctive approach. It is also important that the policy, research and other interested parties in the wider community both within Scotland and elsewhere in the UK and EU, interact to determine specific analytical requirements and policy in developing an environmental IO accounting capacity.

To this end, the current report goes on to consider the extent to which current developments of the Scottish IO framework by Scottish Government will facilitate a sustainability assessment of the Scottish food and drink sector. In terms of current and/or forthcoming data for a single region Scottish analysis, the main concern for such an analysis is likely to be overaggregation of key food and drink supply sectors, the limited set of pollutants and resource uses to be included in the forthcoming sectoral environmental accounts, and lack of information for 'social' aspects of a sustainability analysis. These are practical problems for Scotland and this report recommends that specific requirements for a sustainability assessment of the Scottish food and drink sector using the NAMEA/environmental IO approach be clearly established and communicated to data providers at Scottish Government.

A more basic problem for IO is the time lag in producing IO tables (generally at least 2 years). Because of the sectoral detail in IO accounts, this is a problem that cannot be resolved and must be weighted against the benefits of having access to such a detailed information set for sustainability analysis (there is no alternative that would facilitate the type of detailed sectoral analysis possible in IO). As noted above, his report draws attention to the fact that Scotland is in a unique position in the UK in terms of the availability of high quality economic and (soon to be available) environmental data in the analytical format required for the multiplier analysis required for accounting for pollution/waste and/or resource use from the consumption accounting perspective that is gaining such prominence in public and policy debate. Moreover, the report highlights the fact that NAMEA accounting and environmental IO multiplier analysis have become the accepted methods in the academic literature of accounting for pollution/waste and/or resource use, which suggests that adopting this approach will permit Scotland to move towards consistency with other countries.

However, the report also considers the limitations of the type of single region environmental IO analysis that a NAMEA framework of the type currently being developed for Scotland can be used for. In terms of environmental accounting from a consumption perspective, two important implications/limitations of single region environmental IO analysis are identified:

1. A share of emissions is allocated to external (export) demand.
2. No account is taken of emissions embodied in imports.

A crucial issue impacting on unilateral attempts to fulfil national emissions reductions targets under the Kyoto Protocol is the impact of interregional/international trade on any one region/country's domestic emissions generation. In order to address this issue, the single region environmental framework must be extended to take account of trade flows. The report provides an illustrative analysis for Scotland and the rest of the UK and considers how extensions may be made to take account of trade with the rest of the world. Work is currently underway under the author's ESRC Climate Change Leadership Fellow project to improve (with more sectoral disaggregation and pollutants accounted for) and to update this framework to 2004.

Finally, in terms of responding to the limitations of IO techniques for simulating the impacts of potential *changes* in activity, the report considers the use of environmental IO/NAMEA databases to inform more flexible and theory consistent computable general equilibrium models. This is also a development that is currently underway for Scotland and the Rest of the UK under the author's ESRC Climate Change Leadership Fellows project.

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1. Introduction to the NAMEA approach

The most basic issue for economic-environmental accounting and analysis is that it is not sufficient to establish regular reporting of both economic and environmental data. If there is a need to determine and monitor the impact of the economy on the environment it is necessary to ensure that economic and environmental data are gathered and reported in a consistent format. For this reason the statistical office of the European Union (Eurostat) launched a project just over a decade ago to promote the construction of what are referred to as NAMEA accounts in all EU member states. NAMEA is an acronym for National Accounting Matrix including Environmental Accounts. The earliest work by the research community on the NAMEA approach was reported in a special issue of the journal *Structural Change and Economic Dynamics* titled 'Environmental extensions of national accounts: the NAMEA framework' (see Keuning and Steenge, 1999).

A NAMEA database (see, for example, Keuning et al, 1999; Vaze, 1999; Haan, 2001) provides an integrated set of economic and environmental accounts. The economic accounts are the national accounts in input-output (IO) or social accounting matrix (SAM) format and are presented in monetary units. Under the United Nations System of National Accounts (SNA), IO tables are recommended as the appropriate format for reporting economic activity. IO tables report interactions between each production sector and final consumption group in a given time period (usually a calendar year). They are an example of single entry book-keeping, with each entry along each row a sale from one (local intermediate or primary, or external) production source to one intermediate or final consumer, and each entry down each column a purchase from one intermediate or final consumer from one production source. For example, Table 1 (next page) is a 3 sector aggregation of the 128 sector Scottish analytical IO tables for 1999 (Scottish Executive, 2002).[1]

[1] Table 1 is a highly aggregated IO table, constructed for simplicity of exposition at this early stage of the report. The 128 sectors identified in the Scottish IO tables can be found in Appendix 2. The 3-sector aggregation in Table 1 follows that used in Gilmartin et al's (2008) interregional CGE model for Scotland and the rest of the UK and is detailed in Appendix 6.

Table 1. 1999 Scottish Analytical Input-Output Table - Aggregated to 3-sector industry-by-industry (£ million) - augmented with environmental data to give a Scottish NAMEA for 1999

	Purchases by Sector Group (at basic prices):				Final consumption expenditure:						
					LOCAL EXPENDITURES		CAPITAL FORMATION		EXTERNAL EXPENDITURES		
	PRIMARY, MFR AND CONSTRUCTION	**ELEC, GAS & WATER SUPPLY**	**SERVICES**	**Sales to intermediate demand**	**Households**	**General Government Final Consumption**	**Gross Domestic Fixed Capital Formation**	**Change in Inventories**	**Exports to RUK**	**Exports to ROW**	**Total Final Demand**
Sales by Sector group (at basic prices):											
PRIMARY, MFR and CONSTRUCTION	7,706	540	5,657	13,903	1,415	1	5,488	77	12,588	19,000	38,569
ELEC, GAS & WATER SUPPLY	484	981	1,018	2,482	1,266	0	0	0	1,296	1	2,563
SERVICES	7,785	1,000	20,002	28,787	21,479	17,978	981	86	10,259	4,152	54,936
Total Intermediate Inputs	15,975	2,520	26,678	45,172	24,160	17,979	6,470	163	24,143	23,154	96,068
Imports from RUK	9,788	662	8,414	18,864	9,784	0	2,663	55	279	630	13,410
Imports from ROW	7,904	83	1,745	9,731	7,227	0	1,488	13	76	173	8,977
Net product & production taxes	1,671	272	2,906	4,849	2,941	83	572	5	1,162	458	5,221
Income from Employment	11,059	563	28,793	40,415	0	0	0	0	0	0	0
Other Value Added	6,075	945	15,189	22,209	0	0	0	0	0	0	0
Total Primary Inputs	36,497	2,525	57,046	96,068	19,952	83	4,723	73	1,517	1,260	27,609
TOTAL INPUTS	52,472	5,045	83,723	141,241	44,113	18,063	11,192	236	25,660	24,414	123,677
Additional economic variables (example):											
Employment (full-time equivalent)	346,144	1,109,426	573,930	2,029,500							
Additional environmental variables (example):											
CO_2 emissions (tonnes)	12,386,851	16,252,992	9,579,250	38,219,094	10,684,909						

The IO table is easy to read. For example, from Table 1 we can see that in 1999 the Scottish 'Electricity, Gas and Water Supply' produced total output of the value of £5,045million (row total), which, in the symmetric analytical IO table[2], £2,563m of this to meet final demand (e.g. £1,266m sold to Scottish households), and £2,482m to meet intermediate demand from Scottish producers (e.g. £1,018m used as input to production in the Scottish 'Services' sector). One of the main accounting applications of the basic IO table as shown in Table 1 is to report the sectoral composition of GDP. GDP at basic prices is given by the sum of 'income from employment' and 'other value-added' in each production sector. For example, GDP generated in the Scottish 'Services' sector is given by payments to these items (or to total value-added): £28,793m + £15,189m = £43,982m. Total Scottish GDP (at basic prices) for 1999 is given by summing across payments to value added in all the production sectors, or read from the total payments to 'income from employment' and 'other value-added' final column of Table 1: £40,415m + £22,209m = £62,624m. To convert to GDP at market (or purchaser) prices, we would add the element of the 'net product and production taxes' entry in each column that applies to taxes on products (these are separated in the original, pre-aggregated, Scottish IO tables). Annual IO tables are usually reported in current prices so we have current price GDP. To convert to constant price GDP (for time series comparisons), the GDP deflator, indexed to the required base year, would have to be applied to the current price GDP data extracted from the IO table for each year, or a constant price series of IO tables constructed (this is problematic due to the range of prices involved).

We can also read off the value of total capital formation in the Scottish economy in the year that the tables related to, here 1999, by reading down the Gross Domestic Fixed Capital Formation and Change in Inventories columns. These are net flows to capital (e.g. in 1999 £5,488m of output produced in the 'Primary, Manufacturing and Construction' sector was used in the formation of fixed capital (almost 92% of this entry comes from the component entry for sector 88 Construction – see Appendices 2 and 6 for composition of the 'Primary, Manufacturing and Construction' sector

[2] IO tables are produced in other formats, e.g. Supply and Use Tables (SUT), which are reported in purchaser rather than basic (producer) prices. The analytical tables, which are symmetric and reported in basic prices, are required for analytical purposes (multiplier and modelling analyses). The Scottish Government produces annual tables in both of the above formats. At the UK level, on the other hand, only SUT are produced annually, with the last set of analytical tables reported for 1995. Either type of table can be used for a basic NAMEA. However, if any analytical work, such as generation of multipliers for pollution accounting under consumption accounting principles (see below), symmetric tables are required.

in Table 1). IO tables are flow accounts and not useful for recording stock variables. Moreover, they do not record investment demand (i.e. which sectors, consumers require this output for capital formation purposes from the ‘Primary, Manufacturing and Construction’ sector).

It is common to augment the basic IO tables with information on other variables for each sector. For example, one of the additional variables reported at the bottom of Table 1 is employment (reported in full-time equivalents rather than per head) in each production sector. Sectoral employment is reported alongside the Scottish IO tables as standard: this allows the construction of useful analytical tools such as ‘employment multipliers’ (see Section 2), which allow us to examine which activities ultimately support Scottish jobs, and for impact analysis to examine the potential change in employment if activity levels change due to policy interactions or other disturbances.

However, it has become increasingly common to augment the IO tables with information on outputs of pollution, physical or hazardous waste etc, and/or inputs of physical resources, such as energy or water, from/to different production and consumption activities and this is what gives us a NAMEA. Environmental data are reported in physical units and present information on material/physical inputs of natural resources (particularly, but not limited to, energy or water resources) used in each activity and/or outputs of residuals (different types of pollutants and/or other waste materials) generated by activity at a level of sectoral detail consistent with the economic accounts. For example, in the last row of Table 1, the direct generation of CO2 emissions (as carbon, not equivalents) in each production sector and final consumption activity is reported (households are the only final consumer that directly pollutes; emissions generation in public sector activities will be reported for public sector production activities – e.g. sectors 115-121 in Appendix 2, which are aggregated within the ‘Services’ sector in Table 1 – rather than final consumption by government). It would also be useful to break down these emissions by source – e.g. emissions from different types of energy use distinguished from emissions from polluting production process, e.g. manufacture of cement – and to report resource use variables, such as physical use of energy or water in each sector and final consumption activity.[3] In the illustrative

[3] The value of energy sales and purchases in the Scottish economy are captured within the economic IO table – e.g. the ‘production and distribution of electricity’ is sector 85 in the 128 sector IO classification in Appendix 2 – though

environmental IO analysis in Section 5 we do employ estimated data on physical energy use per sector, thereby using a fuller, albeit experimental, NAMEA database for Scotland. At this stage, for illustrative purposes, we only report CO2; however, note that current plans by Scottish Government to augment the Scottish IO tables in a first formal Scottish NAMEA do appear to only involve reporting of greenhouse gases and acid rain precursors (as in the UK economic-environmental accounts) and not their sources, though no official details are yet available (see Section 4 below). Nor are there any plans at present to report for other pollutants or waste products, or physical water use relating to the value of activity in the 'Collection, Purification and Distribution of Water' sector in the Scottish IO tables (IOC 87 in Appendix 2. The project underlying the research reported in Allan et al (2007a) did attempt to determine physical waste production (and disposal) for an aggregated Scottish IO table. This involved allocating waste generation data to the SIC/IOC classified activities and final consumption groups identified in the Scottish IO tables. However, there has been no attempt to extend and formalise physical waste accounting in the Scottish national accounting framework.

Thus, Table 1 gives us a (highly aggregated) example of a NAMEA for Scotland. This simply involves augmenting the existing (and annually reported) Scottish economic IO tables for a given year with physical data on 'environmental' variables such as emissions (and/or energy use) directly generated in (used by) each production sector and final consumption group in that year.

However, there are two extensions that we should consider at this point. First, we can examine the structure of pollution and energy use in the Scottish economy by examining indirect and induced emissions generation (i.e. how demand patterns and intersectoral linkages drive pollution generation in the production sectors of the economy) and/or energy use. This is done by taking the analytical IO table in Table 1 and applying simple mathematical routines to construct multiplier matrices. This is a common development of IO accounts, for example, the Scottish Government report as routine output and employment multipliers alongside the basic IO accounts (see, for example, Scottish Executive, 2002). In terms of environmental IO applications, the methodology is

energy supply activities are generally over-aggregated in IO tables, e.g. see sector 86 in Appendix 2, a point we return to below in Section 4 of this report. The 'collection, purification and distribution' of water, on the other hand, is identified as a single IOC sector in the Scottish IO listing in Appendix 2 (IOC 87).

again standardized (and mirrors economic multiplier analysis), originally established in the economic literature by Leontief (1970), and applied to the UK by Vaze (1997) and to Scotland for greenhouse gas emissions by McGregor et al (2001) and for physical waste generation (and disposal) by Allan et al (2007a). We return to this first extension in the next section of the report.

Second, the economic IO table can be extended with information on income transfers between aggregated transactors to report a social accounting matrix (SAM). This may be more informative for sustainability analysis, which often involves analysis of social rather than just economic and environmental variables. However, the environmental reporting will generally remain the same – i.e. for each production sector and final consumption group. See, for example, Table 2 below, where we extend the IO table in Table 1 to take account of income transfers.

However, we may wish to relate the additional NAMEA variables to other variables in the economic accounts (e.g. emissions of greenhouse gases in each sector/activity to purchases from energy supply sectors, if we are able to identify these, or, if we incorporate social variables – see Section 4.2 below – we may wish to report things like nutrition indicators to government payments to households etc). We return to such issues below. At this stage, the main point to note is that a SAM can also be used for the type of multiplier analysis outlined in Section 2 (and will generally be used in place of the IO for more sophisticated modeling applications such as the CGE analysis discussed in Section 6.3). Different final consumption (but not production sector) multiplier values will be generated from IO and SAM accounts for any given economy in any given year (e.g. the Scottish accounts for 1999 in Tables 1 and 2). This is due to the additional variables reported in the SAM for each type of final consumer (income transfers).

Table 2. 1999 Scottish SAM - Aggregated to 3-sector industry-by-industry (£ million) - augmented with environmental data to give a Scottish NAMEA for 1999

(Addional/extended accounts and additional data points relative to 10 highlighted)

	PRIMARY, MFR AND CONSTRUCTION	ELEC, GAS & WATER SUPPLY	SERVICES	Households	Aggregate Production	Government	Capital	Stocks	RUK	ROW	Labour	Other Value Added	Net. P&P Tax	Total Income/output
PRIMARY, MFR and CONSTRUCTI	7706	540	5657	1415	0	1	5488	77	12588	19000	0	0	0	**52472**
ELEC, GAS & WATER SUPPLY	484	981	1018	1266	0	0	0	0	1296	1	0	0	0	**5045**
SERVICES	7785	1000	20002	21479	0	17978	981	86	10259	4152	0	0	0	**83723**
RUK (total)	9788	662	8414	9784	3331	0	2663	55	279	630	0	0	0	**35606**
Goods and Services	9788	662	8414	9784	0	0	2663	55	279	630	0	0	0	**32275**
Transfers	0	0	0	0	3331	0	0	0	0	0	0	0	0	**3331**
ROW (total)	7904	83	1745	7227	7773	0	1488	13	76	173	0	0	0	**26482**
Goods and Services	7904	83	1745	7227	0	0	1488	13	76	173	0	0	0	**18708**
Transfers	0	0	0	0	7773	0	0	0	0	0	0	0	0	**7773**
Taxes on products and production	1671	272	2905	2941	0	83	572	5	1162	458	0	0	0	**10070**
Income from Employment	11059	563	28793	0	0	0	0	0	0	0	0	0	0	**40415**
Other Value Added	6075	945	15189	0	0	0	0	0	0	0	0	0	0	**22209**
Households	0	0	0	0	14016	10957	0	0	1111	1299	40415	3413	0	**71211**
Aggregate Production	0	0	0	10326	0	828	0	0	3243	3243	0	17263	0	**34903**
Government	0	0	0	13350	5550	0	0	0	78	0	0	1533	10070	**30581**
Capital	0	0	0	3422	4232	733	0	0	5514	-2474	0	0	0	**11428**
Total expenditure/inputs	**52472**	**5045**	**83723**	**71211**	**34903**	**30581**	**11192**	**236**	**35606**	**26482**	**40415**	**22209**	**10070**	**424145**
Additional economic variables (example):														
Employment (full-time equivalent)	346,144	1,109,426	573,930											**2,029,500**
Additional environmental variables (example):														
CO_2 emissions (tonnes)	12,386,851	16,252,992	9,579,250	10,684,909										**48,904,002**

2. Application of environmental IO methodology to sustainability analysis

2.1 Introduction to environmental IO methodology

The basic NAMEA accounts in the format illustrated in Tables 1 and 2 provide us with a very valuable dataset that can be used for a variety of analyses. Given that the IO accounts include detailed information on all production sectors and final consumption activities in the economy, as with the example of GDP given above, it is possible to simply extract information from the environmental IO (or SAM) accounts to carry out a wide range of analyses. For example, information on physical resources such as energy and/or water use, total material intermediate input use and primary input use (capital and labour) and on sectoral outputs could be used (along with information on resource prices) to estimate production functions. Alternatively, or in addition, the economy-wide database can be used as the core database for general equilibrium analysis.

The simplest general equilibrium analytical technique is input-output analysis. Given that the NAMEA is basically an environmental IO accounting framework, we can use it to carry out structural analysis of pollution, waste or natural resource use problems in the economy, using what are known as multipliers to attribute responsibility for the generation of pollutant/waste products and/or physical resource use to different types of final consumption activities for the accounting period that the IO accounts are constructed for. As noted above, it is common to apply simple mathematical (matrix algebra) routines to IO tables in order to generate a range of multipliers, which tell us the level of different types of activity throughout the economy and/or at the sectoral level (e.g. production of output, employment, GDP generation) that are ultimately supported by one monetary unit of (different types of) final consumption activity in the accounting period that the tables relate to. Also as noted above, the Scottish Government routinely produce output and employment multiplier data and they regularly use these to estimate the impacts of policy instruments and economic disturbances that may or have been employed or occurred. As explained in Sections 2.3 and 6, as with any analytical technique, assumptions are involved in using IO for this type of purpose and these will impact on the results obtained. However, as long as these assumptions and their implications are made clear, IO multiplier analyses constitute one of the most straightforward, transparent and rigorous approaches to analyzing interactions between sectors of the economy and between the economy and the environment.

The basic environmental IO method was first proposed by Leontief (1970) and is largely unchanged today (and the basic method would be essentially unchanged if applied to a SAM rather than an IO database). Leontief's (1970) initial focus was on the cost of internalizing negative externalities through the identification of pollution as an additional output of production and consumption and of a cleaning sector that removes pollution from the system. However, the data requirements of constructing his full model – particularly in terms of identifying cleaning/pollution removal activities - have largely prohibited its development (see Allan et al, 2007a, for a fuller discussion and attempted application for the case of waste generation and disposal for Scotland). Instead, environmental IO applications have focused on augmenting the economic accounts with information on emissions directly generated in each production sector and final consumption activity and using multiplier analysis to attribute these emissions to different types of final demand (by type of consumer and/or type of commodity consumed).

In this section, the environmental IO attribution/multiplier method is outlined (with a more technical/formal exposition provided in Appendix 1), with particular attention to how this method can be applied to analyse particular sectors instead of/as well as the economy as a whole. This is followed in Section 3 with a review of how the method has been applied elsewhere and in Section 5 with an illustrative empirical analysis for Scotland (using limited existing data; Section 4 outlines past, current and potential future developments of the Scottish IO framework for economy-environment analyses).

2.2 IO attribution analysis – consumption and production accounting principles

The 3-sector Scottish IO table for 1999 is an example of an analytical IO table. All entries are reported in basic or producer (factory gate) prices and the table is symmetric: the column total for each of the production sectors (total inputs) equals the row total (total output) for each sector. Total sales to intermediate demand (the sum of the three rows in the top left hand quadrant) also equals total intermediate input demand (the sum of the three columns in the top left hand quadrant). In terms of final demands, note that total final demand (the total of the second last column) equals total non-intermediate (primary input) demand (the total of the second last row). Overall, total inputs equal total outputs. These are the main balancing identities of an analytical IO table, which we can use for multiplier or attribution analysis.

The first thing that we can do with an environmental IO table is to calculate direct emissions generation under the production accounting principle. This has already been done in the NAMEA in Table 1, where we have direct emissions generated in each production sector and by households at the bottom of their respective columns. However, in analytical IO we generally work with input-output relationships – i.e. the amount of X required per unit of output (or expenditure in the case of final consumption). For example, the (aggregated) 'Primary, Manufacturing and Construction' sector directly generates 12,386,851 tonnes of CO2 and its total input/output is £52,472million.[4] This means that (in our accounting year of 1999) this sector directly generated 236 tonnes of CO2 per monetary unit of output (£1million) produced. Table 3 shows the equivalent calculation (CO2 emissions divided by total output/expenditure) for each of the production sectors and final consumption groups that directly generate CO2 emissions:

Table 3. Direct CO2 intensities/output-CO2 coefficients

	PRIMARY, MFR AND CONSTRUCTION	ELEC, GAS & WATER SUPPLY	SERVICES	Housholds (per unit expenditure)
CO2 (tonnes) per unit of output (£million)	236	3222	114	242

This allows us to compare the direct CO2 intensity of different activities (here we can see that, as would be expected, energy supply activities are the most directly CO2 intensive, and that service provision is the least CO2 intensive). If we then take these intensities (generally referred to in IO analysis as pollution coefficients – i.e. pollution per unit of output/expenditure) and multiply them against our total outputs (row or column totals) for each production sector, or total expenditure (column total) for households (household output in IO terms is value added from provision of labour services, so we could alternatively define the household coefficient in terms of the 'income from

[4] All of the illustrative analyses in this report take the example of CO2 as a polluting by-product of economic activity. This is due to the availability of the experimental sectoral CO2 account/NAMEA produced by Turner (2003). However, it is important to note that the environmental IO method outlined here can be applied to any type of pollutant/waste output and/or physical resource use by the producers and consumers identified in the IO tables.

employment row total), we recreate our base year data in terms of total emissions generated in 1999 in each polluting activity. This gives us total CO_2 emissions generated in Scotland in 1999 under what Munksgaard and Pedersen (2001) term the production accounting principle. This is what we are interested in under, for example, the Kyoto Protocol. If technology were to change such that the CO_2 intensity in any activity fell for a given level of output/expenditure, we can recalculate emissions under the production accounting principle by applying the revised CO_2 coefficients (although we would probably want to model the wider impacts of technological change as this is likely to affect activity levels; at this stage we focus on accounting).

However, the argument underlying the 'consumption accounting principle' and the growing interest in measures such as carbon footprints is that producers only pollute because human consumption activities create demand their outputs. The application of IO techniques to accounting for emissions under the consumption accounting principle (see Wiedmann et al, 2007, for a review) is a natural extension because in an analytical IO framework all activity is driven by final demand. The top right hand quadrant of Table 1 reports local and external final consumption demands for the outputs of Scottish production sectors. The first three entries in the last column of Table 1 give us total final demand for each sector's output. An accounting identity of the analytical IO framework is that total emissions directly generated in each Scottish production sector (and all other variables, such as sectoral output and employment), and in Scottish production as a whole, in the accounting period that the IO table applies to (here, 1999), can be entirely attributed to these final demands. That is, all production activities in Scotland (and associated generation of pollution), are ultimately driven by final demands. Appendix 1 provides a formal exposition of the attribution of activities to final consumption demand. A more intuitive explanation is attempted here.

The reasoning underlying IO attribution analysis is that in order to produce output to meet final demand, each production sector requires inputs from other sectors of the economy (as well as primary inputs – capital and labour – and imports). Therefore, there is a *multiplier effect* as production to meet one unit of final demand for output in each sector, i, requires the production of output in all other sectors (including the household sector if we want to examine the effects of employment to produce output) so that there are indirect (and induced) demands for output in all areas of the economy for each unit of direct demand for the output of any one sector of the economy.

The first step in attempting to quantify these indirect (and/or induced) effects in any IO analysis is to identify input requirements from other sectors for each unit of output in each sector (here we focus on indirect effects in what is referred to as a Type I analysis).[5] The top left hand quadrant of Table 1 shows us the value of intersectoral transactions in the accounting period of 1999. Therefore, our first step is to convert this into a matrix of input-output coefficients. Each element of this matrix will tell us the input from each sector j required per unit of output in sector i. For example, the first entry in Table 4 below, 0.147, is equal to the first entry in Table 1, showing the intrasectoral purchases from the Primary, Manufacturing Construction sector to itself, £7,706million, divided by total inputs to the Primary, Manufacturing Construction sector, £52,472million (column total). This gives us the input requirement per unit (£1million) of sectoral output.

Table 4. Matrix of intermediate input-output coefficients

	PRIMARY, MFR AND CONSTRUCTION	ELEC, GAS & WATER SUPPLY	SERVICES
PRIMARY, MFR and CONSTRUCTION	0.147	0.107	0.068
ELEC, GAS & WATER SUPPLY	0.009	0.194	0.012
SERVICES	0.148	0.198	0.239

With some mathematical manipulation - see Appendix 1 – we use this to calculate a corresponding matrix of output multipliers, shown in Table 5 below. Basically what we have here is a conversion of the data in order to state the input requirements in Table 4 in terms of one unit (£1million) of final demand for the output of each sector, rather than one unit of gross output (as in Table 4). This means we do not attribute pollution generation to meet intermediate demand by other production sectors to the commodity produced by sector i. Instead we focus on attribution to *final* consumption. If we read down the column of Table 5 for each sector, we have the total value of output required in each and every sector of the economy in order to meet £1million of final demand

[5] A Type II analysis would involve (partially or wholly) moving households from the final consumption to the production block of the IO table in order to take account of the provision of labour services by households and the resulting consumption and income effects of economic transactions. It is standard to report both Type I and Type II analyses (e.g. Scottish Executive, 2002). However, it is possible to vary the treatment of any final consumer (see McGregor et al, 2008).

for output in the sector in question. For example, £1million of final demand for the Primary, Manufacturing and Construction sector required (in our accounting year of 1999) £1.193million of own sector output (including the additional £1million demanded – the direct effect – so that £0.193million is additional own-sector output required – the own-sector indirect effect), £0.017million output in the Electricity, Gas and Water Supply sector, and £0.237million in the Service sector. The total output multiplier for the Primary, Manufacturing and Construction sector is the sum of these: 1.447 (i.e. for every £1million of final demand for the output of the Primary, Manufacturing and Construction sector, £1.447million output is generated throughout the economy).

Table 5. Composition of sectoral output mulitpliers

TYPE I MULTIPLIER MATRIX	PRIMARY, MFR AND CONSTRUCTION	ELEC, GAS & WATER SUPPLY	SERVICES
PRIMARY, MFR and CONSTRUCTION	1.193	0.185	0.109
ELEC, GAS & WATER SUPPLY	0.017	1.249	0.021
SERVICES	0.237	0.361	1.341
TYPE I OUTPUT MULTIPLIERS	**1.447**	**1.795**	**1.471**

Since the columns of the multiplier matrix in Table 5 tell us the output produced in each and every Scottish production sector to support £1million of final demand for the sector named at the top of the column, we can apply the output–CO2 coefficients/direct CO2 intensities to these outputs in order to determine the total amount of CO2 (direct and indirect) generated in the economy per £1million final demand for each sector. Just as Table 5 gave us a matrix of sectoral output multipliers, if we take the output-pollution coefficient for each producing sector from Table 3 and multiply it against each entry in that sector's output row in Table 5 (sales to intermediate demand per £1million final demand in the consuming sector), we get the corresponding output-pollution multipliers (here for the example of CO2) shown in Table 6:

Table 6. Composition of sectoral output-CO2 mulitpliers			
TYPE I Output-CO2 MULTIPLIER MATRIX			
	PRIMARY, MFR AND CONSTRUCTION	ELEC, GAS & WATER SUPPLY	SERVICES
PRIMARY, MFR and CONSTRUCTION	282	44	26
ELEC, GAS & WATER SUPPLY	56	4023	69
SERVICES	27	41	153
TYPE I OUTPUT-CO2 MULTIPLIERS	**364**	**4108**	**248**

This allows us to do several things.

Identification of pollution/waste generation and/or resource use 'hot spots' in the supply chain for each Scottish production sector

For example, in Table 3 we saw that the Services sector is the least directly CO2-intensive of the three identified (in the highly aggregated illustrative framework here), with 114 tonnes of CO2 directly generated per £1million commodity output produced. However, the total of the third column in Table 6 shows that, in order to produce £1million of output to meet final demand for Services output, 248 tonnes of CO2 are actually generated across all Scottish production sectors. Reading up the column, we can see that just under 28% of this (69 tonnes) is generated in the Electricity, Gas and Water Supply sector. The corresponding entry in Table 5 (output multipliers) shows that less than 1.5% (£0.021million of the £1.471million Scottish output generated per £1million of final demand for 'Services') of the Services multiplier is accounted for by output required in the Electricity, Gas and Water Supply sector. However, Table 3 shows that, with a direct CO2 coefficient of 3222 tonnes per unit of output, this is by far the most CO2-intensive sector of the economy. Indeed, what this multiplier analysis shows us is that, due to a larger output multiplier in the Electricity, Gas and Water Supply sector (£0.021million relative to £0.017million), one unit of final demand for Services output has actually generates more CO2 in this sector than one unit of final demand for Primary, Manufacturing and Construction sector output (see first column of Tables 5 and 6). However, due to larger multiplier effects in other polluting sectors, combined with its own direct CO2 intensity, the Primary, Manufacturing and Construction sector remains more CO2 intensive than Services with a total output-CO2 multiplier of 364 tonnes per £1million final demand relative to the Services multiplier of 248 tonnes.

Attribution of base year pollution generation or resource use by final consumption demand for commodities

The basic environmental IO/NAMEA account in Table 1 gives us the CO2 emissions directly generated by each production and final consumption sector. Therefore, under the **production accounting principle**, by taking the information in the last row of Table 1 (or by multiplying the direct CO2-intensities in Table 3 against the sectoral output/total expenditure data in Table 1) we are able to examine the composition of total CO2 generation in the year that the accounts relate to (here 1999) by source – see Table 7 below:

Table 7. Share of CO2 emissions directly generated in different activities (production accounting principle)

	PRIMARY, MFR AND CONSTRUCTION	ELEC, GAS & WATER SUPPLY	SERVICES	Housholds (per unit expenditure)	Total
CO2 generated in 1999	25.33%	33.23%	19.59%	21.85%	100%

While the Electricity, Gas and Water Supply sector is the most directly CO2-intensive, the value of its total output in 1999 (£5,045) is small relative to the other activities identified here (it is the least aggregated in the illustrative framework in this section – see Appendices 2 and 6), but it accounts for the largest single share of direct CO2 generation (33.23%). However, if we use the output-CO2 multipliers in Table 6 to examine the total CO2 emissions generated in the Scottish economy to produce output in each sector to meet own-sector final demand, the picture is somewhat different, as shown in Table 8:

Table 8. Attribution of total CO2 generation to final consumption demand for Scottish outputs

	PRIMARY, MFR AND CONSTRUCTION	ELEC, GAS & WATER SUPPLY	SERVICES	Total CO2 from production	Household expenditure	Total CO2 in 1999
Total final demand (£million)	38,569	2,563	54,936		44,113	
Output-CO2 multiplier (tonnes CO2 per £1m final demand)	364	4108	248		242	
CO2 (tonnes) attributable to commodity output in 1999	14,050,293	10,528,588	13,640,221	**38,219,101**	10,684,909	**48,904,010**
CO2 (%) attributable to commodity output in 1999	28.73%	21.53%	27.89%	**78.15%**	21.85%	**100%**

The household expenditure column in Table 8 shows the same information for direct CO2 emissions by households as we've already seen in Tables 1 and 7. However, the first 3 columns reallocate CO2 generated in the production sectors (in the accounting year of 1999) so that each sector is allocated the CO2 emissions throughout the economy required to meet final demand for that sector's commodity output. We see that the share of emissions attributable to the Electricity, Gas and Water Supply sector fall from 33.23% to 21.53%, taking into account the fact that (from Table 1) almost 50% of output in this sector is produced to meet intermediate demand from other Scottish production sectors. The share attributable to Primary, Manufacturing and Construction rises slightly from 25.33% to 28.73% but the biggest increase is in the Services sector, where 19.59% of CO2 emissions are directly generated in this sector, but 27.89% of total Scottish CO2 emissions in 1999 are generated to support the production of Service sector output produced to meet final consumption demand.

In this way, the attribution in Table 8 is done under **consumption accounting principles**, but can be clearly traced back to the production process reported in Tables 1, 4, 5 and 6. This type of approach may be applicable to Life Cycle type analysis of products (though, note that, at present, we are focusing only on Scottish C02 generation – an interregional framework of the type introduced in Section 6.2 would be required for a full product life cycle analysis.

Attribution of base year pollution generation and/or resource use to type of final consumer

Instead of or as well as examining the pollution/waste (and/or resource use) attributable to what commodities are consumed, we may wish to look at what type of consumers are driving these activities. As noted above, in a conventional IO framework, all activity is ultimately attributable to final consumption demand. If we take the matrix of output-CO2 multipliers (Table 6) and multiply this against the matrix of final consumption expenditures in Table 1 (a matrix algebra calculation – see Appendix 1) we can see how the total emissions (directly) generated in each and all Scottish production sectors are ultimately attributable to the different types of final consumer identified in the IO table. See Table 9 below:

Table 9. Attribution of total CO2 generation to different types of final consumer

	Final consumption expenditure: LOCAL EXPENDITURES		CAPITAL FORMATION		EXTERNAL EXPENDITURES				
	Households (indirect)	General Government Final Consumption	Gross Domestic Fixed Capital Formation	Change in Inventories	Exports to RUK	Exports to ROW	CO2 (tonnes) directly generated in production	Households direct	**Total CO2 generation**
PRIMARY, MFR and CONSTRUCTION	1,005,986	462,462	1,570,924	23,858	3,865,579	5,458,038	**12,386,848**		
ELEC, GAS & WATER SUPPLY	6,657,164	1,243,937	372,611	10,067	6,623,382	1,345,837	**16,252,999**		
SERVICES	3,385,619	2,757,883	299,400	15,286	1,968,700	1,152,366	**9,579,254**		
CO2 (tonnes) attributable to types of final consumer	**11,048,769**	**4,464,282**	**2,242,935**	**49,212**	**12,457,662**	**7,956,241**	**38,219,101**	**10,684,909**	**48,904,010**
CO2 (%) attributable to types of final consumer	**22.59%**	**9.13%**	**4.59%**	**0.10%**	**25.47%**	**16.27%**	**78.15%**	**21.85%**	**100%**

For example, if we sum across the direct emissions by households (second last column of Table 9) and indirect emission in the production sectors that are attributable to household demand (first column total), we see that in our accounting year of 1999, 44.44% of CO2 emissions generated within Scottish borders were attributable to local Scottish household consumption demand. Another 9.13% were attributable to government final consumption in Scotland, and 4.69% to capital formation. The other 41.74% was attributable to external (export) demand for Scottish outputs in the rest of the UK (25.47%) and the rest of the world (16.27%).

This raises a problem with the analyses in both Tables 8 and 9 in terms of footprint measurement using the consumption accounting principle. There are two points. First, a share of (in this example) CO2 emissions is allocated to external (export) demand and, therefore, is not part of Scotland's CO2 footprint. Second, no account is taken of emissions embodied in imports, with the implication that Scotland's CO2 footprint is not fully accounted for here. In the following sections we will discuss how these factors have implications in terms of meeting regional/national targets for domestic emissions reductions (where polluting activities are partly driven by external demands) and in terms of concerns over 'importing sustainability' (i.e. we could reduce Scottish emissions under the production accounting principle by shifting away from commodity production that drives Scottish pollution and import these commodities instead). As a first step in addressing these issues, Section 6.2 proposes extension of the single region Scottish IO framework to a multi region framework where we are able to take account of the pollution/waste and/or resource content of interregional trade flows.

Calculation of other multipliers

Once we have generated the output-CO2 multipliers in Table 6 for any given pollutant/waste product or type of resource use, we can produce other multipliers that may be of interest. For example, if we take the total CO2 emissions attributable to RUK export demand from Table 9 (12,457,662 tonnes) and divide by total RUK expenditure on Scottish outputs from Table 1 (£24,143million) we have a final consumption multiplier for RUK expenditure in Scotland: for every £1million of RUK export demand 516 tonnes of CO2 were generated in the Scottish economy (in our accounting year of 1999). This compares to 343.6 tonnes for ROW export demand. Thus, we can say that, on average in 1999, RUK export demand expenditures were less CO2 intensive than ROW export demand expenditures. This is due to the composition of these export demands. Note from Table 9 that almost half the emissions generated to meet RUK export demand expenditure were in Electricity, Gas and Water Supply sector. The figure in Table 9 (5,325,923 tonnes) includes all emissions to meet Scottish production. However, if we examine Table 1, we see that direct purchases of Scottish Electricity, Gas and Water Supply by RUK export demand (£1,296million) accounted for just over 50% of production in this sector in 1999. If we apply the direct CO2 coefficient for the Electricity, Gas and Water Supply sector from Table 3 (3222 tonnes of CO2 per £1million output), we see that 4,175,421 tonnes of CO2 were directly generated by this transaction. This reflects the fact that Scotland is a net exporter in electricity to the rest of the UK and raises a number of issues in terms of whether it is better for the UK for Scotland to generate electricity for consumption in the whole of the UK, particularly if Scotland can do this using more renewable technology, but what the implications are in terms of Scotland's 'fair' contribution to UK emissions targets.

A range of other multipliers that would give us an insight into the structure of the CO2 problem could be derived from the results reported so far (e.g. total direct and indirect CO2 per tonne of direct emissions). Also, all of the results derived above for the example of CO2 could be generated for any type of pollutant or waste by-product or for resource use (e.g. energy or water) ***if*** physical data can be reported according to the IOC/SIC classified activities used to construct the IO accounts. That is, can physical data be produced in the NAMEA format shown in Table 1 for the case of CO2? This is one of our biggest challenges in Scotland. The illustrative analysis here (and in the sections below) is intended to demonstrate the potential value-added from investment in the collection, collation and reporting of economic and environmental data in a consistent and compatible NAMEA format.

Use of multipliers for impact analysis

In the illustrative analyses above (and in the following sections) we interpret all multiplier values as telling us about average relationships in the accounting year the NAMEA account applies to (here, 1999). For example, the output-CO2 multiplier for the Services sector in Table 6 tells us that, on average in 1999, 248 tonnes of CO2 were generated throughout the Scottish economy for every £1million of final demand for Service sector outputs. All of the multipliers rest on the average technology reflected in the input-output coefficients shown in Table 4 and the direct CO2-intensities shown in Table 3.

However, a common application of the type of analytical IO framework presented here, and the wide range of multipliers that can be derived from it, is to consider the impact of actual or potential *changes* in activity (see Section 6.3 for an example). So, for example, if demand for Scottish Services increases by £1million, an IO impact analysis would suggest that an additional 248 tonnes of CO2 will be generated. It is important to note that this involves much stronger assumptions than using the IO framework and multipliers for accounting work for a given year. It implies that the input-output coefficients in Table 4 and the direct CO2-intensities translate to fixed proportional relationships between inputs and outputs, outputs and pollution generation. This implies a particular type of, very inflexible production function. In particular, the conventional IO model is a demand-driven system, where supply is entirely passive and unconstrained (infinitely elastic). Therefore, the IO model is silent on prices. However, if supply is constrained at all, prices would be expected to change, at least in the short run, which we would expect to impact on input use. Also, there are no changes in technology (unless these are introduced 'off-line') that may lead to a change in the output-pollution relationship. We return to these issues below and, as a possible response, we suggest in Section 6.3 that we build on the IO framework to develop more flexible computable general equilibrium (CGE models) that use the IO as a core database but relax the restrictive assumptions regarding demand and supply side behavior, technology, prices etc.

This section has introduced the basic environmental IO method that can be applied using a NAMEA database. In the next section we review how this approach has been used, adapted and extended in the literature, before going on to consider the potential for empirical analysis for Scotland, with particular focus on sectoral level analysis for the Scottish Food and Drink sector. This focus raises another issue for environmental IO analysis as a demand driven system. It may be preferable for policy to focus on changing production rather than consumption activities. We consider how such issues can be addressed in and IO framework, and where the limits to the usefulness of this approach are likely to occur.

3. Literature review of NAMEA/Environmental IO applications

In the analysis above, we have used environmental IO analysis to demonstrate how pollution/waste generation and/or resource use can be accounted from both production and consumption accounting perspectives. Munksgaard and Pedersen (2001), in attempting to identify a foreign 'trade balance' in pollution, are the first to explicity use IO techniques to distinguish between emissions under the consumption and production accounting principles (and, in turn, to estimate a CO2 trade balance for the case of Denmark). Particularly in the ecological footprint literature, where focus is on accounting for emissions under the consumption accounting principle, input-output analysis has become increasingly common in the academic literature as a technique to measure and allocate responsibility for emissions generation (see Wiedmann et al., 2007, for a review). As explained by Turner et al (2007) this would seem a natural development, given that the focus of footprint measures is to capture the *total* (direct plus indirect) resource use embodied in final consumption in an economy. Input-output analysis is based around a set of sectorally disaggregated economic accounts, where inputs to each industrial sector, and the subsequent uses of the output of those sectors, are separately identified. The primary function of IO analysis more generally is to quantify the interdependence of different activities within the economy. It uses straightforward mathematical routines to track all direct, indirect and, where appropriate, induced, resource use embodied within consumption (Leontief, 1970, Miller and Blair, 1985). Input-output tables are generally constructed in monetary units for national accounting purposes while Leontief's (1970) initial environmental exposition was in physical units. However, this is an empirical issue (see for example Allan et al, 2007a; Lenzen and Murray, 2001; Hubacek and Giljum, 2003; Minx et al., 2006; Weisz and Duchin, 2006); the analytical arguments (as laid out in Appendices 1 and 4) do not differ whether we are working with physical or monetary units.

Leontief's (1970) initial focus was on the generation of air pollutants as a by-product of production and consumption activities, and specifically on the costs of internalising such negative externalities. However, as noted earlier in this report, this latter focus has generally not been developed in the literature, most likely due to data availability problems with respect to cleaning and/or waste disposal activities in an IO context (see Allan et al, 2007a). Instead, empirical applications have tended to focus on the pollution/waste generation issue and attribution of responsibility to final consumption (as in the example in Section 2). See, for example, Lenzen's (1998) analysis of greenhouse gas emissions embodied in Australian final consumption.

However, environmental IO applications have increasingly attempted to take account of resource use issues, sometimes linking this to pollution generation. For example, Lenzen (1998) links greenhouse gases to physical energy use, as do Gale (1995); Hyami et al (1997); Weir (1998). That is, these studies take the step of relating the generation of pollution directly to input use rather than sectoral outputs. However, there are two important issues in terms of the focus this permits, and assumptions required in an IO analysis. First, in terms of focus, these authors all follow the Leontief (1970) approach of focusing on *marketed* natural resources, and tend to focus on energy as this is a category of natural resource for which markets *do* exist (*after* the point of extraction from the environment). Where natural resources such as energy resources are marketed, this means that they can be treated as economic commodities that are the outputs of economic sectors whose activity is to extract, refine and/or supply energy products. Energy flows tend to be converted to physical units in order to calculate pollution coefficients, since emissions factors for different energy types tend to be given in physical terms. Therefore, one issue is whether the IO data available will allow the appropriate level of sectoral disaggregation to identify flows of energy materials, and the associated waste/pollution generation, through the economy. However, it also raises the question of how we treat resource use that is not marketed in the standard way. A related example, but on the waste/pollution side is Allan et al's (2007a) study of physical waste generation and disposal in Scotland, where, due to public provision of waste disposal services, payments to a Waste Disposal sector by each producer and consumer is unlikely to equate directly to use of the services provided by that sector (and the sectoral disaggregation issue also applied – Waste Disposal is aggregated with Sewage and Sanitation in IOC 119 in Appendix 2). In terms of resource use, similar problems are likely to relate to cases such as water supply and use: IOC 87 in Appendix 2 records the activities of the Collection, Purification and Distribution of Water sector; however, without metering and payment by units used, the row entries for this sector will not equate to actual water usage. Instead, physical data on water use by SIC/IOC sector would have to be separately recorded.

In terms of the over-aggregation of activities that are important for environmental analysis, it is worth noting that several authors highlight this issue in the literature. For example, Hawdon and Pearson (1995) – in an environmental IO analysis for the UK - explain that, because IO tables are not normally designed with the main purpose of exploring energy-environment questions, the sectoral classifications may be inappropriate, often over-aggregating important energy sectors and industries with significantly different pollution characteristics. Lenzen (1998) and Gale (1995) both cite over-aggregation as a principle shortcoming of their analyses, with respect to fuel-use and electricity sector data respectively. Lange (1998), in a study that focuses specifically on natural resource use (rather than pollution generation) in the case of Indonesia, also raises the issue of IO sectoral classifications being compatible with environmental concerns. Therefore there may be a need for further, often extensive, disaggregation of existing IO tables, a process which is likely to have significant cost implications or rely on assumptions as to how an existing sector should be further disaggregated.[6]

Returning to the question of whether pollution is related to inputs or outputs, the simplest and most basic way to model pollution in an IO model is the approach adopted by Leontief (1970): augmenting the standard model with a matrix of output-pollution coefficients for each sector of the economy. In terms of modelling the amount of pollution generated by any given economic activity, the distinction between input- and output-pollution coefficients is not an important one if we are modeling the impacts of *changes* in activity using environmental IO methodology. This is because

[6] Take for example how Gale (1995) had to use assumptions based on foreign data in order to disaggregate the Mexican electricity sector.

the assumption of universal fixed (Leontief) production technology means that there is a constant proportional relationship between inputs and outputs: with the input mix fixed, output-pollution coefficients will be equivalent to input-pollution coefficients in terms of impact. However, where IO is being used for such descriptive analysis as tracking the relationship between natural resource use and pollution generation, linking pollution to resource inputs would more directly capture the causal relationships that exist.

Weir (1998) highlights another motivation for modelling input-pollution relationships in an IO framework. This model was built for a study that involved looking at the relationship between energy consumption patterns/alternative technologies and emissions of pollution in the Danish economy over several time periods (a comparative static analysis). Therefore, Weir's (1998) study was concerned with examining the chain of causality between natural resource (energy) use and the generation of pollution, making it worthwhile to model the direct relationship between input use and pollution. However, given that Weir (1998) is a historical study (based on actual energy use data) the input-pollution coefficient approach is more suitable because the fuel mix used and energy intensity of production over the study period is known to have changed. In other words, although this is an input-output study, Weir (1998) makes off-line adjustments to the input mix according to the historical data. In this type of case constant output-pollution coefficients would *not* give numerically equivalent results for the amount of pollution generated.

Therefore, there are important reasons why it may be desirable to model input- rather than output-pollution relationships in an IO framework, even though the assumption of Leontief technology means that, by definition, the two methods will give the same results in terms of the amounts of pollution generated. This means that, by carrying over the assumption of linearity to the relationship between each sector's output and the quantity of pollutant emitted, (constant) coefficients of pollutant per unit of output can be derived. However, if we are interested in carrying out impact analysis of *changes* in activity, it means that (unless we have historical data to allow us to manually change input-output coefficients, as in Weir's, 1998, historical decomposition analysis), we will not be able to capture changes in pollution due to changes in input mix and/or technology.

However, developments in the literature in terms of focusing on input use as a key source of pollution, also illustrate how applications of environmental IO analysis have tended to focus on air pollutants, and greenhouse gases in particular. For example, Lenzen (1998) focuses on CO2 (and other greenhouse gas) emissions resulting from the combustion of fossil fuels, which are calculated by combining the matrices of industrial and household consumption of different fuel types (explained above) with a vector of CO2 contents per energy unit of combusted fuel. Gale (1995), who also only models CO2 pollution, models emissions as the product of the fuel use vector (giving fossil fuel use in production for three fuel types) for each sector and a vector giving the quantity of CO2 emissions per unit of each type of fuel. However this model also includes modelling of output-pollution relationships in the case of non-fossil fuel (non-combustion) sources of CO2 emissions, mainly because of the prevalence of activities such as brick, tile, cement and glass production which give rise to this type of emissions in the economy in question (Mexico). Weir (1998) does not include non-combustion emissions, but models three pollutants – CO2, SO2 and NO_X – with the implication that the information requirements are increased, especially given that emissions of pollutants like SO2 and NO_X accompanying fuel use vary significantly according to the combustion technology used.

However, as noted earlier in this report, environmental IO methodology can be applied to any type of pollution or waste generation and/or resource use, and is not limited to analysis of greenhouse gases. The limited focus in terms of pollution/waste on greenhouse gases perhaps reflects the dominance of climate change as the environmental problem of key concern to policymakers. Where there has been a shift in focus towards resource use, this has tended to be in the context of attempting to use environmental IO methodology to calculate ecological footprints (which focus mainly on land-use, but with some attention to water use). In recent years this has become one of the main areas of development of environmental IO methods, particularly in terms of moving towards interregional rather than single region analysis in order to capture the pollution content of trade flows. There have been a number of contributions to the literature attempting to use input-output techniques to calculate Ecological Footprints (Bicknell et al., 1998; Ferng, 2001; Ferng, 2002; Lenzen and Murray, 2001; McDonald and Patterson, 2004; Lenzen et al., 2005; Wiedmann et al., 2006) or similar indicators (Eder and Narodoslawsky, 1999; Proops et al., 1999; Hubacek and Giljum, 2003; Sánchez-Chóliz and Duarte, 2004). A more extensive literature review is outwith the scope of the present study. However, Turner et al (2007) and Wiedmann et al (2007) offer an extensive recent review of studies using IO to estimate footprints and other measures under the consumption accounting principle.

The other area where there has been increased use of environmental IO methodology is the development of a hybrid approach to Life Cycle Analysis (LCA). Pan and Kraines (2001) and Wood et al (2006) provide good introductory examples of hybrid IO-LCA analysis. See Appendix 8 for abstracts of these two papers. Some other examples of studies where IO has been introduced to LCA measures are Hendrickson et al (1998); Jin et al (2003); Maenpaa and Juutinen (2001); Munksgaard et al (2005); Munksgaard et al (2005); Nakamura & Kondo (2002); Ni et al (2001); Sinclair et al (2005); Suh (2004); Suh and Kagawa (2005).

4. A Scottish NAMEA? The current state of play

4.1 Previous and current developments

Scotland has a very strong foundation for developing a NAMEA framework in the format that can be used for the type of environmental IO multiplier analysis demonstrated for the illustrative 3-sector case in Section 2. This is because the IO team in the Office of the Chief Economic Adviser at Scottish Government routinely construct 128-sector economic IO tables in the required analytical format. This is not the case at the UK level, where analytical IO tables have not been produced since those reported for 1995 in National Statistics (2002a) – the annual UK IO tables are in the supply and use (SUT) format that is not appropriate for multiplier analyses. Despite this, a pilot analytical environmental IO table was produced by Prashant Vaze, the (then) Head of Environmental Accounts at ONS in Vaze (1993). Since then, sectoral environmental accounts have been produced in NAMEA format for the UK (starting with Vaze, 1999). However, the economic IO tables in these accounts are in SUT format, but with the greatest level of sectoral disaggregation possible: 76 sectors that map the 123 sectors (UK) or 128 sectors (Scotland[7]) of the economic accounts to the 93 sectors identified in the UK environmental accounts (see Appendix 7). The UK environmental IO accounts focus on air emissions (greenhouse gas emissions and acid rain

[7] The Scottish IO tables include an extra five sectors, mainly to further disaggregate fishing and forestry activities.

precursors) and fuel uses and have recently been reported for a more aggregated 68 sector breakdown.[8] However, the only attempt since Vaze (1993) to report UK NAMEA/environmental IO data in the analytical format required for the type of multiplier analysis outlined in Section 2 has been a project by the Stockholm Environment Institute (SEI) and the University of Sydney for DEFRA (Wiedmann et al, 2008) where analytical IO tables for the UK were estimated for the years through 1992-2004. These tables are augmented with information on sectoral CO2 generation and used for the purpose of attempting to estimate CO2 emissions attributable to final consumption activities in the UK.

At the Scottish level, the first environmental IO framework was constructed by McNicoll and Blackmore (1993) in a study for Scottish Enterprise. In contrast to many of those reviewed above, McNicoll & Blackmore (1993) did not focus solely on greenhouse gas emissions, accounting for a wider range of pollutants (twelve in total), including several of more local concern (as opposed to the more global nature of concern over greenhouse gas emissions). They also attempted to construct a framework where sectoral emissions of each pollutant are based on fuel use. McNicoll and Blackmore (1993) explain that emissions would then be calculated as the product of a pollution emissions factor, denoting the volume of the pollutant in question per unit of each of the fuel types, and the volume of each fuel used by the sector. However in the actual environmental IO framework constructed, McNicoll and Blackmore (1993) opt for an approach involving “compilation of actual total sectoral outputs of pollutants, which can then be related to sectoral gross outputs” (p.43), over one involving “application of appropriate pollution emission coefficients to appropriate inputs, especially fuels” (p.43). They explain that this choice was made on the basis that the former approach was better suited to the data available at the time of model construction.

The next attempt to construct a Scottish environmental IO framework was by McGregor et al (2001). This was intended as an illustrative study to demonstrate the types of analysis (along the lines of that in Section 2 above) that would be possible if Scottish environmental IO accounts were available. The study used the Scottish economic IO tables, but the environmental coefficients (in output-pollution format, and focusing on greenhouse gases) were based on UK average emissions

[8] The 2004 and 2005 UK environmental accounts (supply and use input-output tables with greenhouse gas and acid rain precursor emissions and fuel uses can be downloaded at http://www.statistics.gov.uk/CCI/nscl.asp?ID=6805.

intensities (from the UK environmental accounts). National parameters are often adopted at the regional level (often with some attempt at regionalisation – see Turner, 2006, for an overview) where appropriate regional data do not exist. Basically, the question to be asked is whether average technologies that apply at the national level are a good approximation for application at the regional level. Turner (2006) argues that the application of national parameters is not appropriate where we expect regional technology to differ significantly from national averages. For example, we know that the portfolio of generation methods in the Scottish electricity sector is very different from that in the UK.

In 2001 the Scottish Government set up the Scottish Environmental Accounts Working Group to examine the potential costs and benefits of Scottish-specific economic-environmental accounting and address questions such as what format this may take, what types of analysis would be feasible and of interest etc. One of the outcomes of this group was Turner's (2003) paper 'A pilot study on constructing a Scottish sectoral CO2 emissions account' published in the (then) Fraser of Allander Institute Quarterly Economic Commentary. This study concluded that there are two main problem areas that must be considered before a sectorally disaggregated economic-environmental database can be reported. These are:

1. The availability of region-specific data for Scotland on sources and generation of emissions.
2. Even if region-specific emissions data of an acceptable quality are available, can these be reported for a sectoral breakdown that is consistent the 1992 Standard Industrial Classification (SIC) used in the economic accounts?

Turner (2003) addressed each of these issues in turn before reporting a provisional set of environmental accounts for a limited sectoral breakdown of the Scottish economy (25 SIC/IO classified production sectors plus household and tourist categories of final consumption – this sectoral breakdown was illustrative; a fuller breakdown, up to the 76 sector mapping between the 128 sectors of the economic accounts and the 93 sectors commonly used, e.g. in the UK environmental accounts, would be possible). While the pilot study in this paper focused on emissions of the pollutant CO2 (measured in kilotonnes), it argued that the two issues identified above are relevant in considering the relationship between different types of economic activity and the impact on a wide range of environmental variables (e.g. physical waste production).

In terms of point (1) above, Turner's (2003) pilot CO2 account was based on the aggregate CO2 generation estimates in AEA Technololgy/Salway et al's (2001) 'Greenhouse Gas Inventories for England, Scotland, Wales and Northern Ireland: 1990, 1995. 1998 and 1999'. Salway et al's (2001) aggregate regional GHG emissions estimates were based on a top-down approach, where UK emissions were allocated to the regions based on a number of proxy variables. Turner (2003) attempted to relate these two Scottish energy uses (in a 'bottom-up' approach) using energy use-pollution intensities reflected in the UK environmental accounts and adjusting these for energy purchases reported in the Scottish economic IO tables.

One of Turner's (2003) conclusions/recommendations was that, because of the availability of good quality Scottish economic data, it is worthwhile investigating the feasibility of constructing a set of region-specific economic-environmental accounts that link environmental outputs (and inputs) to individual economic activities. The paper argues that adopting a 'bottom-up' approach that captures and accounts for region-specific sources of pollution generation is necessary both in terms of understanding economy-environment relationships and in terms of setting targets and objectives relating to these relationships at the regional level.

However, the Scottish Environmental Accounts Working Group disbanded in 2004 without any plans to progress the environmental IO development that had begun in Turner's (2003) study. Instead, unofficial development of the framework was undertaken only by the regional modeling team at the Fraser of Allander Institute, Department of Economics, University of Strathclyde in developing the AMOSENVI computable general equilibrium (CGE) modeling framework (see Section 6.3 below). Emphasis in this work was placed on energy use, reflecting the focus of several large projects funded by the UK research councils. However, as all papers produced using this model (including Hanley et al, 2006, 2009, and Turner, 2009) have argued, the quality of results from the AMOSENVI model is affected by the lack of reliable environmental IO data for Scotland, given that the IO tables are the core database for the CGE model. These concerns were highlighted when the Scottish Government recently commissioned a study (Allan et al, 2008) using the AMOSENVI model to consider the economic and environmental impacts of potential Scottish policy interventions to address the problem of climate change.

However, real progress on the development of a Scottish environmental IO accounting framework has come from another direction. In 2006 the Scottish Government set up a Steering Group on Additional Measures of Progress (SGAMP) to investigate the potential for reporting indicators of sustainable development alongside GDP and other existing indicators of economic performance. Among the indicators under consideration were ecological and carbon footprints as measures of resource use and pollution generation under the consumption accounting principle. The Scottish Environment Protection Agency (SEPA) contributed to the work of SGAMP by commissioning a workshop on economy-environment statistics and potential calculation of ecological and/or carbon footprints using input-output techniques, the proceedings and conclusions of which are reported in Turner (2008a). This workshop was attended by a number of participants from the Scottish policy and research communities and among its key conclusions/recommendations were the following (Turner, 2008a, pp.5-6):

- "While the development of the IO framework is resource-intensive, if we have faith in market-based solutions to the problem of climate change, we absolutely need to adopt an IO approach.
- Uses of an environmental IO approach are not limited to footprint calculations. It would facilitate the construction of a wide range of environmental indicators. Therefore, it is likely to represent 'good value for money' to policymakers.
- IO analysis would allow us to develop a better understanding of domestic and direct emissions generation as well as the indirect effects that can be measured through multiplier analysis. Therefore, it would allow us to investigate how Scottish and/or UK direct emissions generation (as accounted for under the type of emissions inventory approach used in the UK environmental accounts) sit within the wider footprint picture. For example, it would be possible to separate domestic emissions attributable to local and external demands, and to consider the relative importance of emissions that may be attributable to imports under different assumptions regarding technology.

- If, as expected by some participants, the Scottish Climate Change Bill focuses on the consumption accounting principle, it will be necessary to explicitly consider the treatment of emissions embodied in imports and the implications in terms of data requirements."

Thus, the key outcome of this workshop was to report to SGAMP a clear consensus among participants that an environmental IO framework is a necessary development for analysis of economy-environment issues in Scotland. A recommendation reflecting this outcome was made by SGAMP to Scottish Ministers in autumn 2008 and, as a result, the Scottish Government has now commissioned sectoral environmental data that will allow development of Scottish environmental IO/NAMEA tables for the years 1998-2004. This development is discussed in the next section.

4.2 Scottish IO data and proposed environmental extensions

As noted above, Scotland has a very strong foundation for NAMEA accounting and environmental IO multiplier analysis (as explained in Section 2) due to the regular construction of economic IO tables in analytical format. The first economic IO tables were constructed for the year 1979, with the assistance of the Fraser of Allander Institute for Research on the Scottish Economy at the University of Strathclyde. From 1998 these tables have been produced on an annual basis. At the time of writing this report, the IO team at Scottish Government is in the process of revising the economic IO tables for the years through 1998-2004 to take account of updated information and changes in accounting practices etc. Also at the time of writing this report, Scottish Government had also just commissioned AEA Technology (who produce the UK emissions inventory) to produce sectoral level data on emissions of the same greenhouse gases and acid rain precursors, and also physical fuel uses, for the 93-sector classification used in the UK Environmental Accounts for the years 1990, 1995, and 1998-2006. As explained at the start of Section 4.1, this will permit mapping to a 76-sector aggregation of the 128-sector Scottish economic IO tables (see Appendices 2 and 7), for which a NAMEA in the form of an analytical environmental IO framework can be reported for the years both economic and environmental data will exist (1998-2004), and can be updated for years economic IO tables are yet to be produced for (2005-2006). This does raise one issue for environmental IO analysis: the comprehensive nature of IO data means that there is generally (i.e. not just in Scotland or the UK) a time-lag in reporting IO tables. This is usually shorter than the 5-year lag we currently have (with the latest tables available in 1999 being for 2004); the current issue is that production of tables may be delayed in order to allow time for improvements to existing data (such as the 1998-2004 update currently being carried out).

Nonetheless, the production of data to construct an inaugural set of official, published environmental IO tables for Scotland is a huge and very positive development for Scotland, and one that will mean that Scotland will have environmental IO accounts that can be used for multiplier analysis of local emissions generation under both production and consumption accounting principles for the years 1998-2004. This is something that is not available for any other UK region, or even the UK national economy (at least not through ONS, which produces national IO data; as noted at the start of Section 4.1 Wiedmann et al, 2008, have *estimated* UK analytical environmental accounts for the years 1992-2004, which is a 'second best' to the actual survey-based analytical tables available for Scotland).

Of course, at the time of writing this report, the Scottish environmental accounts have yet to be produced by AEA Technology, and the extent to which these will use the 'bottom-up' methodology (i.e. pollution generation and fuel uses based on Scottish economic activity as reported in the Scottish economic IO tables) recommended by Turner (2003) – see Section 4.1 – will be used to improve on Salway et al's (2001) 'top-down' allocation of UK emissions to Scottish activity.

Moreover, the coverage of the forthcoming Scottish environmental accounts is limited in that only greenhouse gas emissions, acid rain precursors and fuel uses will be reported. There are, of course, many more pollutants and resource uses that we may be interested in (e.g. local air pollutants such as PM10, physical waste generation, water use etc). However, now that the first step has been taken in actually producing some form of NAMEA framework for Scotland, if this triggers sufficient interest and discussion, hopefully the framework can be extended to other environmental variables of interest in the future.

Of more concern is the sectoral breakdown of the 76-sector NAMEA framework. It may be argued that even the full 128-sector breakdown of the Scottish IO tables does not provide sufficient sectoral detail on activities that are likely to have important environmental impacts. For example, there is only one sector – IOC 85 – in Appendix 2 to cover ‘Production and distribution of electricity’ and this sector is reported as selling its output directly to consumers. Two issues arise: (1) most emissions from electricity production arise at the generation stage and (intermediate and final) consumers do not purchase directly from generators (i.e. the IO sector is vertically aggregated); (2) different types of generation technology have very different energy use and pollution generation patterns. In response to this second point, and related to the activities of the former Scottish Environmental Accounts Working Group (see Section 4.1), the Scottish Government IO team did work with the Fraser of Allander Institute to attempt to disaggregate IOC 85 in the 1999 IO tables by generation type. These data have been used by the latter in CGE modeling applications (e.g. Hanley et al, 2006, 2009, and Turner, 2009), and in the 25-sector framework used for an illustrative environmental IO analysis in Section 5 below (see Appendix 3). However, they have not been published or developed since (i.e. these data remain experimental). As another example, Allan et al (2007a) also cite the aggregation of waste disposal activities with sewage and sanitation activities as problematic in their attempt to analyse sectoral waste production and disposal in the Scottish economy.

No doubt there are other cases where concern may arise in terms of over-aggregation of key activities in the 128-sector IOC classification of activities in Appendix 2. As discussed in Section 3, there is a problem in that neither the Standard Industrial Classification that IO tables use to identify IOC sectors, or national accounting programmes using IO tables, were initially designed to take account of environmental issues. However, even greater concern may arise if we examine the 76-sector NAMEA classifications in Appendix 7. One area of particular concern in the context of this report is that both the 93-sector Environmental Accounts and 76-sector NAMEA classifications aggregate over the 12 IOC sectors 8-19 in Appendix 1 (13 sectors in the Scottish case, where IOC 18 is split to separate spirits and wines from beers and ales). Also the Scottish split of fishing activities (IOC 3) is lost in the EA and NAMEA classifications. Appendix 7 shows that there are a number of areas where sectors identified in the 93-sector Environmental Accounts have to be aggregated to map to the classifications used in the IO accounts (e.g. the EA classification system does identify 5 electricity sectors – this breakdown is by generation type rather than stages of the supply chain; i.e. addressing issue (2) rather than (1) above).

Where there is over-aggregation of key activities, one possibility is to ask the Scottish Government if it is possible to disaggregate existing sectors given that the IO tables are based on ABI survey data carried out at firm level. There may be issues in terms of firm confidentiality and the detail available in the ABI data that can actually be accessed; however, this possibility should be explored on a case-by-case basis.

4.3 Social accounting matrices and other social indicators

In a broader sustainability analysis, it may be desirable to extend the NAMEA framework to take account of social variables in order to take account of well-being or welfare issues other than environmental concerns. In the current context – where this report is intended to help inform consideration of Scotland's National Food Policy – this may include taking account of variables related to nutrition and health. In principal, an IO framework can be augmented with information on any variable that can be related to one or more economic variables reported within the tables. So, for example, we could report a health or nutrition index related to household income or expenditure (i.e. where income is believed to have a positive impact on nutrition/health) or to one or more specific expenditure categories. For example, we could represent a positive relationship between nutrition and expenditure on the output of IOC sector 9 (Processing and preserving of fish and fish products, fruit and vegetables) and a negative one with respect to the output of IOC sector 18.2 (beers and ales). Again, the issue of sectoral classifications arises – those in Appendix 2 may be too highly aggregated, and, as noted above, the NAMEA classifications in Appendix 7 aggregates across all manufacturing of food and drink. It may be possible to use regional data from the UK Expenditure and Food Survey produced by ONS[9] to construct some type of food and drink satellite account with more detailed information but this is something that would require consultation with government statisticians in Scottish Government and ONS.

It may also be possible to disaggregate the single household expenditure column in the Scottish IO tables by different income and socio-demographic groups. Data do exist (see Appendix 9 for a brief review), for example in the UK Expenditure and Food Survey, that detail income and expenditure

[9] In 2001 the Family Expenditure Survey and National Food Survey were combined into the Expenditure and Food Survey – see http://www.esds.ac.uk/Government/fes/ for details.

for households in different income bands, geographical areas etc that could be used to either disaggregate households within the IO accounts or to construct a satellite account. However, again, consultation with government statisticians would be required as to the feasibility and likely costs of such a development.

Another option, as explained in Section 1, is to extend the IO with income on income transfers to produce a Social Accounting Matrix (SAM). Not only does a SAM contain additional income on income transfers and expenditures (e.g. the IO tables only include wage income and expenditure on goods and services; a SAM would record *all* household incomes and expenditures), it can also, in principal, be extended in all the ways suggested above for the case of IO.

However, SAMs are not routinely constructed as part of the national accounting framework, at least for regional economies like Scotland. This is because it is difficult to separately identify much of the data on income transfers at the regional level. For example, income taxes, social security payments etc are transfers that flow to/from the UK level. Largely because of tax reporting requirements, many firms would similarly be unable (and/or unwilling) to identify cross border flows and retention of profit within the UK. One basic distinction between an IO and a SAM is that IO gives us Gross Domestic Product (income generated within our borders) while a SAM gives us Gross National Product (income accruing to local residents). For the type of reasons outlined above, while the UK can report both GDP and GNP, Scotland is only able to report the former.

Finally, we need to be careful in terms of whether augmentations of the economic framework represent causal relationships, particularly where we may want to carry out impact analyses. For example, while it would seem appropriate to report generation of any given pollutant to sectoral output or expenditure levels, in practice this is only likely to be an indirect relationship in many cases. In Section 3 we discussed the question of relating pollution generation to inputs or to outputs. Where, for example, CO_2 emissions are related to energy use, these will increase with output in any sector/activity, but this increase will only be proportionate where the input mix does not change. Similarly, in reporting variables related to nutrition or health alongside income, we need to be careful in thinking about exactly *how* nutrition or health will change with income, and even what the precise form of the relationship is in our base year accounts.

5 An illustrative application of single region environmental IO methodology - the impact of the Scottish Food and Drink sector on CO2 emissions under the production and consumption accounting principles

Section 2.2 gave us a basic introduction to environmental IO multiplier analysis for the case of CO2 emissions for a highly-aggregated (3-sector) version of the Scottish IO tables. In this section, we attempt to provide a more relevant illustrative analysis for the current policy focus of the National Food Policy by taking a slightly more detailed (25-sector) version of the Scottish IO tables, where we identify sectors that may be of more interest than in the 3-sector version. These include Food, Drink and Tobacco (the latter is effectively an empty sector in the Scottish IO tables due to the absence of tobacco production), Agriculture, Sea Fishing and Fish Farming – see Appendix 3 for details. We remain with the example of CO2 (as this is the pollutant that experimental NAMEA data have been constructed for), but refer the reader to Allan et al (2004a, 2007a) for another example, focusing on physical waste generation, and McGregor et al (2001) for an example with other greenhouse gases. However, we introduce experimental data on different types of energy use (which are related to CO2 generation).

Table 10 below is the equivalent of Table 1, showing a 25-sector version of the experimental 1999 Scottish NAMEA, with additional environmental data on CO2 emissions, and physical use of electricity, coal, gas and oil (with the latter including petrol, diesel etc). Table 11 is the 25-sector equivalent of Table 5, showing the matrix of (Type I) sectoral output multipliers.[10] Table 12 contains information on direct CO2 intensities (Table 3 in the 3-sector case); the composition of sectoral output-CO2 multipliers (Table 6 in the 3 sector case); and the attribution of CO2 emissions to final consumption demand for the outputs of each Scottish production sector (Table 8 in the 3-sector case).

[10] As noted in Section 2.2 (see Footnote 5), a Type I analysis focuses on indirect multiplier effects in other production sectors. However, we can vary the treatment of different final consumers, for example households, to take account of other types of multiplier effects, such as induced (consumption and income) effects.

Table 10. 1999 Scottish Analytical Input-Output Table - Aggregated to 25-sector industry-by-industry (£ million) - augmented with environmental data to give a Scottish NAMEA for 1999

	AGRICULTURE	FORESTRY PLANTING AND LOGGING	SEA FISHING	FISH FARMING	OTHER MIN & QUARR.	OIL & GAS EXTRAC.	MFR FDT	MFR T&C	MFR CHEM	MFR M&NMG	MFR T&OM, EEE	MFR OTHER	WATER	CONSTRUC.	DISTRIB.	TRANSPORT	COMM, FIN & BUS.	R&D	EDUCAT.	PUB & OTH SERVICES	COAL EXTRAC.	OIL (REFINE & DIST)	GAS	ELEC RENEWABLE	ELEC NON-REN	**Sales to ID**	**Households**	**Tourist Expend.**	**GGFC**	**GDFCF**	**Change in Stocks**	**Exports RUK**	**Exports RoW**	**Total Final Demand**	**Gross Output (Total Demand)**
AGRICULTURE	327	6	0	0	0	2	943	0	2	2	2	1	0	28	227	4	14	3	1	27	0	0	0	0	2	**1,593**	102	3	1	86	-22	601	230	**1,002**	**2,596**
FORESTRY PLANTING AND LOGGING	0	42	0	0	0	0	0	0	0	0	0	27	0	5	0	0	1	0	0	1	0	0	0	0	0	**78**	4	0	0	1	51	95	28	**179**	**257**
SEA FISHING	0	0	0	0	0	0	25	0	0	0	0	0	0	0	3	1	0	0	0	0	0	0	0	0	0	**30**	1	5	0	0	1	114	203	**324**	**354**
FISH FARMING	0	0	0	36	0	0	12	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	**51**	3	2	0	0	0	46	264	**316**	**367**
Other mining and quarrying	0	0	0	0	30	0	0	0	1	16	0	3	0	142	8	1	1	0	0	9	0	0	0	0	0	**213**	0	0	0	0	2	102	79	**183**	**396**
Oil and gas extraction	1	0	0	0	2	25	6	1	5	4	8	3	0	29	9	12	28	0	2	16	1	179	3	1	7	**341**	15	4	0	23	-3	674	1,240	**1,953**	**2,294**
Mfr food, drink and tobacco	95	0	6	69	0	0	291	0	1	1	1	5	0	55	429	9	60	2	2	174	0	3	0	0	2	**1,207**	554	63	0	0	-9	1,884	2,342	**4,834**	**6,040**
Mfr textiles and clothing	1	0	20	2	0	0	0	24	0	3	0	1	0	12	33	2	20	3	5	90	0	0	0	0	1	**216**	51	35	0	0	47	505	493	**1,130**	**1,346**
Mfr chemicals etc	31	2	1	1	6	4	8	2	115	12	18	17	2	80	13	5	12	9	10	177	0	26	1	0	8	**560**	13	17	0	0	-38	1,013	1,404	**2,408**	**2,968**
Mfr metal and non-metal goods	16	4	2	6	2	25	193	1	4	143	324	30	3	403	62	42	42	1	17	106	1	12	0	0	9	**1,447**	17	29	0	79	26	1,596	1,106	**2,862**	**4,299**
Mfr transport and other machinery, electrical and inst eng	23	5	23	16	7	3	37	2	10	27	685	22	4	259	29	83	91	2	27	154	3	4	0	16	36	**1,568**	121	12	0	207	-87	3,906	10,804	**14,963**	**16,531**
Other manufacturing	8	3	2	5	0	0	118	2	2	11	13	229	2	224	79	34	424	1	36	313	0	4	0	6	8	**1,523**	127	23	0	59	32	1,139	759	**2,141**	**3,664**
Water	18	0	0	0	0	0	11	1	3	2	5	2	0	1	8	1	5	1	80	33	0	1	0	0	2	**172**	185	2	0	0	0	0	0	**188**	**360**
Construction	74	9	0	0	12	45	14	2	10	22	17	6	9	1,574	261	69	1,244	4	171	679	56	2	55	26	126	**4,488**	280	11	0	5,033	119	160	16	**5,619**	**10,107**
Distribution	103	5	8	27	8	31	197	29	78	109	522	89	3	185	246	258	270	8	91	291	22	42	5	6	149	**2,782**	9,667	1,284	3	299	-3	783	524	**12,558**	**15,340**
Transport	31	27	24	3	68	206	112	13	76	43	122	63	5	83	259	2,125	660	3	60	349	14	5	15	2	82	**4,452**	629	148	0	17	0	2,644	801	**4,239**	**8,691**
Communications, finance and business	175	17	19	29	54	708	481	53	154	202	491	179	11	2,227	888	1,275	5,414	13	88	2,259	30	33	37	43	450	**15,332**	7,142	209	2	547	76	4,227	1,374	**13,577**	**28,909**
R&D	2	0	0	0	1	0	5	2	6	4	15	3	1	1	1	15	22	2	1	90	1	1	3	2	33	**210**	13	0	0	0	3	51	22	**89**	**299**
Education	1	0	0	0	0	0	3	1	3	3	9	2	0	5	2	18	68	0	22	124	0	0	1	1	18	**282**	1,536	18	2,823	1	1	276	176	**4,833**	**5,115**
Public and other services	43	9	2	9	7	2	57	13	41	25	50	57	2	196	44	114	252	2	61	4,606	4	2	8	4	120	**5,730**	2,491	131	15,150	117	9	1,397	344	**19,640**	**25,369**
COAL (EXTRACTION)	0	0	0	0	0	0	0	0	0	0	0	2	0	5	0	0	0	0	0	4	1	1	0	0	188	**203**	1	1	0	0	-38	26	21	**11**	**214**
OIL (REFINING & DISTR OIL AND NUCLEAR)	18	3	6	1	3	1	12	1	12	5	5	5	1	12	34	75	48	0	0	97	2	17	0	1	21	**383**	127	0	0	0	-4	531	1	**655**	**1,038**
GAS	0	0	0	0	0	0	11	2	7	12	7	7	0	1	21	8	15	0	10	49	0	2	7	3	88	**252**	325	5	0	0	0	19	0	**350**	**602**
Electricity - Renewable (hydro and wind)	3	0	0	0	1	1	7	1	8	8	10	5	1	4	37	5	12	0	5	39	0	1	0	16	94	**259**	95	1	0	0	0	159	0	**255**	**514**
Electricity - Non-renewable (coal, nuke and gas)	22	1	0	2	5	6	49	9	53	53	68	36	6	26	258	36	86	2	33	273	2	9	3	112	650	**1,799**	660	10	0	0	0	1,100	0	**1,770**	**3,569**
Total Intermediate Inputs	**993**	**136**	**113**	**207**	**207**	**1,060**	**2,592**	**161**	**594**	**703**	**2,374**	**796**	**48**	**5,557**	**2,954**	**4,191**	**8,789**	**56**	**724**	**9,963**	**137**	**345**	**140**	**239**	**2,092**	**45,172**	**24,160**	**2,015**	**17,979**	**6,470**	**163**	**23,050**	**22,231**	**96,068**	**141,241**
Imports from Rest of UK	473	3	33	15	1	65	1,133	431	700	1,179	3,552	748	50	1,026	1,716	675	3,295	101	512	2,116	21	408	235	46	332	**18,864**	9,784	909	0	2,663	55	0	0	**13,410**	**32,275**
Imports from Rest of World	263	1	13	17	22	16	359	149	428	492	5,379	536	5	206	443	104	347	1	176	675	1	22	16	12	50	**9,731**	7,227	249	0	1,488	13	0	0	**8,977**	**18,708**
Net production and commodity taxes	91	-9	26	12	12	48	56	45	107	161	605	124	20	332	754	443	810	8	123	768	16	45	37	33	183	**4,849**	2,941	225	83	572	5	1,098	296	**5,221**	**10,070**
Income from employment	273	85	131	78	83	571	1,051	445	549	1,362	2,801	1,050	108	2,463	5,572	2,606	7,047	101	3,460	10,021	35	70	55	46	354	**40,415**	0	0	0	0	0	0	0	**0**	**40,415**
Other value added	501	41	39	37	71	535	850	116	590	402	1,820	410	129	524	3,902	673	8,622	32	120	1,826	4	148	121	138	558	**22,209**	0	0	0	0	0	0	0	**0**	**22,209**
Total Primary Inputs	**1,602**	**121**	**241**	**160**	**189**	**1,235**	**3,448**	**1,186**	**2,375**	**3,597**	**14,157**	**2,868**	**312**	**4,550**	**12,386**	**4,500**	**20,120**	**243**	**4,391**	**15,406**	**77**	**692**	**462**	**275**	**1,476**	**96,068**	**19,952**	**1,383**	**83**	**4,723**	**73**	**1,098**	**296**	**27,609**	**123,677**
TOTAL INPUTS	**2,596**	**257**	**354**	**367**	**396**	**2,294**	**6,040**	**1,346**	**2,968**	**4,299**	**16,531**	**3,664**	**360**	**10,107**	**15,340**	**8,691**	**28,909**	**299**	**5,115**	**25,369**	**214**	**1,038**	**602**	**514**	**3,569**	**141,241**	**44,113**	**3,398**	**18,063**	**11,192**	**236**	**24,149**	**22,526**	**123,677**	**264,917**
Employment (FTE, thousands)	**25,205**	**2,422**	**4,110**	**1,447**	**3,172**	**18,845**	**52,620**	**28,037**	**15,179**	**53,615**	**102,879**	**46,169**	**3,443**	**126,156**	**377,895**	**75,518**	**308,207**	**6,946**	**128,453**	**437,176**	**1,655**	**1,851**	**1,772**	**1,044**	**8,032**	**1,831,846**									**1,831,846**
Total CO2 generation (tonnes)	**586,090**	**88,282**	**227,927**	**29,938**	**81,725**	**563,294**	**769,807**	**96,126**	**576,924**	**1,083,220**	**437,095**	**767,606**	**36,664**	**717,629**	**2,878,635**	**3,054,954**	**2,138,336**	**10,948**	**754,851**	**4,724,074**	**47,399**	**746,418**	**188,001**	**142,040**	**13,765,253**	**34,513,236**	**13,630,631**	**366,041**						**13,996,672**	**48,509,908**
PHYSICAL NON-ELECTRICITY ENERGY USE (tonnes oil equivalent):																																			
Coal	32	0	0	0	39	0	7,109	1,953	14,128	2,171	11,468	34,170	5	106,315	0	25	75	0	8,493	64,417	17,416	18,305	0	0	2,780,226	3,066,347	472,378	15,572						487,950	3,554,297
Oil	203,259	29,385	78,981	8,555	25,107	45,722	104,598	10,525	106,869	66,712	59,738	56,433	11,923	110,194	420,508	1,205,321	573,791	585	36,018	980,607	14,087	138,242	560	9,065	58,400	4,355,185	1,705,040	70,429						1,775,469	6,130,653
Gas	795	71	7	2,404	4,256	895	202,344	26,909	103,522	173,557	102,955	221,194	1,286	11,255	768,747	90,209	231,801	4,256	284,785	766,953	177	17,037	86,016	53,224	1,787,020	4,941,673	3,318,817	52,980						3,371,797	8,313,470
Total non-elec use per sector	**204,086**	**29,457**	**78,988**	**10,959**	**29,402**	**46,616**	**314,051**	**39,387**	**224,518**	**242,440**	**174,161**	**311,797**	**13,214**	**227,764**	**1,189,255**	**1,295,556**	**805,666**	**4,841**	**329,296**	**1,811,977**	**31,679**	**173,584**	**86,576**	**62,289**	**4,625,647**	**12,363,205**	**5,496,235**	**138,981**						**5,635,216**	**17,998,420**
PHYSICAL ELECTRICITY USE (Gigawatt hours):	**281**	**10**	**2**	**23**	**66**	**79**	**635**	**119**	**685**	**680**	**883**	**474**	**76**	**338**	**3,397**	**466**	**1,136**	**25**	**428**	**3,533**	**26**	**113**	**41**	**1,448**	**8,417**	**23,382**	**8,529**	**126**						**8,656**	**32,038**

Table 11. Composition of sectoral output multipliers

TYPE I OUTPUT MULTIPLIER MATRIX

	Agriculture	Forestry Planting and Logging	Sea Fishing	Fish Farming	Other Mining and Quarring	Oil and Gas Extraction	Mfr Food drink and tobacco	Mfr textiles and clothing	Mfr Chemicals	Mfr metal and non-metal goods	Mfr transport and other machinery, electrical and inst
Agriculture	1.153726	0.036120	0.004508	0.043178	0.002449	0.002377	0.190602	0.001033	0.001988	0.001438	0.001093
Forestry Planting and Logging	0.000139	1.196358	0.000158	0.000310	0.000356	0.000212	0.000303	0.000058	0.000076	0.000105	0.000040
Sea Fishing	0.000215	0.000050	1.000106	0.000993	0.000067	0.000061	0.004470	0.000018	0.000025	0.000022	0.000017
Fish Farming	0.000115	0.000036	0.000062	1.108549	0.000075	0.000066	0.002299	0.000019	0.000025	0.000024	0.000016
Other Mining and Quarring	0.000978	0.001253	0.000223	0.000484	1.082519	0.000879	0.000591	0.000148	0.000721	0.004346	0.000204
Oil and Gas Extraction	0.002641	0.005771	0.004098	0.002118	0.008888	1.012162	0.002339	0.001163	0.003092	0.001457	0.000771
Mfr food, drink and tobacco	0.047012	0.004122	0.020854	0.225161	0.002825	0.002327	1.060670	0.001417	0.001979	0.001466	0.001367
Mfr textiles and clothing	0.000847	0.002112	0.056935	0.007412	0.000558	0.000496	0.000745	1.018158	0.000275	0.000847	0.000193
Mfr chemicals	0.015503	0.014169	0.004218	0.005321	0.018893	0.002942	0.004709	0.002238	1.041063	0.003417	0.001520
Mfr metal and non-metal goods	0.012306	0.025524	0.009981	0.030126	0.010964	0.015279	0.038501	0.001554	0.002795	1.035657	0.021862
Mfr transport and other machinery, electrical and inst	0.014192	0.028958	0.068740	0.054590	0.027409	0.005812	0.011371	0.002379	0.005479	0.008148	1.044087
Other Manufacturing	0.009237	0.019511	0.008502	0.024416	0.008122	0.008871	0.026507	0.003369	0.003405	0.004808	0.002240
Water	0.008110	0.000491	0.000217	0.000907	0.000989	0.000337	0.003325	0.000592	0.001156	0.000538	0.000410
Construction	0.050093	0.067538	0.008136	0.015817	0.059347	0.048416	0.020907	0.007264	0.012956	0.013148	0.005604
Distribution	0.054416	0.040202	0.031829	0.099641	0.038951	0.024598	0.049655	0.024995	0.032589	0.030140	0.035767
Transport	0.028404	0.180646	0.097382	0.030566	0.259773	0.135809	0.038435	0.016430	0.041297	0.019276	0.013562
Communications, finance and business	0.133844	0.169115	0.102215	0.165003	0.263243	0.428751	0.147895	0.060997	0.089807	0.076099	0.048804
R&D	0.001241	0.000915	0.000538	0.000845	0.002779	0.000743	0.001572	0.001797	0.002714	0.001327	0.001139
Education	0.001175	0.001433	0.000874	0.000969	0.001625	0.001539	0.001313	0.001062	0.001745	0.001036	0.000825
Public and other services	0.028752	0.061424	0.010339	0.041672	0.033233	0.009661	0.020774	0.013931	0.020929	0.010011	0.005491
COAL (extraction)	0.000910	0.000610	0.000263	0.000833	0.001260	0.000415	0.000993	0.000646	0.001528	0.000971	0.000400
Oil (refining &distr oil and nuclear)	0.009373	0.019266	0.019554	0.005222	0.011178	0.002643	0.004629	0.001036	0.005312	0.001910	0.000730
Gas	0.000895	0.000909	0.000573	0.002060	0.002347	0.000707	0.002866	0.002183	0.003484	0.003566	0.000809
Electricity-Renewable (hydro and wind)	0.002335	0.001437	0.000597	0.002114	0.003262	0.001034	0.002372	0.001460	0.003683	0.002550	0.001018
Electricity-Non- renewable (coal, nuke and gas)	0.016201	0.009971	0.004144	0.014669	0.022629	0.007176	0.016455	0.010132	0.025554	0.017692	0.007063
Type I output multipliers	**1.593**	**1.888**	**1.455**	**1.883**	**1.864**	**1.713**	**1.654**	**1.174**	**1.304**	**1.240**	**1.195**

	Other manufacturing	Water	Construction	Distribution	Transport	Communications, finance and business	R&D	Education	Public and other services	COAL (EXTRACTion)	OIL (refining & Distr oil and nuclear)	Gas	Electricity-Renewable 9hydro and wind)	Electricity-non-renewable (coal, nuke and gas)
Agriculture	0.001801	0.000758	0.006458	0.023143	0.002497	0.001987	0.014248	0.001151	0.004111	0.005278	0.002259	0.001586	0.002371	0.003421
Forestry Planting and Logging	0.009396	0.000119	0.001075	0.000137	0.000185	0.000292	0.000123	0.000137	0.000299	0.000449	0.000115	0.000158	0.000301	0.000233
Sea Fishing	0.000029	0.000014	0.000094	0.000323	0.000176	0.000041	0.000053	0.000016	0.000064	0.000082	0.000042	0.000028	0.000040	0.000058
Fish Farming	0.000027	0.000014	0.000082	0.000170	0.000139	0.000039	0.000034	0.000035	0.000044	0.000076	0.000035	0.000034	0.000068	0.000072
Other Mining and Quarring	0.001315	0.000642	0.018701	0.001107	0.000782	0.001124	0.000574	0.000749	0.001339	0.005351	0.000512	0.001866	0.001499	0.001605
Oil and Gas Extraction	0.001651	0.001341	0.004669	0.001546	0.004475	0.002047	0.000605	0.000842	0.002290	0.006476	0.177975	0.005950	0.004685	0.005337
Mfr food, drink and tobacco	0.002898	0.001045	0.009251	0.031532	0.004007	0.003926	0.009408	0.001601	0.010449	0.006959	0.005122	0.001726	0.002662	0.004713
Mfr textiles and clothing	0.000656	0.000180	0.001930	0.002445	0.000727	0.001085	0.009072	0.001277	0.004723	0.001121	0.000448	0.000404	0.000611	0.001109
Mfr chemicals	0.005780	0.005846	0.011314	0.001836	0.002050	0.001578	0.030526	0.002900	0.010058	0.005283	0.027886	0.002448	0.002998	0.005123
Mfr metal and non-metal goods	0.010610	0.011161	0.052355	0.007304	0.009326	0.005590	0.004698	0.006131	0.008888	0.021413	0.015886	0.006214	0.007017	0.009581
Mfr transport and other machinery, electrical and inst	0.008407	0.014411	0.035363	0.004453	0.015707	0.006872	0.008493	0.007823	0.010815	0.028758	0.006403	0.005312	0.041706	0.020326
Other Manufacturing	1.069172	0.007010	0.035343	0.008955	0.011239	0.022003	0.007435	0.009858	0.020666	0.015041	0.007853	0.005813	0.019844	0.011549
Water	0.000594	1.000806	0.000366	0.000804	0.000342	0.000337	0.002862	0.015871	0.001837	0.000591	0.000907	0.000254	0.000574	0.001114
Construction	0.010306	0.035625	1.207255	0.029102	0.029084	0.066691	0.022486	0.044959	0.050657	0.335489	0.016396	0.118390	0.092239	0.096028
Distribution	0.030813	0.011748	0.032751	1.022785	0.046157	0.016452	0.030874	0.021864	0.021320	0.122165	0.050178	0.014871	0.033121	0.069357
Transport	0.031096	0.021632	0.033282	0.029387	1.335457	0.041354	0.018111	0.019862	0.031485	0.105632	0.034870	0.041638	0.027189	0.058648
Communications, finance and business	0.084150	0.059698	0.355315	0.098728	0.262262	1.264086	0.077130	0.045386	0.165396	0.306016	0.129887	0.125934	0.194852	0.264077
R&D	0.001346	0.001945	0.000820	0.000568	0.002752	0.001225	1.008367	0.000474	0.004889	0.005343	0.001035	0.004854	0.006499	0.012613
Education	0.001096	0.001127	0.001828	0.000664	0.003593	0.003253	0.001145	1.004724	0.006660	0.002027	0.000985	0.002675	0.003274	0.007399
Public and other services	0.023622	0.008710	0.035533	0.008066	0.026127	0.016787	0.013693	0.017433	1.227431	0.039562	0.007154	0.022465	0.027523	0.060554
COAL (extraction)	0.001516	0.001143	0.001117	0.001275	0.000581	0.000394	0.000602	0.000570	0.001268	1.005055	0.002011	0.000535	0.014846	0.065476
Oil (refining &distr oil and nuclear)	0.002507	0.003307	0.003075	0.003239	0.012543	0.002831	0.001053	0.000639	0.005748	0.010929	1.017851	0.001084	0.004795	0.009542
Gas	0.002782	0.000963	0.001004	0.002267	0.001796	0.001002	0.001979	0.002492	0.003200	0.001251	0.002371	1.012371	0.012643	0.031480
Electricity-Renewable (hydro and wind)	0.002247	0.003034	0.001292	0.003399	0.001469	0.000925	0.001570	0.001461	0.002790	0.002736	0.002100	0.001271	1.040291	0.034195
Electricity-Non- renewable (coal, nuke and gas)	0.015588	0.021048	0.008965	0.023582	0.010190	0.006418	0.010891	0.010132	0.019354	0.018978	0.014571	0.008821	0.279525	1.237232
Type I output multipliers	**1.319**	**1.213**	**1.859**	**1.307**	**1.784**	**1.468**	**1.276**	**1.218**	**1.616**	**2.052**	**1.525**	**1.387**	**1.821**	**2.011**

Table 12. Direct CO2 intensities and composition of sectoral output-CO2 multipliers, attribution of CO2 in production to final demand for commodity outputs

	Agriculture	Forestry Planting and Logging	Sea Fishing	Fish Farming	Other Mining and Quarring	Oil and Gas Extraction	Mfr Food drink and tobacco	Mfr textiles and clothing	Mfr Chemicals	Mfr metal and non-metal goods	Mfr transport and other machinery, electrical and inst	Other manufacturing	Water	Construction	Distribution	Transport	Communications, finance and business	R&D	Education	Public and other services	COAL (EXTRACTion)	OIL (refining & Distr oil and nuclear)	Gas	Electricity-Renewable 9hydro and wind)	Electricity-non-renewable (coal, nuke and gas)
Direct CO2 intensities (tonnes CO2 per £1mill. Output)	226	343	643	82	206	246	127	71	194	252	26	210	102	71	188	351	74	37	148	186	221	719	312	276	3857

TYPE I OUTPUT-CO2 MULTIPLIER MATRIX

	Agriculture	Forestry Planting and Logging	Sea Fishing	Fish Farming	Other Mining and Quarring	Oil and Gas Extraction	Mfr Food drink and tobacco	Mfr textiles and clothing	Mfr Chemicals	Mfr metal and non-metal goods	Mfr transport and other machinery, electrical and inst	Other manufacturing	Water	Construction	Distribution	Transport	Communications, finance and business	R&D	Education	Public and other services	COAL (EXTRACTion)	OIL (refining & Distr oil and nuclear)	Gas	Electricity-Renewable 9hydro and wind)	Electricity-non-renewable (coal, nuke and gas)
Agriculture	260.52	8.16	1.02	9.75	0.55	0.54	43.04	0.23	0.45	0.32	0.25	0.41	0.17	1.46	5.23	0.56	0.45	3.22	0.26	0.93	1.19	0.51	0.36	0.54	0.77
Forestry Planting and Logging	0.05	410.36	0.05	0.11	0.12	0.07	0.10	0.02	0.03	0.04	0.01	3.22	0.04	0.37	0.05	0.06	0.10	0.04	0.05	0.10	0.15	0.04	0.05	0.10	0.08
Sea Fishing	0.14	0.03	643.31	0.64	0.04	0.04	2.88	0.01	0.02	0.01	0.01	0.02	0.01	0.06	0.21	0.11	0.03	0.03	0.01	0.04	0.05	0.03	0.02	0.03	0.04
Fish Farming	0.01	0.00	0.01	90.53	0.01	0.01	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.01
Other Mining and Quarring	0.20	0.26	0.05	0.10	223.25	0.18	0.12	0.03	0.15	0.90	0.04	0.27	0.13	3.86	0.23	0.16	0.23	0.12	0.15	0.28	1.10	0.11	0.38	0.31	0.33
Oil and Gas Extraction	0.65	1.42	1.01	0.52	2.18	248.49	0.57	0.29	0.76	0.36	0.19	0.41	0.33	1.15	0.38	1.10	0.50	0.15	0.21	0.56	1.59	43.69	1.46	1.15	1.31
Mfr food, drink and tobacco	5.99	0.53	2.66	28.70	0.36	0.30	135.18	0.18	0.25	0.19	0.17	0.37	0.13	1.18	4.02	0.51	0.50	1.20	0.20	1.33	0.89	0.65	0.22	0.34	0.60
Mfr textiles and clothing	0.06	0.15	4.07	0.53	0.04	0.04	0.05	72.70	0.02	0.06	0.01	0.05	0.01	0.14	0.17	0.05	0.08	0.65	0.09	0.34	0.08	0.03	0.03	0.04	0.08
Mfr chemicals	3.01	2.75	0.82	1.03	3.67	0.57	0.92	0.44	202.35	0.66	0.30	1.12	1.14	2.20	0.36	0.40	0.31	5.93	0.56	1.95	1.03	5.42	0.48	0.58	1.00
Mfr metal and non-metal goods	3.10	6.43	2.51	7.59	2.76	3.85	9.70	0.39	0.70	260.93	5.51	2.67	2.81	13.19	1.84	2.35	1.41	1.18	1.54	2.24	5.39	4.00	1.57	1.77	2.41
Mfr transport and other machinery, electrical and inst	0.38	0.77	1.82	1.44	0.72	0.15	0.30	0.06	0.14	0.22	27.61	0.22	0.38	0.94	0.12	0.42	0.18	0.22	0.21	0.29	0.76	0.17	0.14	1.10	0.54
Other Manufacturing	1.94	4.09	1.78	5.12	1.70	1.86	5.55	0.71	0.71	1.01	0.47	224.00	1.47	7.40	1.88	2.35	4.61	1.56	2.07	4.33	3.15	1.65	1.22	4.16	2.42
Water	0.83	0.05	0.02	0.09	0.10	0.03	0.34	0.06	0.12	0.05	0.04	0.06	101.91	0.04	0.08	0.03	0.03	0.29	1.62	0.19	0.06	0.09	0.03	0.06	0.11
Construction	3.56	4.80	0.58	1.12	4.21	3.44	1.48	0.52	0.92	0.93	0.40	0.73	2.53	85.72	2.07	2.07	4.74	1.60	3.19	3.60	23.82	1.16	8.41	6.55	6.82
Distribution	10.21	7.54	5.97	18.70	7.31	4.62	9.32	4.69	6.12	5.66	6.71	5.78	2.20	6.15	191.94	8.66	3.09	5.79	4.10	4.00	22.93	9.42	2.79	6.22	13.02
Transport	9.98	63.50	34.23	10.74	91.31	47.74	13.51	5.78	14.52	6.78	4.77	10.93	7.60	11.70	10.33	469.40	14.54	6.37	6.98	11.07	37.13	12.26	14.64	9.56	20.61
Communications, finance and business	9.90	12.51	7.56	12.20	19.47	31.71	10.94	4.51	6.64	5.63	3.61	6.22	4.42	26.28	7.30	19.40	93.50	5.71	3.36	12.23	22.64	9.61	9.32	14.41	19.53
R&D	0.05	0.03	0.02	0.03	0.10	0.03	0.06	0.07	0.10	0.05	0.04	0.05	0.07	0.03	0.02	0.10	0.04	36.92	0.02	0.18	0.20	0.04	0.18	0.24	0.46
Education	0.17	0.21	0.13	0.14	0.24	0.23	0.19	0.16	0.26	0.15	0.12	0.16	0.17	0.27	0.10	0.53	0.48	0.17	148.28	0.98	0.30	0.15	0.39	0.48	1.09
Public and other services	5.35	11.44	1.93	7.76	6.19	1.80	3.87	2.59	3.90	1.86	1.02	4.40	1.62	6.62	1.50	4.87	3.13	2.55	3.25	228.56	7.37	1.33	4.18	5.13	11.28
COAL (extraction)	0.20	0.14	0.06	0.18	0.28	0.09	0.22	0.14	0.34	0.22	0.09	0.34	0.25	0.25	0.28	0.13	0.09	0.13	0.13	0.28	222.43	0.45	0.12	3.29	14.49
Oil (refining & distr oil and nuclear)	6.74	13.86	14.06	3.76	8.04	1.90	3.33	0.75	3.82	1.37	0.52	1.80	2.38	2.21	2.33	9.02	2.04	0.76	0.46	4.13	7.86	732.10	0.78	3.45	6.86
Gas	0.28	0.28	0.18	0.64	0.73	0.22	0.89	0.68	1.09	1.11	0.25	0.87	0.30	0.31	0.71	0.56	0.31	0.62	0.78	1.00	0.39	0.74	316.11	3.95	9.83
Electricity-Renewable (hydro and wind)	0.64	0.40	0.16	0.58	0.90	0.29	0.65	0.40	1.02	0.70	0.28	0.62	0.84	0.36	0.94	0.41	0.26	0.43	0.40	0.77	0.76	0.58	0.35	287.27	9.44
Electricity-Non- renewable (coal, nuke and gas)	62.49	38.46	15.98	56.58	87.29	27.68	63.48	39.08	98.57	68.25	27.25	60.13	81.19	34.58	90.97	39.31	24.76	42.01	39.08	74.66	73.21	56.21	34.02	1078.25	4772.52
Type I output-CO2 multipliers	**386**	**588**	**740**	**259**	**462**	**376**	**307**	**134**	**343**	**357**	**80**	**325**	**212**	**206**	**323**	**563**	**155**	**118**	**217**	**354**	**434**	**880**	**397**	**1429**	**4896**

	Agriculture	Forestry Planting and Logging	Sea Fishing	Fish Farming	Other Mining and Quarring	Oil and Gas Extraction	Mfr Food drink and tobacco	Mfr textiles and clothing	Mfr Chemicals	Mfr metal and non-metal goods	Mfr transport and other machinery, electrical and inst	Other manufacturing	Water	Construction	Distribution	Transport	Communications, finance and business	R&D	Education	Public and other services	COAL (EXTRACTion)	OIL (refining & Distr oil and nuclear)	Gas	Electricity-Renewable 9hydro and wind)	Electricity-non-renewable (coal, nuke and gas)
Total final demand (£million) for sectoral output	1002	179	324	316	183	1953	4834	1130	2408	2852	14963	2141	188	5619	12558	4239	13577	89	4833	19640	11	655	350	255	1770
CO2 (tonnes) attributable to commodity output in 1999	387,334	105,289	239,908	81,609	84,506	734,033	1,483,418	151,962	825,806	1,019,547	1,192,231	695,394	39,876	1,159,969	4,056,797	2,384,955	2,109,781	10,529	1,048,671	6,953,313	4,918	576,762	139,046	364,480	8,663,102
CO2 in production (%) attributable to commodity output in 1999	1.12%	0.31%	0.70%	0.24%	0.24%	2.13%	4.30%	0.44%	2.39%	2.95%	3.45%	2.01%	0.12%	3.36%	11.75%	6.91%	6.11%	0.03%	3.04%	20.15%	0.01%	1.67%	0.40%	1.06%	25.10%

For example, if we use the information in Tables 10-12 to examine the impact of production in the Mfr Food, Drink and Tobacco sector. Table 10 shows that of a total output in 1999 of £6,040million (row total), 80% of this (£4,834million) is produced to meet final consumption demand (the other 20% - £1,207million is produced to meet intermediate demand from other Scottish production sectors). Just over 31% of output (£1,884million) is to meet export demand from the rest of the UK, but the biggest share, just under 39% (£2,342million) is to meet export demand from the rest of the world. This means that, under the consumption accounting principle, the majority of CO2 pollution generated in the Scottish economy to support production in this sector would not be accountable as part of Scotland's footprint. Table 12 shows that 1,483,418 tonnes of CO2 generated in Scotland in 1999 were attributable to final consumption demand for the outputs of the Mfr Food, Drink and Tobacco sector. As 87.4% ((£1,884m+£2,342m/4,834m) of final demand for this sector's output is export demand, this means that 87.4% of this total (1,296,752 tonnes of CO2), or 3.76% of total CO2 generated across Scottish production, would not be attributed to Scotland's footprint. On the other hand, however, this analysis does not take account of emissions engendered in other countries to produce imports of food and drink to Scottish final consumption.

However, even if the bulk of emissions generated in Scotland to support final demand for the outputs of the Scottish Mfr Food, Drink and Tobacco sector would not be accountable in Scotland's footprint, it is still useful to use consumption accounting principles to trace pollution generation and/or resource use 'hotspots' in the supply chain that supports this sector. The Mfr Food, Drink and Tobacco sector column in Table 11 shows us how much output (£million) was produced in each production sector of the Scottish economy for every £1million of final demand for the output of this sector in 1999. Identifying whether each entry translates to a CO2 hotspot will depend on (1) the size of the output multiplier in each sector – e.g. the strongest backward linkage is with Agriculture, £0.1906million – and (2) the CO2 intensity of that output – e.g. the top row of Table 12 tells us that Agriculture directly generates 226 tonnes of CO2 per £1million output produced. So, for example, £1million of final demand for Mfr Food, Drink and Tobacco output has a relatively low output multiplier effect in the Electricity-Non-renewable sector (£0.016455million), but the latter is the most directly CO2 intensive sector of the Scottish economy (3857 tonnes per £1million output) so that the largest indirect output-CO2 multiplier effect in Table 12 is observed here (63.48 tonnes per £1million final demand for Mfr Food, Drink and Tobacco output). On the other hand, the second largest output multiplier effect in the Mfr Food, Drink and Tobacco sector column of Table 11 is observed for the Communications, Finance and Business sector (£0.148million). However, this sector has a relatively low direct CO_2 intensity (74 tonnes per £1million output) so that the output-CO_2 multiplier effect is 10.94 tonnes per £1million final demand for Mfr Food, Drink and Tobacco. In the Agriculture sector, where we have the strongest output multiplier effect (£0.191million), we also have a relatively high direct CO_2 intensity (226 tonnes per £1million output) so that the output-CO_2 multiplier effect is also large (43 tonnes CO_2 per £1million final demand for Mfr Food, Drink and Tobacco). In terms of aggregation (here we have a similar aggregation to the 76-sector NAMEA – see Appendices 3 and 7), note that there are large own-sector output and output-CO_2 multiplier effects for Mfr Food, Drink and Tobacco. It would be useful and interesting to be able to examine the composition of these effects in a more disaggregated framework.

This type of 'hotspot' analysis allows us to begin considering how Scottish production (which Scottish and/or UK government has some jurisdiction over – in contrast to production in other countries, which would seem to be a key issue for policy analysis based on footprint analyses) processes could be targeted in potential policy interventions to improve the sustainability of Scottish production. For example, given that the biggest output-CO_2 multiplier effect is observed here in the Electricity-Non-renewable sector, a shift/switch towards using electricity generated from renewable sources would be beneficial. However, this would involve a change in supply-side behaviour towards an activity (electricity generation from renewable sources) that is currently constrained in terms of the total amount of output it can produce. An IO model, where we assume unconstrained/infinitely elastic supply and fixed production technologies, would not be an appropriate framework for an impact analysis of this nature: in Section 6.3 we discuss using the IO accounting framework as a database for a more flexible and theory consistent CGE modeling framework.

It is also useful to examine the extent to which the total output-CO_2 multiplier for each sector (column totals of the output-CO_2 multiplier matrix in Table 12) is accounted for by direct and indirect emissions. For example, in Figure 1 below, the direct CO_2 intensities for each of the non-energy supply production sectors (sectors 1-20 in Appendix 3) are graphed alongside the output-CO_2 multipliers:

Figure 1. Direct CO2 intensities and output-CO2 multipliers in the 20 non-energy supply production sectors of the Scottish economy

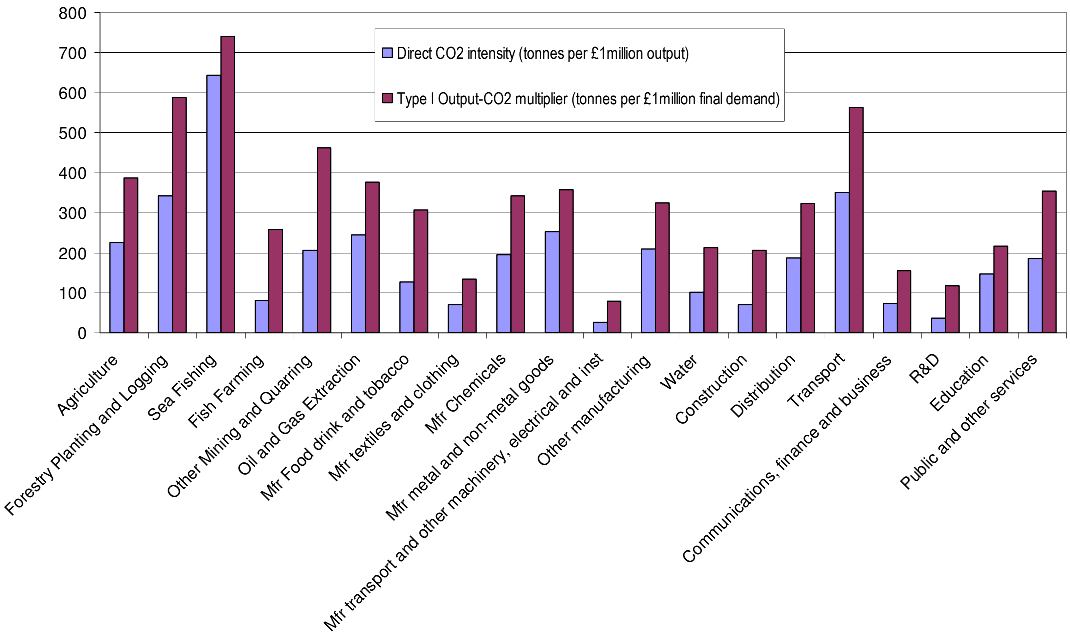


Figure 1 shows that indirect effects dominate in sectors such as Fish Farming, Other Mining and Quarrying and Mfr Food, Drink and Tobacco. However, they are less important in some sectors, such as Mfr Metal and Non-Metal Goods, where just over 70% of the emissions attributable to final consumption demand for this sector's output are direct own-sector emissions (plus some indirect own-sector emissions). This is reflected in the very large own-sector entry Mfr Metal and Non-Metal Goods column of the output-CO2 multiplier matrix in Table 12. Another sector where direct rather than indirect output-CO2 multiplier effects dominate is the Sea Fishing sector. We can take this as an example of how we can trace the source of CO2 effects back to energy use. Table 13 below shows the direct oil use intensities (dividing total oil use from the 25-sector NAMEA in Table 10 by total output in the Sea Fishing sector), along with the Type I oil-output multipliers (i.e. total oil use in all Scottish production sectors required to support £1million final demand for Sea Fishing output – calculated in the same way as the column totals of the output-CO2 multiplier matrix in Table 12).

Table 13. Direct oil use intensities and Type 1 oil-output multipliers

	Agriculture	Forestry Planting and Logging	Sea Fishing	Fish Farming	Other Mining and Quarring	Oil and Gas Extraction	Mfr Food drink and tobacco	Mfr textiles and clothing	Mfr Chemicals	Mfr metal and non-metal goods	Mfr transport and other machinery, electrical and inst	Other manufacturing	Water
Direct oil intensities (tonnes per £1million output)	78	114	223	23	63	20	17	8	36	16	4	15	33
Type I oil-output multipliers (tonnes per £1million final demand)	104	176	244	48	116	50	47	13	49	23	9	27	40

cont....

	Construction	Distribution	Transport	Communications, finance and business	R&D	Education	Public and other services	COAL (EXTRACTion)	OIL (refining & Distr oil and nuclear)	Gas	Electricity-Renewable 9hydro and wind)	Electricity-non-renewable (coal, nuke and gas)
Direct oil intensities (tonnes per £1million output)	11	27	139	20	2	7	39	66	133	1	18	16
Type I oil-output multipliers (tonnes per £1million final demand)	32	39	196	34	11	14	59	99	151	13	36	46

From the Sea Fishing entries for total physical energy use in 1999 in Table 10 we can see that oil (in this case diesel) is the main type of energy used in the Sea Fishing sector, and that direct rather than indirect oil use what is the key determinant of direct emissions in this case. The sector has a larger electricity-output multiplier but total electricity use attributable to this sector is still very small (0.07% - calculation not shown). Generally, while the Sea Fishing column total of Table 11 shows that this sector has an output multiplier of 1.455 (£1.455million output generated in the Scottish economy per £1million final demand for Sea Fishing output), CO2 multiplier effects are relatively unimportant in this sector. Instead it is direct use of oil (diesel) that is the most important source of emissions to support this sector's activity.

The analysis in this section has focused on sectors that are likely to be important in terms of use of a NAMEA framework in a sustainability assessment. However, a much fuller analysis would be possible, even with the experimental data used here. Such an analysis is outwith the scope of this report; instead we have focused on using potential key sectors to demonstrate the type of analysis that would be possible with the fuller, more comprehensive, accurate and up-to-date environmental IO data that will shortly be available for Scotland.

6 Limitations of and potential extensions to a single region Scottish NAMEA/environmental IO framework

So far in this report, we have introduced environmental IO accounts for Scotland as an example of a NAMEA framework, gone through the basic multiplier methodology that we can use to examine pollution/waste generation and/or resource use under production and consumption accounting principles, and considered the extent to which current developments of the Scottish IO framework will facilitate a sustainability analysis of the Scottish food and drink sector. In terms of current and/or forthcoming data for a single region Scottish analysis, the main concern for such an analysis is likely to be overaggregation of key food and drink supply sectors, and lack of information for 'social' aspects of a sustainability analysis.

These are practical issues for the specific case of Scotland. In principal they can be resolved with more detailed data but this will have resource implications and require further consultation. However, there are more generic issues to be considered in terms of the strengths and weaknesses of the environmental IO method. This is the purpose of this section of the report.

6.1 Strengths and weaknesses of the environmental IO method

Input-output analysis of the structure of economic activity is already commonplace, particularly in Scotland. This reflects the transparency and analytical rigour of the approach, strengths that are shared by the extension to environmental IO analysis of the structure of resource use and/or pollution/waste generation problems in a given region/country for a given time period (the year that the accounts relate to). As the previous sections of this report have hopefully demonstrated, given the very high level of sectoral detail captured in IO accounts, environmental IO analysis is an ideal framework for quantifying the interdependence of different activities and tracking all direct, indirect and, where appropriate, induced, resource use and/or pollution generation embodied within consumption at both the sectoral and aggregate levels. Moreover, given the increasing use of environmental IO techniques for pollution and resource accounting, under both production and consumption accounting principles, its adoption will hopefully lead to standardisation and consistency across regions and countries in the world, just as economic IO methods have become part of standard national accounting practices.

The main limitations of IO lie in the assumptions required for analyses. The key issue, however, is to be clear on what assumptions are required in different types of analysis and their implications. As explained more fully in Section 2.2, where we considered the use of multipliers for impact analysis, if we are using environmental IO multiplier analysis to consider the structure of pollution and/or resource use problems in the year that the accounts relate to, the input-output coefficients and physical coefficients that underlie IO multipliers can be taken to represent average relationships/technologies in the accounting year that the IO accounts apply to. Moreover, we are examining historical supply and demand activities that actually took place. However, if we want to use multipliers for impact analyses/what if scenarios, the coefficients become fixed proportional technologies that imply rigid production functions that do not respond to changes in prices, and we cannot consider the presence of any constraints on supply (that may lead to changes in prices). For these reasons, it is appropriate to use the environmental IO framework as a database for a more flexible model, rather than a model in its own right. However, generally, in developing more sophisticated models it is necessary to work with a smaller number of sectors than is possible in an IO framework. It is necessary, therefore, to carefully consider what sectors need to be modeled separately, and an IO attribution analysis of the type illustrated here (Sections 2.2 and 5) may be an ideal first step in this process.

We return to the issue of modeling 'what if' scenarios in Section 6.3. Before this we consider a particular problem with the type of single region environmental IO analysis outlined above for accounting for pollution generation and/or resource use under the consumption accounting principles that are gaining prominence in the public and policy debate.

6.2 Interregional environmental IO analysis

The illustrative attribution of Scottish CO2 emissions to final consumption demand by commodity or type of consumer under the consumption accounting principle in Sections 2.2 and 5 raises two important additional implications/limitations for single region environmental IO analysis:

3. A share of emissions is allocated to external (export) demand.
4. No account is taken of emissions embodied in imports.

A crucial issue impacting on unilateral attempts to fulfil national emissions reductions targets under the Kyoto Protocol is the impact of international trade on any one country's domestic emissions generation. The problem is that the generation of emissions in producing goods and services to meet export demand is charged to the producing nation's emissions account. This means that point (1) here has implications in terms of meeting regional/national targets for domestic emissions reductions where local activity is partly driven by external demand. The flip-side of this issue is that point (2) has implications in terms of concerns over 'importing sustainability' from other countries.

Both concerns are reflected in the consideration of 'environmental trade balances', as the difference between the pollution (or resource use) embodied in exports and that embodied in imports (Munksgaard and Pedersen, 2001; McGregor et al, 2008). As with the trade balance in goods and services, the environmental trade balance relationship for any economy can be examined in an IO framework. If we extend the single region IO framework presented in Sections 3 and 5 (and Appendix 1) to a multi or interregional IO framework (see Appendix 4), identifying Scotland's key direct and indirect trade partners, it is possible to examine emissions under the consumption accounting principle more accurately, taking account of the pollution content of trade flows and pollution trade balances between regions/countries. Ideally what would be required is a world interregional IO framework, in order to fully capture technologies embodied in production located in the economies of all direct and indirect trade partners. However, the data requirements of constructing the interregional IO system in Appendix 4 to account for all of the countries that Scotland directly and indirectly imports goods and services from are demanding. As explained by Turner et al (2007) and Turner (2008b), for a very open economy like Scotland, this would essentially require a world interregional input-output table, with compatible environmentally augmented input-output tables for each of the countries that directly and indirectly exports goods and services to Scotland. Moreover, corresponding data on interregional trade flows at the sectoral/commodity level would also be required.

At present, such a database is simply not available. For practical applications at this stage, where interest lies in accounting for emissions under the consumption accounting principle, this report recommends that the main focus should be on extending to an interregional IO framework that incorporates information on Scotland's main trade partners, beginning with the rest of the UK economy.

Appendix 4 provides a technical specification of the interregional environmental IO method. This basically involves identifying additional production sectors and final consumption groups located in other regions. The method in Appendix 4 is applicable to the *N*-region case. However, McGregor et al (2008) apply this method to the two-region case of Scotland and the rest of the UK (RUK) in an interregional IO analysis of the CO2 trade balance between Scotland and the rest of the UK for the same 10-sector aggregation in each region (see Appendix 5). This (illustrative) analysis adopts a mix of accounting principles, with emissions embodied in intra-UK trade treated under the consumption accounting principle but with the system closed at the national (UK) level under the production accounting principle to reflect national policy objectives under the Kyoto Protocol.

It is important to note that McGregor et al's (2008) analysis[11] is based on highly experimental data (for the accounting year of 1999) in terms of the interregional trade flows between Scotland and the rest of the UK and the UK analytical IO table. However, it uses an aggregated version of the official Scottish 1999 IO table. In terms of sectoral CO2 data, UK emissions intensities (from the UK environmental accounts) are applied to both Scotland and the rest of the UK, with differences in the emissions intensities of each of the 10 production sectors in each region arising from differences in the composition of these sectors. However, Scottish-specific data are applied to electricity generation within the Electricity, Gas and Water Supply Sector (based on the results from Turner, 2003).

However, under Karen Turner's current ESRC Climate Change Leadership Fellow project, the quality and accuracy of the Scotland-RUK interregional framework (mostly likely to be constructed for 2004) will be greatly improved with the assistance of the Scottish Government IO team, and up to the 76-sector NAMEA sectoral breakdown in Appendix 7 will be possible in each region. It is likely that the spatial disaggregation will also be extended, with identification of Wales as a region (contained within RUK in the illustrative application reported here), and the range of pollutants accounted for (though this will be limited as explained in Section 4.2), with some fuel uses.

[11] McGregor et al's (2008) work originated with a small project sponsored by the Scottish Economic Policy Network. Various non-technical papers are available on request from karen.turner@strath.ac.uk.

Table 14. Scottish columns of Type I Scotland-rest of the UK interregional output multiplier matrix

	Purchasing sector / Producing Sector	SCOTLAND PRIMARY	MANUFACT-URING	ELEC, GAS & WATER SUPPLY	Construc-ion	WHOLESALE & RETAIL TRADE	TRANSPORT & COMMUNICATION	FINANCIAL INT & BUSINESS	PUBLIC ADMINISTRATION	EDUC, HEALTH & SOCIAL WORK	OTHER SERVICES
	PRIMARY	1.086846	0.043404	0.060291	0.035470	0.022727	0.007401	0.006759	0.006074	0.006253	0.018802
D	MANUFACTURING	0.099517	1.087226	0.061695	0.154721	0.059950	0.053094	0.047104	0.047178	0.047058	0.146546
N	ELEC, GAS & WATER SUPPLY	0.018855	0.017724	1.249028	0.012155	0.029347	0.013478	0.008994	0.012799	0.022691	0.072194
A	CONSTRUCTION	0.056595	0.010993	0.081569	1.208470	0.028811	0.029243	0.069771	0.063455	0.029146	0.078108
L	WHOLESALE & RETAIL TRADE	0.044984	0.036769	0.050456	0.033374	1.022263	0.039882	0.016589	0.019732	0.023172	0.021493
T	TRANSPORT & COMMUNICATION	0.112807	0.031147	0.068068	0.046212	0.038474	1.281631	0.084181	0.039813	0.030838	0.090074
O	FINANCIAL INT & BUSINESS	0.241559	0.078797	0.217808	0.346989	0.091457	0.212936	1.236655	0.133679	0.112500	0.190948
C	PUBLIC ADMINISTRATION	0.001779	0.000443	0.001025	0.001915	0.000525	0.002117	0.003118	1.001993	0.000508	0.001108
S	EDUC, HEALTH & SOCIAL WORK	0.007967	0.002874	0.015764	0.003271	0.001621	0.006738	0.005853	0.016252	1.333096	0.003310
	OTHER SERVICES	0.012544	0.008481	0.032404	0.026725	0.005258	0.016486	0.009527	0.032284	0.020125	1.023287
K	PRIMARY	0.035165	0.030306	0.013546	0.021437	0.011403	0.008717	0.005603	0.008149	0.008233	0.007719
U	MANUFACTURING	0.128671	0.234685	0.071690	0.167466	0.108815	0.125163	0.074437	0.130229	0.126109	0.072831
	ELEC, GAS & WATER SUPPLY	0.005875	0.010629	0.038657	0.006698	0.011741	0.005655	0.004902	0.008098	0.010358	0.005555
F	CONSTRUCTION	0.008107	0.009346	0.024088	0.031329	0.013800	0.008120	0.012413	0.005674	0.012172	0.012644
O	WHOLESALE & RETAIL TRADE	0.016288	0.021889	0.026785	0.016713	0.016943	0.016397	0.013874	0.021440	0.015482	0.010457
	TRANSPORT & COMMUNICATION	0.030279	0.038875	0.038916	0.032082	0.029981	0.054618	0.054172	0.028468	0.035361	0.030682
T	FINANCIAL INT & BUSINESS	0.074344	0.107752	0.159530	0.086972	0.067742	0.079500	0.117164	0.062219	0.058122	0.069958
S	PUBLIC ADMINISTRATION	0.000587	0.000848	0.001028	0.000591	0.000450	0.000538	0.000735	0.000416	0.000401	0.000466
E	EDUC, HEALTH & SOCIAL WORK	0.003587	0.006941	0.018209	0.003882	0.002863	0.005325	0.005115	0.002676	0.002992	0.003529
R	OTHER SERVICES	0.003639	0.009159	0.018331	0.004367	0.002959	0.004560	0.003908	0.003346	0.002850	0.003579
	Type I output multiplier (Scotland)	**1.68**	**1.32**	**1.84**	**1.87**	**1.30**	**1.66**	**1.49**	**1.37**	**1.63**	**1.65**
	Type I output multiplier (RUK)	**0.31**	**0.47**	**0.41**	**0.37**	**0.27**	**0.31**	**0.29**	**0.27**	**0.27**	**0.22**
	Type I output multiplier (UK)	**1.99**	**1.79**	**2.25**	**2.24**	**1.57**	**1.97**	**1.78**	**1.64**	**1.90**	**1.86**

Table 15.Direct CO2 intensities and composition of Scottish sectoral Scotland-rest of UK interregional output-CO2 multipliers

	PRIMARY	MANUFACT-URING	ELEC, GAS & WATER SUPPLY	Construc-ion	WHOLESALE & RETAIL TRADE	TRANSPORT & COMMUNICATION	FINANCIAL INT & BUSINESS	PUBLIC ADMINISTRATION	EDUC, HEALTH & SOCIAL WORK	OTHER SERVICES
CO2 (tonnes) per unit output (£1million):										
Scottish sectors	608.7	224.1	3221.6	39.8	58.9	490.2	32.8	120.1	56.2	42.6
RUK sectors	663.1	312.3	3059.5	39.8	58.9	482.9	32.5	120.1	57.6	38.8

Scottish columns of Type I interregional output-CO2 multiplier matrix

	Purchasing sector / Producing Sector	SCOTLAND PRIMARY	MANUFACT-URING	ELEC, GAS & WATER SUPPLY	Construc-ion	WHOLESALE & RETAIL TRADE	TRANSPORT & COMMUNICATION	FINANCIAL INT & BUSINESS	PUBLIC ADMINISTRATION	EDUC, HEALTH & SOCIAL WORK	OTHER SERVICES
	PRIMARY	661.609	26.422	36.702	21.592	13.835	4.505	4.114	3.697	3.807	11.446
D	MANUFACTURING	22.297	243.594	13.823	34.665	13.432	11.896	10.554	10.570	10.543	32.834
N	ELEC, GAS & WATER SUPPLY	60.744	57.098	4023.852	39.157	94.544	43.421	28.977	41.234	73.102	232.580
A	CONSTRUCTION	2.254	0.438	3.248	48.126	1.147	1.165	2.779	2.527	1.161	3.111
L	WHOLESALE & RETAIL TRADE	2.649	2.165	2.971	1.965	60.198	2.349	0.977	1.162	1.365	1.266
T	TRANSPORT & COMMUNICATION	55.296	15.268	33.366	22.653	18.859	628.236	41.264	19.516	15.117	44.153
O	FINANCIAL INT & BUSINESS	7.930	2.587	7.150	11.391	3.002	6.990	40.598	4.388	3.693	6.269
C	PUBLIC ADMINISTRATION	0.214	0.053	0.123	0.230	0.063	0.254	0.375	120.347	0.061	0.133
S	EDUC, HEALTH & SOCIAL WORK	0.448	0.162	0.887	0.184	0.091	0.379	0.329	0.914	74.982	0.186
	OTHER SERVICES	0.534	0.361	1.380	1.138	0.224	0.702	0.406	1.375	0.857	43.569
K	PRIMARY	23.317	20.095	8.982	14.214	7.561	5.780	3.715	5.403	5.459	5.118
U	MANUFACTURING	40.190	73.302	22.392	52.307	33.988	39.094	23.250	40.676	39.389	22.748
	ELEC, GAS & WATER SUPPLY	17.974	32.521	118.273	20.492	35.923	17.303	14.998	24.776	31.690	16.996
F	CONSTRUCTION	0.323	0.372	0.959	1.248	0.550	0.323	0.494	0.226	0.485	0.504
O	WHOLESALE & RETAIL TRADE	0.959	1.288	1.577	0.984	0.997	0.965	0.817	1.262	0.911	0.616
	TRANSPORT & COMMUNICATION	14.622	18.773	18.793	15.493	14.478	26.376	26.160	13.747	17.076	14.817
T	FINANCIAL INT & BUSINESS	2.415	3.500	5.182	2.825	2.200	2.582	3.806	2.021	1.888	2.272
S	PUBLIC ADMINISTRATION	0.070	0.102	0.124	0.071	0.054	0.065	0.088	0.050	0.048	0.056
E	EDUC, HEALTH & SOCIAL WORK	0.207	0.400	1.049	0.224	0.165	0.307	0.295	0.154	0.172	0.203
R	OTHER SERVICES	0.141	0.355	0.711	0.169	0.115	0.177	0.152	0.130	0.111	0.139
	Type I output-CO2 multiplier (Scotland)	**813.98**	**348.15**	**4123.50**	**181.10**	**205.40**	**699.90**	**130.37**	**205.73**	**184.69**	**375.55**
	Type I output-CO2 multiplier (RUK)	**100.22**	**150.71**	**178.04**	**108.03**	**96.03**	**92.97**	**73.78**	**88.45**	**97.23**	**63.47**
	Type I output-CO2 multiplier (UK)	**914.19**	**498.86**	**4301.54**	**289.13**	**301.43**	**792.87**	**204.15**	**294.18**	**281.92**	**439.01**

The analyses in the McGregor et al (2008) paper focus on attribution of CO2 emissions generated within the UK to final consumption demand in the two regions, Scotland and RUK, and the consequent CO2 trade balance between these regions. This constitutes an interregional variant of the type of single region results reported in Table 9 above. Here, we focus instead on extending the 'hot spot' backward supply chain analysis reported in Tables 5 and 6 and 11 and 12 for the single region case.

Table 14 above shows the composition of each Scottish sector's output multiplier (output in each other sector produced to meet £1million of final demand in the accounting year of 1999). The top half of this matrix (output multiplier effects in Scottish production sectors) shows the same information (but for a different sectoral aggregation) that we have seen for 1999 in Tables 5 and 11). However, the bottom half shows output (£million) that were produced (according to the experimental interregional trade data available for 1999) in the rest of the UK per £1million of final demand for each Scottish sector. (Note that the equivalent data could be shown for RUK production sectors – here we stick with the example of Scottish production.) The Agriculture, Sea Fishing and Fish Farming sectors that we identified to be of interest in the current context in the 25-sector analysis in Section 5 are now aggregated with forestry and mining activities in the Primary sector (see Appendices 2 and 5) and the Mfr Food, Drink and Tobacco sector is aggregated with other Manufacturing activities. (As noted, above, this will not be the case in the interregional framework now being constructed for 2004.)

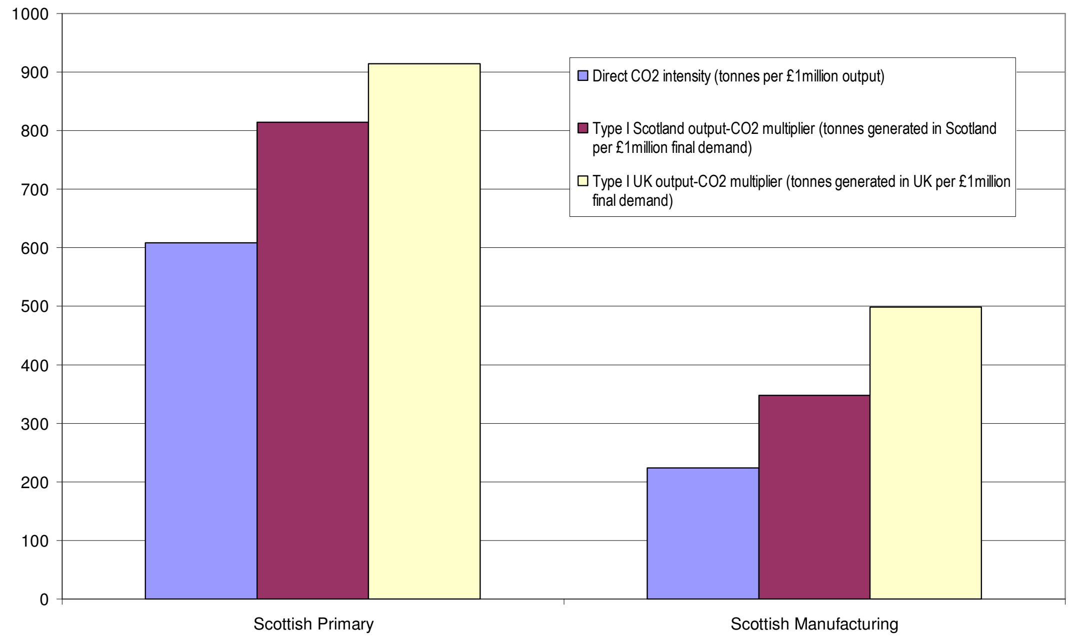
If we read down the Primary and Manufacturing sector columns in Table 14, the first thing to note is that the Scottish Primary sector has stronger backward linkages in both Scotland and the rest of the UK than the Manufacturing sector (bigger output multipliers). Primary's strongest backward linkages/output multiplier effects in Scotland are to the Financial Intermediation and Business sector (again, see Appendices 2 and 5 for sectoral compositions) and the Transport and Communications sector. If we look at the top row of Table 15, we can see that the latter has the third highest direct CO2 intensity among the 10 Scottish production sectors identified, while the former has the smallest. As explained in Sections 2.2 and 5, this will impact on the size of the output-CO2 multiplier effects.

However, what the interregional framework adds relative to the analyses in Sections 2.2 and 5, is that using Tables 14 and 15 we can also examine output and output-CO_2 multiplier effects that take place outside of Scotland in the rest of the UK. For example, from the bottom half of Table 14, we can see that the Scottish Primary sector's strongest output multiplier effect in the rest of the UK is in the RUK Manufacturing sector. For every £1million of final demand for Scottish Primary output in 1999, £0.128671million, or £128,671, production of output was required in RUK Manufacturing. The latter had a direct CO_2 intensity of 313 tonnes per unit of output (2^{nd} row in grid at the top of Table 15) so that the output-CO_2 multiplier for this transaction is 40.19 tonnes of CO_2 generated in the RUK Manufacturing sector per £1million final demand for Scottish Primary sector output.

Reading down the full column of Table 15 for each sector, we can identify CO_2 'hotspots' in both regions. For Scottish Primary, we see that the largest element of the total UK output-CO_2 multiplier is the 661.6 tonne own-sector effect. However, this includes 608.7 tonnes in direct emissions to produce the £1million directly demanded. The second biggest output-CO_2 multiplier effect is in the Scottish Electricity, Gas and Water Supply sector, 60.7 tonnes CO_2 per £million final demand for Scottish Primary output. Note from Table 14 that the output multiplier is relatively small here (£0.018855million); however, the top row of Table 15 shows that production in this sector is highly CO_2 intensive (3221.6 tonnes). The third largest output-CO_2 multiplier is in Transport and Communication (just under 55.3 tonnes), where we have already noted there is a relatively high output multiplier effect with respect to final demand for Primary sector output (£0.112807million) but also a relatively high CO_2 intensity (490.2 tonnes per £1million output). As noted above, in RUK, the largest output-CO_2 multiplier effect from final demand for Scottish Primary is in the Manufacturing sector; again here we have a relatively strong output multiplier effect combining with a relatively high direct CO_2 intensity in the producing sector. The output-CO_2 multiplier effects from the Scottish Primary sector that are observed in the RUK Primary and Electricity, Gas and Water Supply sectors, on the other hand, result from these being sectors with relatively high CO_2 intensities, rather than from strong output effects.

If we do a similar analysis for the Scottish Manufacturing sector, we can see that there are generally weaker backward output multiplier links throughout the Scottish and RUK economies than in the case of the Primary sector. The strongest output and output-CO2 multiplier effects are observed in the Scottish Manufacturing sector itself (both direct and indirect). Again, we can see relatively strong output-CO2 multiplier effects in the Electricity, Gas and Water Supply sectors in both regions (even with relatively low output multiplier effects, again due to the CO2-intensity of these activities, particularly electricity generation, in both regions). In terms of the interregional output and output-CO2 effects, the biggest impact is generated in the RUK Manufacturing sector. Again, this raises the issue of over aggregation of sectors – Scottish and RUK manufacturing sectors are clearly interdependent but a more disaggregated interregional analysis would allow us to better understand the nature of these interactions and the resulting environmental pressures.

Figure 2. Direct CO2 intensities and regional/interregional UK output CO2 multipliers in the Scottish Primary and Manufacturing sectors



However, this illustrative analysis demonstrates how useful it would be to examine not only direct vs indirect output and output-pollution (or resource) multiplier effects within the Scottish economy, but also the ripple effects of Scottish production and consumption decisions on our trading partners. Figure 2 above summarises the total output-CO2 multiplier effects in the UK for the Scottish Primary and Manufacturing sectors – the key thing to note is that these rise as we take more elements of the supply chain into account (i.e. from direct CO2 emissions to direct plus indirect in Scotland, then in the UK). However, questions arise; for example:

1. Our analysis in Sections 2.2 and 5 tells us that much of the final consumption demand for the outputs produced by Scottish production sectors does not originate in Scotland. What, if any, impact should this have on any attempt to address environmental pressures of Scottish production?
2. A flip-side to the previous question is just what we could or should do about hotspots in other regions? In terms of other UK regions, this may be quite a lot, but the nature of devolution in the UK and policy coordination among UK regions is crucial. However, what if the analysis above were for Scotland and, e.g., China? Can we act or influence to reduce the (direct and/or indirect) pollution intensity of Chinese production? Should we reduce our (intermediate and/or final) consumption of Chinese goods where these are pollution intensive?

This report does not attempt to address such questions. Instead the purpose of presenting these illustrative examples is to show the type of analysis that is, or will shortly be possible for Scotland using a NAMEA approach, and the type of questions we may want to use such frameworks to identify and/or address. The intention in this section is to illustrate how single region analysis may not be sufficient.

The McGregor et al (2008) study and the additional sectoral level analysis above constitutes a limited empirical application of the multi-region input-output (MRIO) method of accounting for pollution trade balances proposed by Turner et al (2007). It uses experimental inter-regional trade data for 1999 supplied by the Scottish Government's input-output (IO) team. It is also important to note this application embodies a particular theoretical and policy perspective. However, once a more reliable interregional IO framework is developed for the UK, it will be possible to investigate the attribution of pollution generation and resource use systematically under a range of alternative theoretical and policy perspectives and combinations of the consumption and production accounting principles. Note that part of this research effort involves a PhD studentship under the ESRC Collaborative Governmental programme, sponsored by the Scottish Government and due to begin in October 2009 under the supervision of Karen Turner and Kim Swales at the University of Strathclyde. This studentship will run alongside and be closely linked to Karen Turner's ESRC Climate Change Leadership Fellow project, but focus specifically on interregional environmental IO analysis for Scotland and the Rest of the UK.

Whether or not the interregional UK framework could be extended to estimate footprint measures that take account of the *global* impact of Scottish consumption behaviour will depend on data availability and what assumptions we are prepared to make. For example, due to a lack of data on actual emissions embodied in external trade flows, Druckman et al (2008) adopt what is known as the 'domestic technology assumption' in accounting for the emissions content of imports. That is, they assume that imported goods are produced using UK technology. While this will not result in an accurate footprint measure (which, as explained above, would ultimately require a world interregional environmental IO account), it does allow consideration of what the impact of UK consumption would be if there were no trade and the UK had to produce all the goods and services required for consumption domestically. This relates directly to concerns over 'importing sustainability' and was also considered as a methodology for taking account of the pollution content of imports by National Statistics (2002b). A similar accounting exercise could be carried out for Scotland in terms of trade with other UK regions as well as external transactors (and would be possible in the single region framework with the only additional data requirement being imports broken down by commodity, data that are currently being prepared by the Scottish Government IO team to assist Karen Turner's ESRC Climate Change Leadership Fellow project).

6.3 Computable general equilibrium modeling

As demonstrated in the preceding sections, input-output analysis is a powerful accounting tool for examining the structure of economic activity and, particularly if/where it can be extended in an interregional context, associated issues such as the pollution and/or resource use engendered or embodied, directly or indirectly, in production, consumption and trade flows. However, where concern lies in analysing the impacts of *changes* in policy, or other disturbances, on variables of interest, such as environmental trade balances, due to the limitations outlined in Section 6.1 (the assumptions of fixed proportionate technology and the ability to model only prices or quantities, demand or supply in particular) a more flexible framework is required. Such a framework would allow us to model both supply and demand side behaviour, and prices and quantities. An approach that incorporates the main strengths of input-output for the treatment of environmental problems – i.e. the multi-sectoral, system wide features of input-output tables – but builds a more flexible (and theory consistent) analytical framework around this, is computable general equilibrium (CGE) modelling. CGE modelling is now firmly established in the academic literature as the dominant approach for analysing global, national and regional environmental issues (see, for example, Bergman, 1988, Beausejour et al., 1995, Conrad, 1999, Welsch, 1996, Wissema and Dellink 2007; and, for the UK and Scotland, Allan et al., 2007b, Hanley et al., 2006, 2009, and Turner, 2009 for Scotland/UK). Moreover, in the current context, it offers the advantage of utilising the same database as required for the IO accounting work outlined above. It also permits more flexibility in terms of modeling *causal* relationships between economic activity and environmental impacts (and/or social ones), thus addressing concerns raised in Section 4.3 above. The most straightforward development here is the ability to model changes in pollution generation due to adjustments in inputs to production/consumption (in response to changes in relative prices) and/or changes in technology.

The regional modeling team at the Fraser of Allander Institute, Department of Economics, University of Strathclyde, have been involved in research to develop an energy-economy-environment CGE modeling framework for Scotland (AMOSENVI) throughout the last decade, mainly through several large scale projects funded by two of the UK research councils (ESRC and EPSRC). In 2008, the Scottish Government commissioned a study (Allan et al, 2008) titled 'The impact on the Scottish economy of reducing greenhouse gas emissions in Scotland: illustrative findings from an experimental computable general equilibrium model for Scotland'. This involved modelling a number of scenarios involving changes in both supply and demand side activities that may impact on the level of greenhouse gas emissions in the Scottish economy and the resultant economic impacts. For example, the impacts of increases in energy efficiency in production (a supply-side change that cannot be easily introduced to an IO model without adjusting the value of fixed input-output coefficients off-line) and the resulting ripple effects throughout the economy (mainly resulting from demand and supply side responses to changes in prices, again, which cannot be modelled simultaneously in an IO model) were simulated.

However, in order to analyse the impacts of changes in activity in Scotland on other regions (including the impact on pollution generation and resource use under consumption accounting principles), and vice versa, an *interregional* CGE modelling framework is required. The Strathclyde regional modelling team has already developed some expertise in this area and a 2-region, 3-sector CGE modelling framework has already been constructed and used for analysis of UK interregional issues (see Gilmartin et al, 2007a,b), including a rudimentary analysis of the environmental trade balance between Scotland and the rest of the UK (Gilmartin et al, 2008), developed with the support of EPSRC to illustrate the type of model development proposed under Karen Turner's ESRC Climate Change Leadership Fellowship and presented to colleagues at recent conferences of the International Input Output Association and US Western Regional Science Association.

Again, while illustrative (as with the IO analyses presented in this report) Gilmartin et al's (2008) analysis demonstrates the limitations of IO and potential value-added from a more flexible CGE modeling framework with respect to one of the applications identified in Section 2.2: use of multipliers for impact analysis. A 10% increase in export demand from the rest of the world (ROW) for the outputs of the RUK Primary, Construction and Manufacturing sector is introduced first to the IO model and then to the CGE model (which shares the 1999 IO database).[12] Table 16 reports the results of the IO impact analysis. While the quantitative results should be regarded with caution due

[12] See Appendix 6 for sectoral classifications in the 2-region, 3-sector framework – these are the same as in the IO analysis in Section 2.2

to the experimental and highly aggregated nature of the database (such a high aggregation is not required for CGE modeling), there are several key features of the qualitative nature of the results that reflect the restrictive assumptions required to use IO for impact analysis. First, note that for any one variable in each sector, all variables change by the same percentage amount. For example, in the Scottish Primary, Manufacturing and Construction sector, output increases by 0.99% and all inputs and associated outputs also increase by 0.99%: use of labour/employment increases by 0.99%, as does capital (not shown here); with no changes in price (due to passive supply and the quantity model used here), total payments to capital and labour (value-added) also increase by 0.99%, as do direct emissions of CO2 in this sector.

Table 16. IO impact analysis of a 10% increase in ROW export demand to the RUK Primary, Manufacturing and Construction sector; % change in key variables

	Output		GDP (Value-added)		Employment		Direct CO2 emissions	
	Base (£million)	% change	Base (£million)	% change	Base (FTE, thousands)	% change	Base (tonnes, millions)	% change
Scotland:								
PRIMARY, MFR and CONSTRUCTION	52471	0.99%	17134	0.99%	483	0.99%	12.4	0.99%
ELEC, GAS & WATER SUPPLY	5047	1.52%	1508	1.52%	14	1.52%	16.3	1.52%
SERVICES	83723	0.81%	43982	0.81%	1334	0.81%	9.6	0.81%
HOUSEHOLDS	40415	0.87%					10.7	0.87%
Total Scotland			62624	0.87%	1832	0.86%	48.9	1.10%
RUK:								
PRIMARY, MFR and CONSTRUCTION	506584	4.46%	198046	4.46%	5581	4.46%	145.4	4.46%
ELEC, GAS & WATER SUPPLY	42067	2.91%	12896	2.91%	142	2.91%	128.9	2.91%
SERVICES	1031837	1.90%	504567	1.90%	16754	1.90%	109.0	1.90%
HOUSEHOLDS	453771	2.63%					132.3	2.63%
Total RUK			715508	2.63%	22477	2.54%	515.5	3.06%
Total UK	2215914	2.60%	778132	2.49%	24309	2.41%	564.4	2.89%

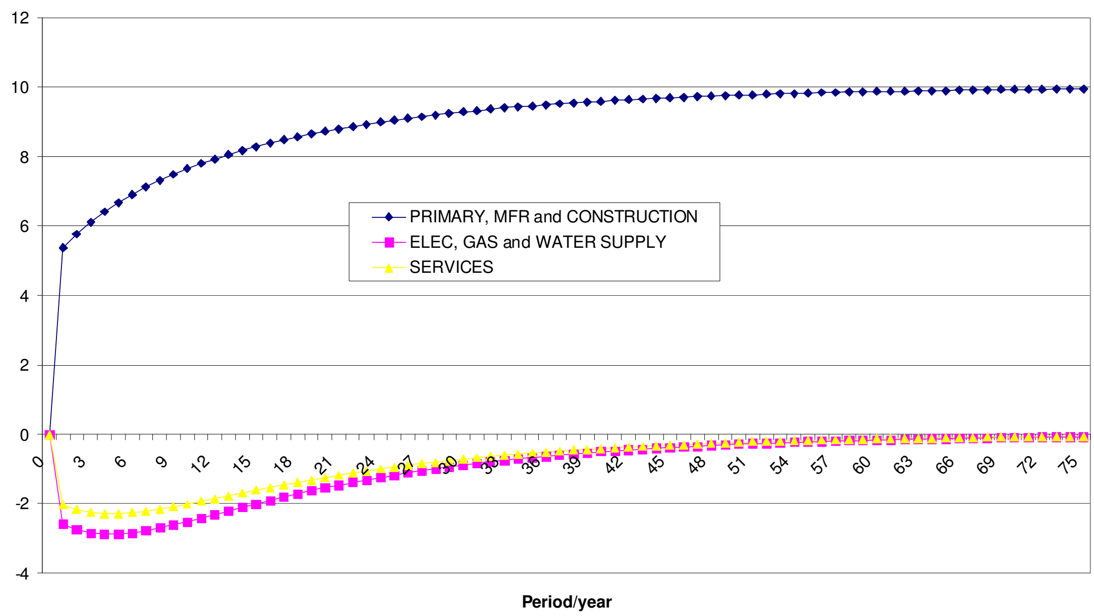
Source: Gilmartin et al (2008)

A second feature of the IO model results is that all final demands are treated as exogenous so that the simulated 10% increase in ROW export demand to the RUK Primary, Manufacturing and Construction sector is the only change in final demand, and both regions experience a direct and/or indirect demand stimulus as a result. Even if final demands were endogenous and responsive to changes in prices, because of the assumption of passive (infinitely elastic) supply in an IO model, no response would occur.

A third feature of the IO model results is that we move from one equilibrium to another, with no modeling of any adjustment process or how long the economy takes to settle on a new long-run equilibrium.

Gilmartin et al (2008) then introduce the same demand disturbance to their interregional CGE model of Scotland and RUK, which shares the IO database (but augmented with information on income transfers to give the SAM in Table 2 above). They simulate the demand disturbance under various assumptions about how the two economies function, with one finding from this process being that the IO model may significantly over-estimate the impacts of such a disturbance. However, the most basic result is that with even with minimal relaxation of the assumption of entirely passive supply (short-run constraints on the availability of primary factors of production – capital and labour are introduced) there is upward pressure on prices, and if we allow any degree of response to these changing prices (i.e. relax the assumption of universal fixed proportionate technology), the demand shock will be accompanied by a negative supply shock. This will cause short run crowding out of activities and a process of adjustment to long-run equilibrium as supply constraints relax over time.

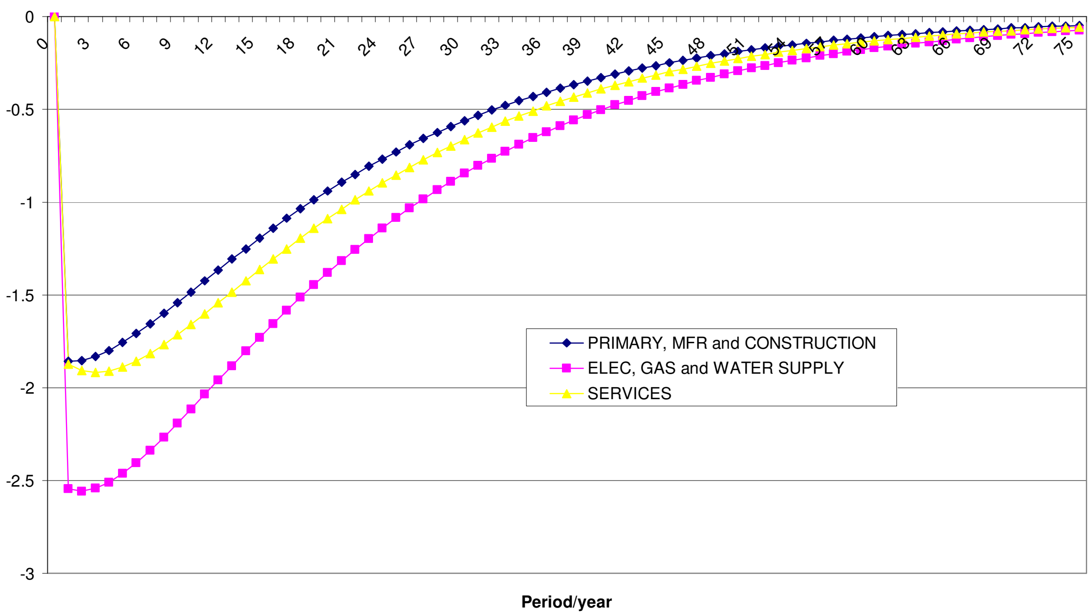
Figure 3. Inter-regional CGE analysis: impact on ROW export demand for outputs of RUK production sectors in response to a 10% increase in ROW export demand to the Primary, Manufacturing and Construction sector (% changes). Source: Gilmartin et al (2008)



For example, Figure 3 shows the impact of the simulated 10% increase in ROW export demand for the RUK Primary, Manufacturing and Construction (PMC) sector on export demand to all three production sectors in RUK (for the model configuration that is closest to the IO case). Note that (particularly given the size of the shock) it takes time for this increase to actually transpire in the PMC sector due to upward pressure on prices until capital and labour supply are able to fully adjust. Because the scarcity of labour and capital in the short run causes the price of these factors faced by all sectors to rise, export demand falls in the other two RUK production sectors (as all output prices are forced up) and only return to the IO-type result of no change over time.

In Scotland, where the initial demand stimulus is an indirect one, the negative supply shock from rising prices in the UK (which raises the cost of intermediate inputs imported from RUK to support the increased (indirect) demand for Scottish production), as well as increased local factor costs as activity expands, leads to reduced competitiveness and crowding out of ROW export demand for all sectors. This effect does not disappear until all supply constraints are eased. See Figure 4:

Figure 4. Interregional CGE analysis: impact on ROW export demand for outputs of Scottish production sectors in response to a 10% increase in ROW export demand to RUK PMC sector (% changes). Source: Gilmartin et al (2008)



Moreover, Gilmartin et al (2008) explain that the CGE model will only produce IO-type results in the long-run for a pure demand shock (such as the one introduced here) and where the disturbance simulated does not lead to lasting changes in supply-side behaviour (e.g. if we introduce permanent supply constraints in the presence of a demand disturbance or if the shock is supply-orientated, such as a change in efficiency in one or more factors of production).

The conclusion that can be drawn here is that while IO is undoubtedly an appropriate, rigorous and informative technique for the type of accounting analysis presented in previous sections, when it comes to modeling the impacts of marginal changes in activity, particularly where these involve changes in supply-side behaviour, it is limited. However, the NAMEA/environmental IO framework still plays an important role in terms of providing the core database that is required for economy-wide analysis of economy-environment issues and problems.

7. Conclusions and recommendations

This report has provided an overview of the NAMEA accounting approach that is increasingly being adopted throughout Europe, and introduces environmental input-output (IO) accounts for Scotland as an example of a NAMEA framework. It went on to provide an introduction to the use of basic IO multiplier methodology, which can be applied to examine pollution/waste generation and/or resource use under production and consumption accounting principles. The report illustrates the type of results we can get from such an analysis and their potential uses. In the specific context of using environmental IO multiplier analysis for a sustainability assessment of the Scottish food and drink sector, the most pertinent application may be the identification of ‘hot spots’ in the supply chain of food and drink production sectors.

The core conclusion and recommendation of this report is that further development and use of the Scottish environmental IO framework to carry out these types of analyses is a fundamental requirement for sectoral sustainability assessments for Scotland. Scotland has a strong foundation in the type of data required, with regular publication of analytical IO tables describing the structure of the economy in any given year, and with data due to be published this summer that will augment the economic accounting framework for environmental analysis. However, as discussed below it is absolutely necessary that agencies such as SEPA engage in a proactive manner with data providers at Scottish Government and with other users and interest groups in order to ensure that

Scotland's environmental IO framework is tailored to meet Scottish needs (such as the sustainability assessment of the Scottish food and drink sector motivating this report).

Moreover, this report has also argued that Scotland is well-placed to play a leading role in the UK in developing a sustainability assessment framework based on IO methods. Indeed, given our interdependence with the rest of the UK in terms of economic activity, policy and statistical capacity, it is important that we play such a role and promote the development of a common and consistent empirical approach to address a range of questions. To this end, it is important that the policy, research and other interested parties in the wider community both within Scotland and elsewhere in the UK and EU, interact to determine specific analytical requirements in developing an environmental IO accounting capacity.

As a starting point in this process, the current report considers the extent to which current developments of the Scottish IO framework by Scottish Government will facilitate a sustainability assessment of the Scottish food and drink sector (as the issue of interest that motivated this project). In terms of current and/or forthcoming data for a single region Scottish analysis (which will most likely be produced for the 76 sector NAMEA breakdown detailed in Appendix 7), the main concern is likely to be overaggregation of key food and drink supply sectors. Another issue of concern is likely to be that the sectoral environmental IO accounts that have been commissioned by Scottish Government are limited to reporting emissions of greenhouse gases, acid rain precursors and fuel uses. However, other types of pollutants/waste products and/or resources (such as water use) may be of interest (and could be analysed using the environmental IO multiplier methodology detailed in this report.

A third issue is likely to be a lack of information for 'social' aspects of a sustainability analysis. The report considered possible developments such as augmentation of IO accounts with information on income transfers to produce a Social Accounting Matrix (but noted that the required data for an official Scottish SAM is unlikely to be available at the present time). Another option may be developing some type of food and drink satellite account using existing survey data (details given in Appendix 9). Issues with the NAMEA framework currently being developed are practical problems for Scotland. This report recommends that specific requirements for a sustainability assessment of the Scottish food and drink sector using the NAMEA/environmental IO approach be clearly established and communicated to data providers at Scottish Government and ONS.

A more basic problem for IO is the time lag in producing IO tables (generally at least 2 years). Because of the sectoral detail in IO accounts, this is a problem that cannot be resolved and must be considered in the context of the benefits of the high level of sectoral detail and information on interactions and interdependencies between different production and consumption activities. This type of detail, and the scope for multiplier analysis of pollution/waste generation and/or resource use embodied in economic transactions, is unique to the environmental IO/NAMEA framework. This report also draws attention to the fact that Scotland is in a unique position in the UK in terms of the availability of high quality economic and (soon be available) environmental data in the analytical format required format for multiplier analysis. This puts us in a very strong position in terms of moving towards consistency with other countries, given that environmental IO multiplier analysis is increasingly becoming the accepted technique for accounting for pollution/waste and/or resource use under the consumption accounting perspective, which is gaining such prominence in public and policy debate.

However, the report also considers the limitations of the type of single region environmental IO analysis that a NAMEA framework of the type currently being developed for Scotland can be used for. In terms of environmental accounting from a consumption perspective, two important implications/limitations are apparent in the single region environmental IO analysis carried out in this report. These are that a share of emissions is allocated to external (export) demand and no account is taken of emissions embodied in imports. In order to address this issue, the single region environmental framework must be extended to take account of trade flows. The report provides an illustrative analysis for Scotland and the rest of the UK and considers how extensions may be made to take account of trade with the rest of the world.

However, the report also considers more basic limitations if we want to use the environmental IO framework to model/simulate the impacts of potential *changes* in activity rather than to account for the structure of pollution/waste generation and/or resource use problems for a given time period (i.e. the year that the accounts relate to). The problem is that in order to use IO as a model we have to impose restrictive assumptions in terms of technology in production and consumption, and that we are only able to model the economy as being entirely demand driven (*or* supply driven) with supply (or demand) entirely passive. In this context, we cannot model the implications of changes in prices, which is a key driver of all economic activity. However, the benefits of environmental IO/NAMEA as a very detailed database remain and the report closes by considering the use of environmental IO/NAMEA databases (and multiplier analyses) to inform more flexible and theory consistent computable general equilibrium models. This development is already being made for Scotland in a project at the University of Strathclyde under the ESRC Climate Change Leadership Fellows programme; again, it is important to consider and specify exactly what questions need to be answered by a sustainability assessment of the Scottish food and drink sector and communicate with the research community in terms of potential developments of more sophisticated modeling frameworks.

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Appendix 1. Technical specification of the single region environmental IO method[13]

The central input equation (see Leontief, 1970, Miller and Blair, 1985) is

[A.1.1] $$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{y}$$

where **x** is an N×1 vector of gross outputs with elements x_i, where i = 1,…,N, for each economic sector i, **y** is an N×1 vector of final demands with elements y_i. **A** is the direct requirements (or input-output coefficients) matrix with elements a_{ij} (where j=1,…M and M = N), describing the amount of intermediate demand of output from domestic sector i used by domestic sector j, per unit of output x_j from sector j. $\mathbf{L} = (\mathbf{I} - \mathbf{A})^{-1}$ is the N×N Leontief inverse with elements b_{ij} describing the amount of output generated in each sector i per unit of final demand for the output of sector j.

Total resource use (or pollution generation) in production is determined as

[A.1.2] $$\mathbf{f}^{\mathbf{x}} = \mathbf{\Omega x}$$

where $\mathbf{f}^x$ is a K×1 vector, with elements f_k^x, where k = 1,…,K, representing the total use of resource or pollutant k generated by all production activities in the economy. Ω is a K×N matrix where element $\varpi_{k,i}$ is the average use of resource/pollutant k per unit of gross output in sector i.

Then the standard input-output attribution (Leontief, 1970; Miller and Blair, 1985) can be employed so that equation [A.1.1] is extended to

[13] The statement of the IO method here and in Appendix 4 is adapted from that in Turner et al (2007).

[A.1.3] $$\mathbf{f}^{y} = \mathbf{\Omega}\left(\mathbf{I} - \mathbf{A}\right)^{-1}\mathbf{y}$$

where $\mathbf{f}^{y}$ is a K×1 vector, with element f_k^y being the total use of resource *k* directly or indirectly required to satisfy total final demand, **y**, in the economy.

If final demanders also directly use resources/generate pollutants, [A.1.3] would be extended for final demand as

[A.1.3a] $$\mathbf{f}^{y*} = \mathbf{\Omega}^{x}\left(\mathbf{I} - \mathbf{A}\right)^{-1}\mathbf{y} + \mathbf{\Omega}^{y}\mathbf{y}$$

where we distinguish the *KxN* matrix of resource use/pollution generation coefficients for the *N* production sectors, now relabelled $\mathbf{\Omega}^{x}$, from a *K*×*Z* matrix, $\mathbf{\Omega}^{y}$, where each *Kx1* column within has elements $\varpi_{k,z}$ as the average <u>direct</u> use/generation of resource/pollutant *k* per unit of expenditure by final demand group *z*.[14] For simplicity we abstract from this extension in the current exposition but, as shown in [A.1.3] and [A.1.3a], it is straightforward to introduce this element where appropriate.

Note that, in the closed or world economy example, it is the case that $\mathbf{f}^{x} = \mathbf{f}^{y}$, so that all resource use/pollution generation in production can be attributed to final consumption demand for the outputs of that production.

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[14] Examples for resource use occurring directly in households are the energy used during the combustion of household and car fuels or land occupied by a residential building.

Appendix 2. Classification of aggregate and 128 Input-Output industry/product (IOC) groups in the Scottish IO tables by SIC(92) classes

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			Standard Industry Classification of economic activities 1992		
Agriculture, forestry & fishing	1	Agriculture, hunting and related service activities	01		
	2.1	Forestry planting and related service activities	02 (part)		
	2.2	Forestry logging and related service activities	02 (part)		
	3.1	Fishing and service activities incidental to fishing	05.01		
	3.2	Operation of fish hatcheries and fish farms and related service activities	05.02		
Mining	4	Mining of coal and lignite; extraction of peat	10		
	5	Extraction of crude petroleum and natural gas, service activities incidental to extraction; mining of uranium and thorium ores	11	12	
	6	Mining of metal ores	13		
	7	Other mining and quarrying	14		
Manufacturing	8	Production, processing and preserving of meat and meat products	15.1		
	9	Processing and preserving of fish and fish products; fruit and vegetables	15.2	15.3	
	10	Vegetable and animal oils and fats	15.4		
	11	Dairy products	15.5		
	12	Grain mill products, starches and starch products	15.6		
	13	Prepared animal feeds	15.7		
	14	Bread, rusks and biscuits; manufacture of pastry goods and cakes	15.81	15.82	
	15	Sugar	15.83		
	16	Cocoa; chocolate and sugar confectionery	15.84		
	17	Other food products	15.85	15.86	15.87 15.88 15.89
	18.1	Spirits and wines	15.91	15.92	15.93 15.94 15.95
	18.2	Beers and ales	15.96	15.97	
	19	Production of mineral waters and soft drinks	15.98		
	20	Tobacco products	16		
	21	Textile fibres	17.1		
	22	Textile weaving	17.2		
	23	Finishing of textiles	17.3		
	24	Made-up textile articles, except apparel	17.4		
	25	Carpets and rugs	17.51		
	26	Other textiles	17.52	17.53	17.5
	27	Knitted and crocheted fabrics and articles	17.6	17.7	
	28	Wearing apparel; dressing and dying of fur	18		
	29	Tanning and dressing of leather; manufacture of luggage, handbags, saddlery and harness	19.1	19.2	
	30	Footwear	19.3		
	31	Wood and wood products, except furniture	20		
	32	Pulp, paper and paperboard	21.1		
	33	Articles of paper and paperboard	21.2		
	34	Publishing, printing and reproduction of recorded media	22		
	35	Coke, refined petroleum products and nuclear fuel	23		
	36	Industrial gases, dyes and pigments	24.11	24.12	
	37	Other inorganic basic chemicals	24.13		
	38	Other organic basic chemicals	24.14		
	39	Fertilisers and nitrogen compounds	24.15		
	40	Plastics and synthetic rubber in primary forms	24.16	24.17	
	41	Pesticides and other agro-chemical products	24.2		
	42	Paints, varnishes and similar coatings, printing ink and mastics	24.3		
	43	Pharmaceuticals, medicinal chemicals and botanical products	24.4		
	44	Soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations	24.5		
	45	Other chemical products	24.6		
	46	Man-made fibres	24.7		
	47	Rubber products	25.1		
	48	Plastic products	25.2		
	49	Glass and glass products	26.1		
	50	Ceramic goods	26.2	26.3	
	51	Bricks, tiles and construction products, in baked clay	26.4		
	52	Cement, lime and plaster	26.5		
	53	Articles of concrete, plaster and cement; shaping and finishing of stone; manufacture of other non-metallic products	26.6	26.7	26.8
	54	Basic iron and steel and of ferro-alloys; manufacture of tubes and other first processing of iron and steel	27.1	27.2	27.3
	55	Basic precious and non-ferrous metals	27.4		
	56	Casting of metals	27.5		
	57	Structural metal products	28.1		
	58	Tanks, reservoirs and containers of metal; manufacture of central heating radiators and boilers; manufacture of steam generators	28.2	28.3	
	59	Forging, pressing, stamping and roll forming of metal; powder metallurgy; treatment and coating of metals	28.4	28.5	
	60	Cutlery, tools and general hardware	28.6		
	61	Other fabricated metal products	28.7		
	62	Machinery for the production and use of mechanical power, except aircraft, vehicle and cycle engines	29.1		
	63	Other general purpose machinery	29.2		
	64	Agricultural and forestry machinery	29.3		
	65	Machine tools	29.4		
	66	Other special purpose machinery	29.5		
	67	Weapons and ammunition	29.6		

Manufacturing (cont.)	68	Domestic appliances not elsewhere classified	29.7			
	69	Office machinery and computers	30			
	70	Electric motors, generators and transformers; manufacture of electricity distribution and control apparatus	31.1	31.2		
	71	Insulated wire and cable	31.3			
	72	Electrical equipment not elsewhere classified	31.4	31.5	31.6	
	73	Electronic valves and tubes and other electronic components	32.1			
	74	Television and radio transmitters and apparatus for line for telephony and line telegraphy	32.2			
	75	Television and radio receivers, sound or video recording or reproducing apparatus and associated goods	32.3			
	76	Medical, precision and optical instruments, watches and clocks	33			
	77	Motor vehicles, trailers and semi-trailers	34			
	78	Building and repairing of ships and boats	35.1			
	79	Other transport equipment	35.2	35.4	35.5	
	80	Aircraft and spacecraft	35.3			
	81	Furniture	36.1			
	82	Jewellery and related articles; manufacture of musical instruments	36.2	36.3		
	83	Sports goods, games and toys	36.4	36.5		
	84	Miscellaneous manufacturing not elsewhere classified; recycling	36.6	37		
Energy and water	85	Production and distribution of electricity	40.1			
	86	Gas; distribution of gaseous fuels through mains; steam and hot water supply	40.2	40.3		
	87	Collection, purification and distribution of water	41			
Construction	88	Construction	45			
Distribution & catering	89	Sale, maintenance and repair of motor vehicles, and motor cycles; retail sale of automotive fuel	50			
	90	Wholesale trade and commission trade, except of motor vehicles and motor cycles	51			
	91	Retail trade, except of motor vehicles and motor cycles, repair of personal and household goods	52			
	92	Hotels and restaurants	55			
Transport & communication	93	Transport and railways	60.1			
	94	Other land transport; transport via pipelines	60.2	60.3		
	95	Water transport	61			
	96	Air Transport	62			
	97	Supporting and auxiliary transport activities, activities of travel agencies	63			
	98	Postal and courier activities	64.1			
	99	Telecommunications	64.2			
Finance and business	100	Banking	65.11	65.12/1		
	100	Other financial intermediation, except insurance and pension funding	65.12/2	65.2		
	101	Insurance and pension funding, except compulsory social security	66			
	102	Activities auxiliary to financial intermediation except insurance	67.1			
	102	Activities auxiliary to insurance	67.2			
	103	Real estate activities with own property, letting of own property, except dwellings	70.1	70.2 (part)		
	104	Letting of dwellings, including imputed rent	70.2 (part)			
	105	Real estate activities on a fee or contract basis	70.3			
	106	Renting of machinery and equipment without operator and of personal and household goods	71			
	107	Computer and related activities	72			
	108	Research and development	73			
	109	Legal activities	74.11			
	110	Accounting, book-keeping and auditing activities; tax consultancy	74.12			
	111	Marketing research and public opinion polling; business and management consultancy activities; management activities	74.13	74.14	74.2	
	112	Architectural and engineering activities and related technical consultancy, technical testing and analysis	74.2	74.3		
	113	Advertising	74.4			
	114	Other business services	74.5	74.6	74.7	74.8
Public admin etc.	115	Public administration and defence; compulsory social security	75			
	116	Education	80			
	117	Human health and veterinary activities	85.1	85.2		
	118	Social work activities	85.3			
	119	Sewage and refuse disposal, sanitation and similar activities	90			
	120	Activities of membership organisations not elsewhere classified	91			
	121	Recreational, cultural and sporting activities	92			
Other services	122	Other service activities	93			
	123	Private households with employed persons	95			

Source: Scottish Government Input Output Tables (www.scotland.gov.uk)

Appendix 3 Sectoral breakdown/aggregation of the 1999 pilot Scottish environmental IO

		IOC
1	AGRICULTURE	1
2	FORESTRY PLANTING AND LOGGING	2.1, 2.2
3	SEA FISHING	3.1
4	FISH FARMING	3.2
5	Other mining and quarrying	6,7
6	Oil and gas extraction	5
7	Mfr food, drink and tobacco	8 to 20
8	Mfr textiles and clothing	21 to 30
9	Mfr chemicals etc	36 to 45
10	Mfr metal and non-metal goods	46 to 61
11	Mfr transport and other machinery, electrical and inst eng	62 to 80
12	Other manufacturing	31 to 34, 81 to 84
13	Water	87
14	Construction	88
15	Distribution	89 to 92
16	Transport	93 to 97
17	Communications, finance and business	98 to 107, 109 to 114
18	R&D	108
19	Education	116
20	Public and other services	115, 117 to 123
	ENERGY	
21	COAL (EXTRACTION)	4
22	OIL (REFINING & DISTR OIL AND NUCLEAR)	35
23	GAS	86
	ELECTRICITY	85
24	Renewable (hydro and wind)	
25	Non-renewable (coal, nuke and gas)	

Appendix 4. Technical specification of the multi-region or interregional environmental IO method

For the purpose of simplicity, the following exposition (derived from Miller and Blair, 1985) is given in terms of a 2-region world. However, it is straightforward to extend to the multiple region case (see Allan et al, 2004b). In [Appendix 1, equation A.1.1] we identified the key equation determining the *Nx*1 vector of output **x** in the single region input-output framework. We take this as region 1 in a 2-region world and separate the element **y** (final demand) into local final demand in region 1 of commodities produced in region 1 ($\mathbf{y}_{11}$) and export demand in region 2 for region 1 commodities ($\mathbf{y}_{12}$). Similarly for region 2, final demand for region 2 commodities is split into export demand in region 1 ($\mathbf{y}_{21}$) and local demand in region 2 ($\mathbf{y}_{22}$). We have

[A.4.1] $$\begin{pmatrix} \mathbf{x}_{11} & \mathbf{x}_{12} \\ \mathbf{x}_{21} & \mathbf{x}_{22} \end{pmatrix} = \begin{pmatrix} \mathbf{I} - \mathbf{A}_{11} & -\mathbf{A}_{12} \\ -\mathbf{A}_{21} & \mathbf{I} - \mathbf{A}_{22} \end{pmatrix}^{-1} \begin{pmatrix} \mathbf{y}_{11} & \mathbf{y}_{12} \\ \mathbf{y}_{21} & \mathbf{y}_{22} \end{pmatrix}$$

where elements a_{ij}^{rs} of the *N*×*J* submatrices $\mathbf{A_{rs}}$ show the transactions between sector *i* in producing region *r* and using sector *j* in consuming region s, per unit of output of sector *j* in region *s*. The partitioned matrix $(\mathbf{I} - \mathbf{A})^{-1}$ is the inter-regional Leontief inverse, breaking down the gross output multiplier for each sector in each region into gross outputs that are induced by domestic and by foreign final demand. In other words, by having partitioned the **A**-matrix for each region into local and imported intermediate consumption, and the **y** vector for each region into domestic and traded final demand, we can determine the level of inter-regional spillovers in terms of how activity in one region drives activity in the other.

Of course, the activity we are interested in here is resource use. Just as we extended the basis economic framework in equation [A.1.3] for the single region case, we simply introduce a *(K×N)* matrix of coefficients showing the direct resource-use or pollution generation intensity of output in each production sector *i* for each region:

[A.4.2]
$$\begin{pmatrix} \mathbf{f}^{y}_{11} & \mathbf{f}^{y}_{12} \\ \mathbf{f}^{y}_{21} & \mathbf{f}^{y}_{22} \end{pmatrix} = \begin{pmatrix} \boldsymbol{\Omega}^{x}_{1} & \mathbf{0} \\ \mathbf{0} & \boldsymbol{\Omega}^{x}_{2} \end{pmatrix} \begin{pmatrix} \mathbf{I} - \mathbf{A}_{11} & -\mathbf{A}_{12} \\ -\mathbf{A}_{21} & \mathbf{I} - \mathbf{A}_{22} \end{pmatrix}^{-1} \begin{pmatrix} \mathbf{y}_{11} & \mathbf{y}_{12} \\ \mathbf{y}_{21} & \mathbf{y}_{22} \end{pmatrix}$$
$$= \begin{pmatrix} \boldsymbol{\Omega}^{x}_{1}\mathbf{L}_{11}\mathbf{y}_{11} + \boldsymbol{\Omega}^{x}_{1}\mathbf{L}_{12}\mathbf{y}_{21} & \boldsymbol{\Omega}^{x}_{1}\mathbf{L}_{11}\mathbf{y}_{12} + \boldsymbol{\Omega}^{x}_{1}\mathbf{L}_{12}\mathbf{y}_{22} \\ \boldsymbol{\Omega}^{x}_{2}\mathbf{L}_{21}\mathbf{y}_{11} + \boldsymbol{\Omega}^{x}_{2}\mathbf{L}_{22}\mathbf{y}_{21} & \boldsymbol{\Omega}^{x}_{2}\mathbf{L}_{21}\mathbf{y}_{12} + \boldsymbol{\Omega}^{x}_{2}\mathbf{L}_{22}\mathbf{y}_{22} \end{pmatrix}$$

where $\mathbf{f}^{y}_{11}$ is a *Kx1* vector of the amount of resources that are used, or pollution directly generated, in production activities in region 1 to support region 1 final demand, while $\mathbf{f}^{y}_{21}$ is the amount of resources used/pollutants generated in region 2 production to support region 1 final demand. The sum of these, in a 2-region world, will give us the resource use/pollution generation footprint for region 1 final demand:[15]

[A.4.3] $$\mathbf{f}^{y}_{1} = \mathbf{f}^{y}_{11} + \mathbf{f}^{y}_{21}$$

And the footprint of region 2 is equal to

[A.4.4] $$\mathbf{f}^{y}_{2} = \mathbf{f}^{y}_{22} + \mathbf{f}^{y}_{12}$$

Similarly if we extend to the *N*-region case, this will simply involve summing down a column with an additional *N*-2 entries for each additional region. For example $\mathbf{f}^{y}_{1}$ would become

[A.4.5] $$\mathbf{f}^{y}_{1} = \mathbf{f}^{y}_{11} + \mathbf{f}^{y}_{21} + \ldots + \mathbf{f}^{y}_{n1}$$

[15] As mentioned above, the direct resource use/pollution generation by final consumers is omitted here for simplicity.

Appendix 5. Sectoral Breakdown of the pilot Scotland/rest of UK inter-regional IO system

Scot/RUK sector		IOC
1	PRIMARY	1-7
2	MANUFACTURING	8-84
3	ELEC, GAS & WATER SUPPLY	85-87
4	CONSTRUCTION	88
5	WHOLESALE & RETAIL TRADE	89-92
6	TRANSPORT & COMMUNICATION	93-99
7	FINANCIAL INT & BUSINESS	100-114
8	PUBLIC ADMINISTRATION	115
9	EDUC, HEALTH & SOCIAL WORK	116-118
10	OTHER SERVICES	119-123

Appendix 6. Sectoral Breakdown of the pilot Scotland/rest of UK inter-regional CGE system

Scot/RUK sector		IOC
1	PRIMARY, MFR and CONSTRUCTION	1-84, 88
2	ELEC, GAS and WATER SUPPLY	85-87
3	SERVICES	89-123

Appendix 7. Mapping between 123 (UK) IOC sectors, 93 Environmental Accounts sectors and 76 NAMEA sectors

NAMEA	EAcode	IOcode (UK)	SIC(92)	Description of NAMEA activity
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	32-33	21	Pulp and paper
15	15	34	22	Printing and publishing
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
	92	Household consumption		Domestic - non-travel
	93	Household consumption		Domestic - travel

Appendix 8. Abstracts for example papers on application of IO methodology to Life Cycle Analysis

1. **Pan, X., Kraines, S.**
Environmental input-output models for life-cycle analysis
(2001) *Environmental and Resource Economics*, 20 (1), Pages 61-72.

Abstract
The Leontief input-output model has been applied for macro environmental analysis since 1970, and life cycle analysis has been used in industrial design over the last decade. This paper presents two extended environmental input-output models for life cycle analysis in pollutant abatement and towards resource recycling. It is demonstrated that the suggested models are systematic tools that can be used for integrated environmental analysis and planning.

2. **Wood, R., Lenzen, M., Dey, C., Lundie, S.**
A comparative study of some environmental impacts of conventional and organic farming in Australia
(2006) *Agricultural Systems*, 89 (2-3), Pages 324-348.

Abstract
The provision of food causes environmental impacts that range from local through to global in scale. Organic farming, used in general here to mean farming practices with a greater emphasis on long-term sustainability, is one general approach to reduce these impacts. Whilst organic farming may be argued to be superior to conventional farming on the basis of local impacts, it is not often clear how organic farming performs relative to conventional farming in terms of wider, global impacts. In this paper we present a comparative assessment of on-farm and indirect energy consumption, land disturbance, water use, employment, and emissions of greenhouse gases, NO_x, and SO_2 of organic and conventional farming in Australia. A hybrid input-output-based life-cycle technique is employed in order to ensure a complete coverage of indirect requirements originating from all upstream production stages. Using data from a detailed survey of organic farms, the results show that direct energy use, energy related emissions, and greenhouse gas emissions are higher for the organic farming sample than for a comparable conventional farm sample. Direct water use and employment are significantly lower for the organic farms than for the conventional farms. However, the indirect contributions for all factors are much higher for the conventional farms, leading to their total impacts being substantially higher. This shows that indirect effects must be taken into account in the consideration of the environmental consequences of farming, in particular for energy use and greenhouse gas emissions, where the majority of impacts usually occur off-farm. Subject to yield uncertainties for organic versus conventional farming, from the sample here we can conclude that in addition to their local benefits, organic farming approaches can reduce the total water, energy and greenhouse gases involved in food production.

Appendix 9. Additional data sources for information on food, drink and nutrition in different types of households

Expenditure and Food Survey

- Report produced by the ONS
- Amalgamation of the Family Expenditure and National Food Surveys (FES and NFS).
- The Office for National Statistics (ONS) has overall project management and financial responsibility for the EFS while the Department for Environment, Food and Rural Affairs (DEFRA) sponsors the specialist food data.
- Reported on an annual basis.
- Details at http://www.statistics.gov.uk/StatBase/Source.asp?vlnk=1385&More=Y.

Family Food Survey

- Report Produced by DEFRA
- Family Food 2007 is the latest in a series of annual reports published by DEFRA on food and drink purchases by households in the United Kingdom. It is based on data collected in the Expenditure and Food Survey which runs continuously throughout the year.
- The report presents trends in average levels of food purchases by type of food and demographic characteristics and converts these into average energy and nutrient intakes.
- Much of the report looks at a four year trend from April 2004 to December 2007. New data covers the period January to December 2007 but is insufficient on its own to show statistically significant changes in purchasing patterns. In most cases the new data supports the evidence of trends identified since April 2004.
- Published Annually
- Details at https://statistics.defra.gov.uk/esg/publications/efs/default.asp.

Low Income Diet and Nutrition Survey

- Published for the Foods Standards Agency
- This survey, of a national sample of the most materially deprived households, provides nationally representative baseline data on the dietary habits and nutritional status of the part of the UK population that has a low income.
- Produced Annually.
- Not clear if this study is linked to other spending surveys but it is a supplement to the National Diet and Nutrition Survey (NDNS) programme (http://www.food.gov.uk/science/dietarysurveys/ndnsdocuments/) that collects information on the dietary habits and nutritional status of the general UK population.
- Details at http://www.food.gov.uk/science/dietarysurveys/lidnsbranch/.