A pilot study on constructing a scottish sectoral CO_2 emissions account*

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Introduction and background

A significant degree of responsibility for setting and achieving UK sustainability objectives (Department of the Environment, 1996) has been devolved to the Scottish Parliament, Northern Ireland Assembly and the National Assembly for Wales and delegated to the English Regional Development Agencies (RDAs). For example, the National Assembly for Wales is unique among European governments in having a constitutional duty to promote sustainable development under section 121 of the Government of Wales Act (DETR, 2001, Section III, Chapter 3). The Scottish Parliament does not have this type of constitutional commitment, but still has responsibility for the protection of the environment and sustainable development is one of the outcome objectives of the Scottish Executive's Framework for Economic Development (Scottish Executive, 2000). Details of the specific priorities set by the Scottish Parliament with respect to sustainable development are published in a document called ***Meeting the Needs...Priorities, Actions and Targets for Sustainable Development in Scotland*** (Scottish Executive, 2002a). This document also identifies 24 indicators against which progress towards achieving the Parliament's sustainability objectives will be measured.

Thus, given the nature of devolution, and the dependence of the success of national sustainability programmes on policies delivered at the regional level, the region has become the natural spatial focus for the evaluation of policies directed at sustainability and formulated within the UK. This means that regional policymakers in the UK need to develop an appropriate database and framework for analysis. One active debate amongst the English and Welsh devolved authorities and the UK Environment Agency is the extent to which region-specific environmental and economic data are required to perform this task. Scotland already benefits from the availability of comprehensive region-specific economic data, particularly in the form of the Scottish Input-Output (I-O) tables (see Stewart, 1991, and Scottish Executive, 2001, 2002b), which describe in detail the structure of the economy and explain the underlying composition of key economic indicators such as GDP. However, environmental reporting in Scotland is less well developed. Therefore, in 2001 the Scottish Executive set up a consultation group, the Scottish Environmental Accounts Working Group (SEAWG) to investigate the need for and feasibility of producing and reporting region-specific environmental accounts for Scotland for the purpose of economic-environmental analysis.

Constructing of a consistent set of economy-environment accounts for Scotland

One key issue recognised by the SEAWG group 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) has launched a project 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 concept of a NAMEA database originated in the Netherlands (see Haan 2001) and focuses on the idea of providing an integrated set of economic and environmental accounts. The economic accounts are the national accounts in input-output (I-O) or social accounting matrix (SAM) format and are presented in monetary units. The environmental accounts are reported in physical units and focus on presenting information on material inputs of natural resources (particularly energy resources) and outputs of residuals (pollution and waste materials) at a level of sectoral detail consistent with the economic accounts.

The UK has already adopted the Eurostat guidelines for the development of a trial version of a 76-sector economic-environmental database at the national level. One of the issues that the SEAWG group in Scotland has been responsible for investigating is the feasibility of developing a NAMEA-style approach to constructing a set of economic-environmental accounts for Scotland. This paper reports a

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pilot study to augment the (1999) Scottish economic I-O accounts (Scottish Executive, 2002b) with physical data on emissions of the main greenhouse gas, CO_2. The availability of a set of economic-environmental accounts for Scotland would permit, among other things, analysis of the underlying sectoral ***composition*** of one of the Scottish Executive's main sustainability indicators, the sustainable prosperity index (CO_2 emissions divided by GDP – see Scottish Executive, 2002a, 2003). It would also facilitate modelling of the potential impact of changes in economic activity on the value of this indicator over time, for example in response to a change in policy (see Ferguson ***et al***, 2003).[1]

However, the findings of this pilot study indicate 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, there is the question of whether these can be reported for a sectoral breakdown that is consistent the 1992 Standard Industrial Classification (SIC) used in the economic accounts. If policy is orientated towards influencing activity in economic sectors, clearly there are benefits to environmental data being presented in a format that is consistent with existing economic accounts.

This paper addresses 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/I-O classified production sectors plus household and tourist categories of final consumption). Note that while the present study has focused on emissions of the pollutant CO_2, 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).

Estimating emissions generated by economic activity

Before moving on to the issue of identifying sectoral emissions accounts for Scotland, however, it is useful to consider the appropriate method for estimating emissions from economic activity.

What the economic-environmental account should provide us with is information on the total flow of emissions (of each pollutant) from each individual sector or final demand category, if this is directly polluting (e.g. private households running cars on petrol or diesel), of the economy to the environment. However, in practice, the flows of pollutants from any one activity over a given time period (for example the year 1999) cannot generally be directly observed. This implies a need to make certain assumptions regarding the relationship between economic activity and pollution generation. The key aspect in determining the flow of emissions that accompanies economic activity, particularly in the case of CO_2 emissions, will generally be the amount of different types of fuel used and the type of technology used to combust it, although non-fuel use sources also need to be identified.

The standard assumption is that emissions from any one economic activity are a function of the volume of fuel combusted during that activity plus the levels of output/activity from other polluting processes. (See, for example, Beauséjour ***et al*** (1994), Vaze (1997). A formal statement of the assumed relationship is given here in the Appendix.). The availability of I-O accounts for the target economy will be of some use, as they provide data on the level and composition of activity in each production sector and final demand category. For example, I-O tables provide data on the distribution of total sales by different (aggregate) energy supply sectors to different users. However, these data will only provide us with information on very broad fuel uses, particularly in the case of oil-based fuels, where only a single distribution sector is generally identified.[2] Therefore, ideally environmental accounts should be built up using data on physical energy uses by sector (indeed, as explained above, physical resource uses are themselves identified as a standard part of a NAMEA account) and scientific data on emissions factors for different fuel combustion and other polluting processes.

Existing emissions estimates for Scotland

The first step in this pilot study is to determine whether any work has already been done on estimating CO_2 emissions from different economic activities in Scotland for any year that economic accounts (in the form of an I-O table) are also available. An earlier study by Salway ***et al*** (2001)[3] has estimated emissions of the three main greenhouse gases – CO_2, methane (CH_4) and nitrous oxide (N_2O) – for each of the four main UK regions (England, Scotland, Wales and Northern Ireland) from different sources identified in the UK national air emissions inventory. The study estimates emissions for the years 1990, 1995, 1998 and 1999. Scottish I-O tables exist for both 1998 and 1999. The present study focuses on the table for 1999. A summary of Salway ***et al***'s (2001) results for Scotland in 1999 is given in Table 1 below.

Table 1: Emissions of CO2 in Scotland, 1999 by GHG inventory source

Source		*CO2 emissions (kt)*
Energy - fuel combustion		
Energy Industries		
a	Public electricity and heat production	15962
b	Petroleum refining	3401
c	Mfr solid fuels and other energy	2008
2.	Manufacturing industries and construction	6866
3.	Transport	
a	Civil aviation	0
b	Road transportation	8020
c	Railways	166
d	Navigation	151
e	Other (aircraft support)	6.2
4.	Other sectors	
a	Commercial/Institutional	2926
b	Residential	7404
c	Agriculture/Forestry/Fishing	314
Total emissions from energy combustion		47224
Fugitive emissions from fuels		
1.	Solid fuels	0
2.	Oil and natural gas	
a	oil	429
b	natural gas	0
c	flaring	322
d	venting	0
Agriculture and industrial processes, waste		508
Land use change and forestry		12409
Total emissions		60892

Source: Salway *et al* (2001)

However, both of the problems identified in the introduction are relevant in assessing the usefulness of these results for the construction of a set of economic-environmental (CO_2) accounts for Scotland. I address each of these in turn in the next two sub-sections.

Assessing the accuracy and region-specificity of existing emissions estimates for Scotland

First, it is not clear just how region-specific the data are on which these estimates for Scotland have been made. Salway ***et al***'s (2001) method involves taking UK national air emissions inventory (NAEI) data on pollution generation from activities classified by the Intergovernmental Panel on Climate Change (IPCC) and distributing these across space within the nation. This allocation of UK emissions to the four regional economies is done using a combination of three methods:

- Æ Point source mapping
- Æ Area source mapping
- Æ Road transport mapping

The first method, 'point source mapping', is where a specific emissions source, usually a large industrial installation or public facility (such as a hospital or cremato- rium) can be individually geographically referenced to a particular region and therefore emissions from that source can be accurately allocated.

However, point source emissions can only be mapped to around 4300 sites in the UK economy as a whole. Moreover, this method will only be applicable to certain types of emissions. Other methods are required for distributing emissions from sources such as domestic, agricultural and road transport emissions. In the case of domestic, agricultural and non-point source commercial/industrial/public sector activity emissions, a method called 'area source mapping' is used. This involves using surrogate datasets, such as population and household fuel use data (for domestic activities), land cover and livestock data (for agricultural activities) and employment data (for industrial/commercial/public sector activities). In the case of emissions from road transport, the third 'road transport mapping' method is employed, which mainly seems to be based on Department of Transport data such as the National Transport Survey.

The problem is that, without fuller detailed information on the mapping methods used, it is difficult to judge the quality and region-specificity of any results using the latter two methods. For example, using employment data to map emissions from industrial/commercial/public sector activities among regions (and different activities within those regions) would seem to imply very strong assumptions about the relationship (if any relationship does in fact exist) between numbers employed and polluting activity/technology. Similarly, using population data to map domestic emissions seems questionable. Any use of household fuel use data ***would*** seem more appropriate. However, if such data are available, the question then arises as to why Salway ***et al*** (2001) have used what is essentially a 'top-down' method of allocating UK emissions among regions rather than a 'bottom-up' approach where fuel emissions factors are applied to fuel use data. This would mean that, where possible, UK 'macro' emissions estimates would be built up from regional 'micro' ones, ensuring that region-specific polluting technologies and production/consumption relationships (such as the fuel intensity of different activities) are fully recognised in the resulting national and regional environmental accounts.

The issue of adopting a bottom-up approach in order to reflect region-specific characteristics in environmental accounting is an important one (just as it is in the case of the economic accounts). In the absence of appropriate regional data, the possibility of adjusting more readily available national data is seen as a tempting option. However, the crucial issue is the likely size of the loss in information if such an option is pursued. An earlier study (Turner, 2003) suggests that for a small open regional economy, with pollution technology and fuel-use characteristics that differ significantly from the national average, the practice of adapting national data at the regional level may generate results that are so misleading as to be of no use whatsoever.

A second issue is that if region-specific indicators and targets for sustainability objectives are required, and are to be measured and monitored at the regional level, these must be based on region-specific information. For example, if Scotland is to deliver a contribution towards the UK goal of a 20% cut in CO_2 emissions by 2010 (DETR, 2001, Section I, Chapter 6), an important factor in determining what contribution it can and should make will be the relative carbon intensity of Scottish economic activity. This point is apparently recognised in the fact that Scotland has a more ambitious target for the use of renewable sources in electricity generation, 18% by 2010 (Scottish Executive, 2002a), compared to the target of 10% within the same timeframe that has been set at the UK level (DTI, 2003). The setting of this more ambitious target for Scotland is based on the fact that the Scottish electricity sector already generating a large share of its output (10%) from renewable sources relative to the UK average.

In general, it would seem appropriate to address the question of whether it is possible identify which of the figures reported in the Salway ***et al*** (2001) study result from Scottish-specific estimates (e.g. point estimates) and which are the result of some top-down allocation of UK emissions across the regions. Specifically, it would be useful to identify three categories of sectoral emissions estimates:

(a) ***Fully Scottish-specific*** – i.e. estimates that are based entirely on Scottish-specific data and can be traced back to actual polluting processes that take place in Scotland.
(b) ***Partially Scottish-specific*** – i.e. estimates that are based on allocating UK emissions to Scottish activities/sectors on the basis of some appropriate region-specific proxy measure that relates to polluting activities in Scotland (e.g. Scottish sectoral fuel-use data).
(c) ***UK-adjusted*** – i.e. estimates that are based on allocating UK emissions to Scottish activities/sectors on the basis of other proxy measures such as UK average emissions and/or fuel-use intensities for different activities (e.g. output or employment).

The problem of mapping emissions inventory data to economic sectors

However, even if the quality and region-specificity of Salway ***et al***'s (2001) emissions estimates for Scotland is judged to be acceptable, the second question is whether these can be reported for a sectoral breakdown that is consistent with the 1992 Standard Industrial Classification (SIC) used in the economic accounts. The results shown in Table 1 are reported for IPCC-defined activities. However, these are generally not easily mapped to SIC/I-O classified economic sectors.[4] For example, the IPCC classified activity 'road transportation' is carried out by most economic sectors. That is to say, in the SIC/I-O accounting system, commercial road transportation services are distinguished from 'in-house' transportation activities carried out by individual production sectors and final demand categories, whereas in the IPCC system all road transportation activities would seem to be classified together. Similarly, the emissions inventory approach reports energy-related emissions from the commercial/institutional sector, but again this covers a large range of SIC/I-O classified sectors, Even where there is more specific identification of activities, for example agriculture/forestry/fishing, this still covers at least 3 SIC/I-O classified activities.

There are really two issues here. The first is the one identified above, how activities are defined under the SIC/I-O and IPCC classifications. However, a second issue introduces even more complications. This is whether, even where the definition of any one activity seems to be the same, the allocation of pollution generation to that activity should be the same under the SIC/I-O and IPCC accounting systems. This second issue can be explained in terms of an example from environmental accounting at UK level, where both IPCC and SIC/I-O classifications are used in reporting emissions (the latter are reclassified as Environmental Accounts, EA, sectors). One IPCC activity that can be directly mapped to an SIC/IO classified activity is 'public electricity and heat production', which is only carried out in I-O sector 85 'electricity production' (EA 51-55). The UK emissions inventory and economic-environmental accounts data for 1999[2] show that the physical amount of CO_2 emissions that are reported for the IPCC-classified sector 'public electricity and heat production' and I-O 85 for 1999 are essentially (at 141030 and 141871 kilotonnes respectively, accurate to 0.06%).[5] However, the problem is that this should not be the case. In terms of the SIC/I-O classified electricity sector, the figure should include any emissions produced within the sector during non-generation activities, for example emissions from fuel combustion in any road transportation activities within the sector. Indeed a supplementary National Statistics database reporting emissions-by-source for each economic sector shows that road transport activities ***are*** included as a source of emissions for I-O 85. However, by definition, the IPCC figure does ***not*** include emissions from road transportation. So it would seem that the UK emissions-by-source data, at least in the case of I-O 85 (electricity production) have not in fact been estimated using a bottom-up approach of actually estimating emissions from different sources such as different types of fuel use. Rather the IPCC figure for 'public electricity and heat production' seems to have been mapped to I-O 85 then allocated among the sources of emissions associated with this sector – i.e. adopting the same type of 'top-down' approach as seems to have been taken in allocating UK emissions among the regions.[6]

An alternative approach to estimating a sectoral CO_2 account for Scotland

Even if we accept the validity of the CO_2 estimates reported for Scotland by Salway *et al* (2001), the mapping problems described above mean that it has not been possible to fully map the data in Table 1 to SIC/I-O classifications for the economic-environmental account being constructed here. Moreover, even if it were possible, this approach would not be satisfactory if the data are to be used for modelling purposes. In order to ***model*** the impact of any policy change or other disturbance to the economy on the environment it is necessary to understand the different sources of emissions within different sectors. That is to say we want to be able to capture the impact on emissions if a policy initiative such as the Climate Change Levy, for example, leads to a reduction in specific types of energy use (as is the intention of this type of policy).

Therefore, this study has attempted to use a mix of region-specific economic data (the 1999 Scottish I-O tables) and UK-adjusted physical fuel-use and emissions factor data (also for 1999) to adopt what is referred to above as a 'bottom-up' approach to constructing a sectoral CO_2 account for Scotland. Obviously, this is not entirely satisfactory due to the lack of region-specific data for all elements of the computations. However, the introduction of as much Scottish-specific data as possible and the adoption of a 'bottom-up' approach should render the results more informative for economic-environmental analysis than what is shown in Table 1.[7]

As explained above, the standard assumption is that emissions from any one economic activity are a function of two factors (see Appendix for formal details):

- The volume of fuel combusted during that activity, plus
- The levels of output/activity from other polluting (i.e. non-fuel-combustion) processes.

In the present study, attention has focussed on the first of the two factors identified above - estimating Scottish emissions from fuel use. This is because the Scottish I-O tables do give us some information regarding different types of energy use in different sectors of the economy. In terms of the second basic source of pollution, and in the absence of any better Scottish-specific information, the non-fuel-combustion emissions in the bottom half of Table 1 are allocated to what would seem the appropriate I-O classified sectors in Table 2 on the basis of Salway *et al*'s (2001) explanation of sources. 'Fugitive emissions' from 'oil' and 'flaring' are allocated to the Oil and Gas Extraction and Refining and Distribution of Oil and Nuclear Fuels sectors (I-O 5, Table 2, Sector 6, and I-O 35, Table 2, Sector 8) respectively. Emissions recorded under 'agriculture and industrial processes, waste' actually all relate to production of mineral products and metal in the case of Scotland; therefore in Table 2 they are allocated to Sector 12, Metal and Non-Metal Goods, which encompasses I-O Sectors 46-61. The only non-fuel-combustion related emissions reported in Table 1 that are not allocated to SIC/I-O sectors in this study are those associated with 'land use change and forestry'. The reason for this omission is simply that this IPCC category does not clearly map to individual SIC/I-O sectors. However, this would seem to be a significant problem because CO_2 emissions from this one IPCC source account for just over 20% of total emissions in the accounts reported in both Tables 1 and 2.

As explained above, it is also not possible to map the energy (fuel consumption) related emissions reported by Salway *et al* (2001) to SIC/I-O classified sectors. Moreover, it is also argued above that a 'bottom-up' approach of estimating emissions from sectoral fuel uses using appropriate emissions factors is more instructive in terms of understanding the underlying sources of emissions, and therefore more appropriate for analytical purposes such as modelling. Unfortunately data on different types of physical fuel use at the sectoral level are not available for Scotland. However, the I-O tables do provide information on the distribution of total sales by different energy supply sectors to different users: coal, I-O 4 (Sector 5 in Table 1), refined oil-based fuels I-O 35 (Sector 8), and gas, I-O 86 (Sector 17). A fourth energy supply sector identified in the I-O tables is the electricity sector, I-O 85 (Sectors 15 and 16).[8] Note, however, that electricity is distinct from the other types of energy (fuels) identified here in that electricity-related emissions are generated during supply (generation) rather than use. Therefore, information is not required on sectoral electricity ***use*** in order to estimate emissions, instead on the fuel used by the electricity sector during its production activities.

Note, however, that the I-O data only provide us with information on very broad fuel supply/use, particularly in the case of oil-based fuels. Moreover, data on the distribution of total sales will mask differences in average prices paid for physical quantities of different fuels by different users and the impact of any secondary goods and services supplied by the energy sectors. For example, I-O 35 also distributes nuclear fuels, although this is believed to account for a very small share of sectoral output. However, in the absence of any better information on the pattern of different types of energy use in the Scottish economy, the present study takes the distribution of energy supply along the rows of the I-O table to be representative of the pattern of energy use among different users. That is, with one adjustment. The energy supply rows in the I-O table only show ***local*** energy supply meaning that any energy requirements met from imports are not yet accounted for. This

Table 2: Emissions of CO2 in Scotland, 1999 by IOC production sectors and final demand categories

	Production sectors:	*IOC*	*CO2 (kt) - fuel combustion*	*CO2 (kt) - other*	*Total CO2 (kt)*
1	Agriculture	1	572	0	572
2	Forestry planting and logging	2.1, 2.2	86	0	86
3	Sea fishing	3.1	223	0	223
4	Fish farming	3.2	29	0	29
5	Coal (Extraction)	4	46	0	46
6	Oil and gas extraction	5	134	429	563
7	Other mining and quarrying	6,7	80	0	80
8	Refining & distribution oil and nuclear fuels	35	413	322	735
9	Mfr food, drink and tobacco	8 to 20	761	0	761
10	Mfr textiles and clothing	21 to 30	96	0	96
11	Mfr chemicals etc	36 to 45	568	0	568
12	Mfr metal and non-metal goods	46 to 61	571	508	1079
13	Mfr transport and other machinery, electrical and inst eng	62 to 80	433	0	433
14	Other manufacturing	31 to 34, 81 to 84	764	0	764
15	Electricity - renewable sources (hydro and wind)	85	1794	0	1794
16	Electricity - non-renewable sources (coal, nuke and gas)	85	12472	0	12472
17	Gas	86	188	0	188
18	Water	87	36	0	36
19	Construction	88	708	0	708
20	Distribution	89 to 92	2854	0	2854
21	Transport	93 to 97	3009	0	3009
22	Communications, finance and business	98 to 107, 109 to 114	2103	0	2103
23	R&D	108	11	0	11
24	Education	116	755	0	755
25	Public and other services	115, 117 to 123	4652	0	4652
	Total emissions from production activities		33356	1259	34615
	Final demand categories:				
	Scottish households		13539	0	13539
	Tourists from RUK and ROW		366	0	366
	total emissions from final consumption		13904	0	13904
	total allocated emissions		47260	1259	48519
	Unallocated - land use change and forestry (Table 1)		0	12409	12409
	total Scottish emissions in 1999		47260	13668	60928
	% difference Table 1 and 2		0.08%	0.00%	0.06%

Source: Fraser of Allander Institute and Salway et al introduces a problem in that the I-O tables only show ***total*** imports of goods and services from the rest of the UK and overseas. However, the I-O team at the Scottish Executive kindly made available an experimental dataset breaking 1999 imports down by commodity for use in the current project. These data are used to adjust the distribution of fuel uses suggested by the published I-O table.

A second problem is that no data are available on ***total*** uses of different types of fuel by Scottish producers and consumers for 1999. The availability of such data would allow us to apply the distribution of sales implied by the I-O table in order to estimate physical fuel use in each sector. Therefore, data from the UK environmental accounts[9] on the physical amount of each of broad fuel groups identified here (oil, gas and coal) used per £million total output/ expenditure in each production sector/final demand category – i.e. the fuel intensity of each activity – are used to estimate Scottish fuel uses. The estimated total physical use of each fuel type is then distributed across different users according to the use patterns determined from the Scottish I-O data.

Once the physical use of each of the three broad fuel types is estimated for each production sector and final demand category, the final set of data required for estimating fuel-combustion-related emissions are relevant emissions factors. Again, no Scottish-specific data are available to compute appropriate emissions factors. Instead, UK data on sectoral uses of total oil-based fuels, coal and gas and on estimated CO_2 emissions from each of these sources are used to compute sector-specific emissions factors that state the average amount (kilotonnes) of CO2 emissions generated per kilotonne (oil equivalent) of each of these fuel types. These emissions factors are then applied to the estimated physical fuel uses in the corresponding Scottish production sectors and final demand categories to produce the estimates of CO_2 emissions from fuel combustion shown in Table 2.[10]

One interesting thing to note is that the estimate for total CO_2 emissions resulting from fuel combustion for Scotland in 1999 shown at the bottom of Table 2 is almost identical (to less than 1%) to Salway ***et al***'s (2001) estimate, reported in Table 1. It would be unwise to speculate at this point as to why this may be the case without a better understanding of how the figures reported by Salway ***et al*** (2001) have been derived.

Summary and conclusions

This pilot study has been carried out for the dual purpose of investigating the feasibility of constructing a set of region-specific economic-environmental accounts for Scotland and to inform the database construction stage of developing an empirical economy-environment modelling framework.

The first stage of the study involved assessing the usefulness of an existing study (Salway ***et al***, 2001) that constructs a Scottish CO_2 emissions account as part of a regional greenhouse gas emissions inventory for England, Scotland, Wales and Northern Ireland. This study gives us the results reported in Table 1. The two issues raised with respect to these results are their region-specificity/validity for the Scottish economy and the fact that they are not linked to SIC/I-O classified economic sectors. The key advantage of the accounts reported in Table 1 is that Salway ***et al***'s (2001) study had access to source-specific (point) estimates of CO_2 emissions in Scotland. The first disadvantage is that we do not know what these are or what share of the emissions reported in Table 1 these account for. In terms of all non-point estimates reported in Table 1, the key problem would seem to be that these do not take full (if any) advantage of the high quality Scottish-specific regional economic data that are available in the form of the Scottish I-O tables. Also it is not clear what use has been made of Scottish-specific fuel use data (and, indeed, if this has been used, why a more ‘bottom-up’ approach to constructing regional accounts has not been adopted).

One problem that has not been explicitly discussed thus far is the issue of the public versus private status of data. A private company was contracted to carry out the Salway ***et al*** (2001) study, and private companies face commercial pressures that force them to be less transparent about the methods employed to arrive at reported results than a public body, which is not subject to this type of pressure. However, where exploratory work, such as the present pilot study on constructing an empirical framework for economic-environmental analysis, is required to inform public policy making and debate it is desirable for data to take the form of a public good.

As noted above, in terms of data that ***are*** publicly available, Scotland is significantly better off that other UK regions; in particular with the availability of regularly updated input-output tables published by the Scottish Executive. However, a key concern is that in Salway ***et al***'s estimation of a regional air emissions inventory, UK data are being allocated in a way that does not fully utilise available regional data. The question then arises as to how far is accounting for Scottish activity being compromised by less accurate data in other UK regions in order to make results consistent with the national accounts. This concern is more general than the environmental case investigated here. National requirements would also seem to dominate in terms of UK regional accounting on the economic side as well as evidenced by the fact that the Scottish I-O tables are not used as the basis for the Scottish components of the UK regional accounts as reported annually in ***Regional Trends.***

The argument underlying the present study is 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. It has been argued 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.

Therefore the second stage of the study involved attempting to construct a sectoral emissions account for the key pollutant CO_2 using a 'bottom-up' methodology that I have argued will provide a better understanding of the various sources of emissions within different production and final consumption activities in the Scottish economy. Given the lack of appropriate data on sectoral fuel uses and other sources of emissions, the results reported here should be regarded with caution. However, it is hoped that the analysis and discussion in this paper will inform the current policy debate over the type of data that are required to help us better understand the interaction between economic activity and the environment.

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Endnotes

1. In fact, this pilot study has been carried out within the context of attempting to develop a suitable database for a system-wide (computable general equilibrium) energy-economy-environment model of the Scottish economy. The modelling work is being carried out at the Fraser of Allander Institute, University of Strathclyde, and the University of Glasgow as part of an ESRC funded project titled 'Modelling the Impact of Sustainability Policies in Scotland'. See Hanley ***et al*** (2003) for details of the modelling framework and preliminary results of simulations relating to UK Climate Change Levy and resource productivity policy initiatives.
2. Moreover, data on the distribution of total sales will mask any differences in average prices paid for physical quantities of different fuels by different users. Note, however, that any such differences in prices would be inconsistent with the basic assumptions underlying the construction of IO tables in monetary

rather than physical units, and would create general problems for any multi-sectoral modelling based on the IO accounts.

3. The Scottish Executive kindly supplied this report for use in the present study. The Salway *et al* (2001) study was carried out by AEA Technology, a commercial body that constructs the UK National Air Emissions Inventory (funded by Defra, the National Assembly for Wales, the Scottish Executive and Department of the Environment, Northern Ireland).
4. The IPCC classification of activities shown in Table 1 is an aggregated version of the one used in the UK National Air Emissions Inventory and for the regional estimates reported in Salway *et al* (2001). However, even at a more disaggregated level, the IPCC classifications do not correspond to SIC/I-O definitions of economic activities.
5. The UK 76-sector economic-environmental accounts for 1999 can be downloaded from the National Statistics web-site, http://www.nationalstatistics.gov.uk/STATBASE. Note that the data currently found at this location, which are consistent with the 2002 Blue Book (National Statistics, 2002), may differ slightly from the data used here. This is because the present study draws on an earlier version of the UK Environmental Accounts that is consistent with both the 2001 Blue Book (National Statistics, 2001) and the 1999 Scottish I-O tables (Scottish Executive, 2002b).
6. However, note that this explanation is speculative and has not been verified by the Environmental Accounts Branch of ONS or by AEAT.
7. Note that for the purposes of this pilot study the account is only constructed for a limited sectoral breakdown, 25 production sectors compared to the 76 for which economic-environmental accounts are constructed at the UK level. This is consistent with the requirements of the ESRC-funded modelling project of which this study forms part. However, for the purposes of formal economic-environmental accounting in Scotland, ideally a greater level of sectoral breakdown would be desirable (and would be possible given the sectoral breakdown of the UK Environmental Accounts and Scottish IO tables). Also, note that this type of account could, in principle, be constructed for pollutants other than CO_2. This study focuses on CO_2 for two reasons. First, CO_2 is the key pollutant in policy terms in the UK and Scotland. Second, the relationship between fuel combustion and carbon emissions is more straightforward and less dependent on combustion conditions than is the case with other pollutants, which makes the computations less complex and data intensive.
8. The Electricity supply sector (I-O 85) is split into renewable and non-renewable generation sectors in this study for the purposes of the wider modelling project. The split in the economic database is made on the basis of experimental data supplied by the Scottish Executive, which breaks down the (input) column for this sector in the 1999 Scottish I-O table. The environmental data are more experimental and, therefore, the disaggregated results for CO_2 emissions from activity in the electricity production sector reported for sectors 15 and 16 in Table 1 should be regarded with some caution.
9. See footnote 5.
10. A fuller set of results, including the full economic (social accounting matrix, SAM) database and pollution coefficients constructed for the ESRC-funded modelling project are available from the author on request (contact karen.turner@strath.ac.uk).

Appendix

Estimating emissions from production and final consumption activities

The standard assumption is that emissions are a linear function of the volume of fuel combusted during that activity plus the levels of output from other polluting processes (see, for example, Beauséjour *et al* (1994), Vaze (1997)). Thus, for each production sector, i, emissions of each pollutant, k, are determined as:

(1) $$P_{k,i} = m_{k,i}X_i = (\Sigma\,(e^k_{ijt}.f_{ijt}) + n^k_i)X_i,$$

“ i = 1,..., I, k = 1,..., K, j = 1,...J, t = 1,...,T j,t

where e^k_{ijt} is an emissions factor, identifying the amount of pollutant k that is generated when sector i uses (combusts) one unit of fuel j using technology/process t, f_{ijt} is the amount of fuel j used by sector i using technology t, and n^k_i is an output-pollution coefficient quantifying the non-fuel-combustion-related generation of pollutant k per unit of output in sector i.

Emissions are determined in the same way for each final demand category, z:

(2) $$P_{k,z} = m_{k,z}C_z = (\Sigma\,(e^k_{zjt}\ .\ f_{zjt}) + n^k_z)C_z,$$

“ z = 1,..., Z, k = 1,..., K, j = 1,...J, t = 1,...,T j,t

where C_z is expenditure by final demand category z.

Therefore the question addressed by this pilot study is whether data are available to permit the estimation of expressions (1) and (2) for the Scottish economy. The Scottish I-O tables provide data on total output in each production sector, i, and total expenditures by each final demand category, z. Therefore, the additional data required to produce a sectoral emissions account, for example for $k=CO_2$, is information on physical fuel uses, the f_{ijt} and f_{zjt}, and on the emissions factors e^k_{ijt}, e^k_{zjt}, n^k_I and n^k_z.

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