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THE ENVIRONMENTAL 'TRADE BALANCE' BETWEEN SCOTLAND AND THE REST OF THE UK: AN INTER-REGIONAL INPUT-OUTPUT AND SAM ANALYSIS

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THE ENVIRONMENTAL 'TRADE BALANCE' BETWEEN SCOTLAND AND THE REST OF THE UK: AN INTER-REGIONAL INPUT-OUTPUT AND SAM ANALYSIS*

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Abstract:

We use an inter-regional input-output (IO) and social accounting matrix (SAM) pollution attribution framework to serve as a platform for sub-national environmental attribution and trade balance analysis. While the existence of significant data problems mean that the quantitative results of this study should be regarded as provisional, the inter-regional economy-environment IO and SAM framework for Scotland and the rest of the UK (RUK) allows an illustrative analysis of some very important issues.

There are two key findings. The first is that there are large environmental spillovers between the regions of the UK. This has implications in terms of the devolution of responsibility for achieving targets for reductions in emissions levels and the need for policy co-ordination between the UK national and devolved governments. The second finding is that whilst Scotland runs an economic trade deficit with RUK, the environmental trade balance relationship for the main greenhouse gas, CO_2, runs in the opposite direction. In other words, the findings of this study suggest the existence of a CO_2 trade *surplus* between Scotland and the rest of the UK. This suggests that Scotland is bearing a net loss in terms of pollutants as a result of inter-union trade. However, if Scotland can carry out key activities, such as electricity generation, using less polluting technology, it is better for the UK as a whole if this type of relationship exists. Thus, the environmental trade balance is an important part of the devolution settlement.

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1. Introduction

Devolution in the UK has led to the regional governments of Scotland and Wales and the English Regional Development Agencies having responsibility for setting and achieving sustainability policies at the regional level. As a result, there is significant interest in developing empirical economy-environment frameworks that can deal with the environmental impacts of economic policies *and* inter-regional spillover effects.

In this paper we report on an initial attempt to generate such a framework by constructing an environmental inter-regional input-output (IO) and social accounting matrix (SAM) for the UK, focussing on the two region case of Scotland and the rest of the UK (RUK). There are a number of problems in terms of data availability. The main issues are the absence of recent analytical IO tables and inter-regional trade data for the UK and problems of consistency between economic and environmental and regional and national data

While the existence of these types of data problems mean that the quantitative results of this study should be regarded as provisional, the inter-regional economy-environment SAM framework for Scotland and RUK allows an illustrative analysis of some very important issues. Specifically, it allows us to investigate methods for attributing responsibility for pollution generation in the UK at the regional level and to analyse the nature and significance of environmental spillovers and the existence of an 'environmental trade balance' between regions.

The remainder of the paper is structured as follows. In Section 2 we discuss the central issues of interest in environmental accounting analysis. In Section 3 we broadly consider the theoretical basis for carrying out environmental attribution analysis in an inter-regional IO or SAM framework. In Section 4 we discuss in more detail the practical problems involved in constructing this type of framework for the UK. In Sections 5 we report the results of our environmental attribution analyses for Scotland and RUK. Section 6 contains a summary and conclusions.

2. Central issues in environmental accounting/attribution analyses

It is a standard environmental accounting approach to attempt to attribute pollution (or resource use) to elements of final consumption. That is, to attribute direct and indirect pollution generation not to production of commodities but to the consumption that drives that production. An example is the "ecological footprint" concept (Wackernagel and Rees, 1996, 1997, and Van den Bergh and Verbruggen, 1999), which has become increasingly popular with policymakers particularly in the UK (see, for example, in the case of Scotland, Best Foot Forward Ltd., 2004, McGregor *et al*, 2004a).

Input-output (IO) methods, which account for the use of commodities as intermediate inputs, would seem ideal for this type of environmental attribution. If the economic information in the IO accounts can be augmented with environmental information relating pollution generation to direct production and consumption activities, the analytical tools associated with IO, such as multipliers, can be used for environmental analysis (Miller and Blair, 1985). This was first recognised by Leontief (1970). Examples of the conventional use of IO for pollution attribution are Lenzen (1998) and McGregor *et al* (2001). However, it has also been recognised that the tracking of resource use and pollution generation required for the ecological footprint can only be rigorously done using an approach based on IO techniques (Bicknell *et al*, 1998, Lenzen and Murray, 2001).

This brings us to a second crucial goal of environmental attribution techniques such as ecological footprints: to focus on attributing to consumption in any one region/country pollution generation that occurs during production to meet this final demand both within *and* outwith the domestic economy. That is, taking into account pollution embodied in imports that are used directly or indirectly in final consumption.

In previous studies (McGregor *et* al, 2004a,b,c) we have been critical of this second goal on two points. The first is information. Not only is an IO approach required, the attribution of *total* (global) pollution generation (and/or resource use) required to meet final consumption in any one region or country can only be rigorously done through the use of inter-linked consistent IO systems for trading nations. This presents huge information problems.

Basically, there is a major practical difficulty in that, in principle, accounting for pollution (or resource use) embodied in imports entails the consistent collection and collation of a large amount of data (Office of National Statistics, 2002). To identify and allocate the direct and indirect pollution embedded in imports requires detailed knowledge of their commodity breakdown and how they are used in the economy. Further, a compatible environmentally augmented IO table for each of the countries that supply imports is needed, so that the direct and indirect resource use and/or pollution generation incorporated in these commodities is identified too. However, such an attribution would require a similar knowledge of the imports of these exporting country, and so on. Except for economies engaged in very restricted trading arrangements, the ecological footprint type of method strictly requires a world IO table that is consistently nationally and sectorally disaggregated. It also requires an associated set of environmental accounts. Such a database is simply not available at present. (Indeed, as explained in Section 4, we even encounter information problems in constructing an inter-regional IO table for the UK.)

In short, tracing through the actual resource use and pollution generation in an economy's imports is extremely difficult, with the implication that short-cut methods tend to be used. This often involves making the assumption that the resource-use and pollution generation characteristics of economies that imports are sourced from are identical to those in the importing economy (see Bicknell *et al*, 1998, Office for National Statistics, 2002).

The second problem is conceptual. It is not obvious that the pollution generation (or resource use) in one legal jurisdiction should be attributed to consumption activity within another. Where trade occurs voluntarily, responsibility for pollution generation might be thought to rest as much with the supplier as with the demander. For example, if a supplying country uses particularly pollution-intensive methods of production, is this the responsibility of the purchasing country? Moreover, attributing the responsibility to the ultimate consumer in the way suggested by the ecological footprint requires, as we have seen above, information that the consumer has neither the ability, nor necessarily the legal power, to collect. Finally, even where the environmental implications are global, rather than local, a country's responsibilities usually apply to its own pollutant generation or resource use. In the case of pollution, countries typically sign up to treaties to limit their own emissions – not the emissions that are directly and indirectly generated in producing their consumption. For example, the UK has targets to limit its production of greenhouse gases under the Kyoto Protocol.

In McGregor *et al* (2004b,c) we propose an alternative approach to get round both the informational and conceptual problems outlined above. We adopt a neo-classical, resource-constrained, view of the operation of the open economy, where exports essentially finance imports (Dixit and Norman, 1980). We call this method the *N*eo-*C*lassical *L*inear *A*ttribution *S*ystem or NCLAS. Using the IO or SAM accounts, this approach can be used to retain local consumption as the driving force behind environmental attribution but allows us to focus on the pollution generation (and/or resource use) within the geographical boundaries of the appropriate local jurisdiction. In this method, an importing sector is attributed the pollution embodied in the domestic export production required to finance those imports. In a national context, this places the responsibility for pollution generation (and resource use) at the appropriate spatial level. It also has the advantage of only needing data from the economy under consideration: we do not need to worry about either detailed economic or environmental information from other economies linked through trade.

In McGregor *et* al (2004c) we use the NCLAS approach to attribute local pollution generation to local private and public final consumption focussing on Scotland as a small open single region economy. In this paper we extend the NCLAS approach in the context of Scotland as a region of the UK. The key distinction in the inter-regional case is that the conceptual problem relating to responsibility for pollution embodied in trade flows is not relevant in the case of inter-regional attribution *within* the UK economy where responsibility for controlling emissions ultimately lies at the national level. Therefore, we account for UK pollution generation embodied in trade flows between Scotland and the rest of the UK, by augmenting the Scottish IO table with an IO table for the whole of the UK for the same year. Combining the two tables produces a two-region UK Input-Output table, with economic activity within and between Scotland and the Rest of the UK (England, Northern Ireland and Wales) separately identified. In this arrangement we can fully track the inter-regional flow of imports and exports. Such an approach is appropriate given that the two regions are part of the same, albeit devolved, legislative system.

However, for trade with the rest of the world (ROW), we impose the NCLAS assumptions. That is to say, we endogenise trade with the demand for imports from ROW treated as a demand for the exports to ROW. As argued above, this reflects the view that the role of such exports is to finance these imports. This is also a sensible practical procedure, given that we have no compatible and easily assembled data for the UK's trading partners. We outline the application of the NCLAS method in the inter-regional case of Scotland-RUK in more detail below (in Section 5). First, we outline the general inter-regional environmental attribution method more formally.

3. The conceptual attribution approach

In a single region IO framework output the vector of sectoral outputs, q_1 (where the first subscript 1 refers to region 1 production), is defined as the sum of the demand vectors: intermediate demand, $A_{11}q_1$, local consumption demand, c_{11} (where the second subscript refers to region 1 consumption), and exports, x_1:

(1) $$A_{11}q_1 + c_{11} + x_1 = q_1$$

where q_1 is an (Ix1) vector where element q_{i1} is the total output of (region 1) sector i (where there are j=1,..,J sectors producing i=1,..,I commodities, and I=J). A_{11} is an IxI (IxJ) matrix of input-output coefficients where each element a_{ij} is the amount of (region 1) commodity i used per unit of output in (region 1) sector j. c_{11} is an (Ix1) vector where c_{i11} is local final consumption expenditure and x_1 is an (Ix1) vector where x_{i1} is export demand for the commodity output of (region 1) sector i. Rearranging in terms of vector q_1

(2) $$q_1 = [1 - A_{11}]^{-1} [c_{11} + x_1]$$

We can then determine how much local output is supported by the two different types of final demand:

(3) $$[q_{c11} | q_{x1}] = [1 - A_{11}]^{-1} [c_{11} | x_1]$$

where q_{c11} is output supported by local consumption demand and q_{x1} is output supported by export demand.

We can extend to a 2-region framework. For simplicity at this stage, we assume that all trade flows are between region 1 and region 2 (i.e. the 2-region system is closed) and endogenise trade in intermediate goods and services between the two regions so that the basic IO relationship becomes

(4) $$A_{11}q_1 + A_{12}q_2 + c_{11} + c_{12} = q_1$$
$$A_{21}q_1 + A_{22}q_2 + c_{21} + c_{22} = q_2$$

where, analogous to region 1 in (1), q_2 is an (Ix1) vector where element q_{i2} is the total output of (region 2) sector i and A_{22} is an (IxI) matrix of intra-regional input-output coefficients showing the amount of region 2 commodity i used per unit of output in region 2 sector j. A_{12} and A_{21} are the (IxI) matrices of inter-regional input output coefficients showing, respectively, the amount of region 1 commodity i used per unit of output in region 2 sector j (region 1 exports to region 2 production) and the amount of region 2 commodity i used per unit of output in region 1 sector j (region 1 exports to region 1 production). c_{11} and c_{22} are the (Ix1) vectors of local consumption demand in region 1 and 2 respectively, while c_{12} and c_{21} are the (Ix1) export vectors of final consumption demand in region 2 for region 1 production and in region 1 for region 2 production respectively.

We can rewrite (4) as

(5) $$\left[\frac{A_{11}\,|\,A_{12}}{A_{21}\,|\,A_{22}}\right]\left[\frac{q_1}{q_2}\right]+\left[\frac{c_{11}+c_{12}}{c_{21}+c_{22}}\right]=\left[\frac{q_1}{q_2}\right]$$

Rearranging (5) in terms of the (2Ix1) partitioned vector of outputs

(6) $$\left[\frac{q_1}{q_2}\right]=\left[\begin{array}{c|c} \frac{1-A_{11}}{-A_{21}} & \frac{-A_{12}}{1-A_{22}} \end{array}\right]^{-1}\left[\frac{c_{11}+c_{12}}{c_{21}+c_{22}}\right]$$

Where the (2Ix2I) partitioned matrix $[1-A]^{-1}$ is the inter-regional Leontief inverse, breaking down the output-multiplier for each sector i in each region into local output and imports from the other region that are required per unit of final demand for that sector.

We can then determine how much output in each region is supported by intermediate and final consumption demand in the two regions:

(7) $$\left[\frac{q_{11}\,|\,q_{12}}{q_{21}\,|\,q_{22}}\right]=\left[\begin{array}{c|c} \frac{1-A_{11}}{-A_{21}} & \frac{-A_{12}}{1-A_{22}} \end{array}\right]^{-1}\left[\frac{c_{11}\,|\,c_{12}}{c_{21}\,|\,c_{22}}\right]$$

where q_{11} is output in region 1 supported by region 1 final consumption demand, q_{12} is output in region 1 supported by region 2 final consumption demand, and similarly for the vector of region 2 outputs q_2, which is attributable to local and region 2 final consumption demands as q_{22} and q_{21} respectively.

In the empirical analyses in Section 5 we extend the IO framework in equations (1) to (7) to carry out SAM-based attribution analysis. The formal analysis is similar so we do not repeat it here. However, the key issue is that more information is included in the SAM in an extended set of accounts built around the IO, taking into account income transfers between firms, households and government, as well as the external 'rest of the world', ROW, sector that we introduce in our empirical analyses.

Endogenising trade in intermediate goods and services between the two regions and attributing all production activity to final consumption in region 1 or 2 as shown in (7), in the IO or SAM framework, also allows us to examine how the pollution generated in production in each region supports final consumption in both regions. We determine a (2Px2I) partitioned matrix N (where there are p=1,..,P pollutants) of output-pollution multipliers for final consumption demand for the outputs of each production sector in each region as

$$(8)\qquad \left[\begin{array}{c|c} N_{11} & N_{12} \\ \hline N_{21} & N_{22} \end{array}\right] = \left[\begin{array}{c|c} E_{q1} & 0 \\ \hline 0 & E_{q2} \end{array}\right] \left[\begin{array}{c|c} 1-A_{11} & -A_{12} \\ \hline -A_{21} & 1-A_{22} \end{array}\right]^{-1}$$

where E_{q1} is the (PxI) matrix of direct output-pollution coefficients. That is, the physical amount of emissions of each pollutant, p, directly generated per monetary unit of output in each production sector, i, in region 1. E_{q2} is the corresponding matrix for production sectors in region 2. Thus, N is partitioned matrix: N_{11} is a (PxI) sub-matrix telling us the amount of pollution generated in region 1 per unit of local final consumption for region 1 production and N_{12} tells us the amount of pollution generation in region 1 per unit of region 2 final consumption demand for region q production. Similarly N_{21} and N_{22} tell us the amount of pollution generated in region 2 per unit of region 1 and region 2 final consumption respectively.

Thus, we can use the output-pollution multipliers to attribute the total amount of pollution generated by production activities in the two regions in the period described by the IO tables among particular sources of consumption expenditure in each region:

$$(9)\qquad \left[\begin{array}{c|c} p_{q11} & p_{q12} \\ \hline p_{q21} & p_{q22} \end{array}\right] = \left[\begin{array}{c|c} N_{11} & N_{12} \\ \hline N_{21} & N_{22} \end{array}\right] \left[\begin{array}{c|c} c_{11} & c_{12} \\ \hline c_{21} & c_{22} \end{array}\right]$$

Where p_{q11} is a (Px1) vector telling us the amount of pollution generated by production activities in region 1 to support region 1 final consumption demand while p_{q12} tells us the amount of pollution generated in region 1 generated to support final consumption demand in region 2. Similarly p_{q21} and p_{q22} tell us how much pollution is generated by production activities in region 2 to support final consumption demand in region 1 and 2 respectively.

Where final consumers are directly responsible for pollution generation we must also estimate the (2Px2) partitioned matrix P_c:

$$(10) \qquad \left[\begin{array}{c|c} p_{c11} & p_{c12} \\ \hline p_{c21} & p_{c22} \end{array}\right] = \left[\begin{array}{c|c} e_{c11} & e_{c12} \\ \hline e_{c21} & e_{c22} \end{array}\right]\left[\begin{array}{c|c} c_{12} & c_{12} \\ \hline c_{21} & c_{22} \end{array}\right]$$

where e_{c11} and e_{c22} are (Px1) sub-vectors of final demand expenditure pollution coefficients. That is, the physical amount of emissions of each pollutant, p, directly generated per unit of local final demand expenditure in region 1 and 2 respectively. Note that, in contrast to the partitioned matrix E_q of output-pollution coefficients for production sector in equation (8), vectors of expenditure-pollution coefficients are defined here for direct pollution generation by region 2 final consumers in region 1 and vice versa (e_{c12} and e_{c21} respectively). This is because, while production activities in one region do not lead to direct pollution generation in the other region, final consumption activities might. Specifically, this applies to the case of tourist expenditure. For example, tourists from region 2 will be directly responsible for pollution generation in region 1 if they visit region 1 in their own cars causing direct emissions from fuel use.

If we add the partitioned matrix P_q of emissions generated by production to support different types of final consumption from equation (9) to the partitioned matrix P_c of emissions directly generated by different types of final consumers from equation (10) we get the partitioned matrix P of total emissions supported by each type of final consumption:

$$(11) \qquad \left[\begin{array}{c|c} p_{11} & p_{12} \\ \hline p_{21} & p_{22} \end{array}\right] = \left[\begin{array}{c|c} p_{q11} & p_{q12} \\ \hline p_{q21} & p_{q22} \end{array}\right] + \left[\begin{array}{c|c} p_{c11} & p_{c12} \\ \hline p_{c21} & p_{c22} \end{array}\right]$$

where p_{11} and p_{12} give us total emissions generated in region 1 during the period that the IO tables apply to in terms of emissions directly or indirectly attributable to final consumers in region 1 and 2 respectively. Similarly p_{21} and p_{22} give us total emissions generated in region 2 to support final consumption in region 1 and 2 respectively.

In this paper we also examine the environmental trade balance between the two regions. For example, region 1's environmental trade balance with region 2 is defined as p_{12} minus p_{21} (pollution in region 1 supported by region 2 consumption minus pollution in region 2 supported by region 1 consumption). We report results of a 2-region analysis for Scotland and the rest of the UK in Section 5. First, however, we discuss the practical problems encountered in constructing the inter-regional environmental IO and SAM accounts for this case study.

4. Practical issues in constructing a 2-region IO and SAM for Scotland and the rest of the UK (RUK)

Our first step is to construct a set of inter-regional environmental input-output (IO) accounts for Scotland and RUK. This involves two steps. The first is the generation of the inter-regional input-output (IO) economic accounts in the format required for multiplier/attribution analyses - i.e. a symmetric and domestic flows matrix in producer prices that balances inputs and outputs at the sectoral level. The second is the creation of matching environmental average production and consumption coefficients – i.e. pollution coefficients for each production and final consumption activity in each region.

In terms of the economic component of this system, the Scottish Executive produces analytical IO tables describing the structure of the Scottish economy on a regular basis, with the most recent set being the 1999 tables (Scottish Executive, 2002). However, corresponding analytical tables have not been produced for the UK since 1995 (National Statistics, 2002). Commodity-by-industry supply and use tables (SUT) in purchaser prices are available for 1999 (National Statistics, 2001). However, the make matrix and other data required to convert these into analytical format are not publicly available. Therefore we take information on gross industry outputs and final demand expenditures from the SUT and use these to mechanically roll forward the 1995 tables to estimate a 1999 industry-by-industry domestic flows matrix in basic prices (see Allan *et al*, 2004, or Ferguson *et al*, 2004, for full details).

The second main data problem for constructing the inter-regional economic IO accounts is the absence of information on inter-regional trade flows at an appropriate level of sectoral disaggregation. In the case of Scottish imports from RUK (sector-by-sector) we have been able to make use of (unpublished) experimental data made available to us by the IO team at the Scottish Executive. However, while the Scottish IO tables give us sectoral detail on the exports to RUK, we have had to estimate the corresponding RUK intermediate and final use data. We do this by making the (very simple) assumption that in using goods and services from any UK sector, i, each RUK production and final consumption sector makes the same proportionate use of Scottish or RUK outputs, and that this proportion is based on the ratio of Scottish sector i exports to total RUK use of sector i outputs. Again, see Allan *et al*, 2004, or Ferguson *et al*, 2004, for full details and results.

Aside from our reservations with regard to the quality of the resulting Scotland-RUK inter-regional IO table, the other main consequence of relying on this process of estimation for so much of the table is that we are restricted to the 10-sector breakdown detailed in Table 1 due to the occurrence of some negative entries in the domestic flows matrices at higher levels of disaggregation (see Allan *et al*, 2004 and Ferguson *et al*, 2004).

INSERT TABLE 1 AROUND HERE

However, for environmental IO analysis a greater degree of disaggregation should ideally be used, because of the importance of separately identifying sectors with distinct pollution generation and resource-use characteristics. At this stage, however, we focus on only a limited sectoral breakdown in order to work through the key issues for constructing an inter-regional IO framework. However, in future developments of the framework presented here we hope data improvements allow us to select a more detailed and appropriate sectoral disaggregation for economic-environmental analysis.

The extension to an inter-regional SAM framework involves constructing a set of income-expenditure accounts for each of the aggregate transactors - households, firms, government, the external sector (ROW) and the capital account - in Scotland and RUK. Full details are given in Allan *et al* (2004). Here, we note that while determination of the *intra*-regional components of these accounts is fairly straightforward, as in the case of flows of goods and services in the IO component of the system, very little data are available to estimate *inter*-regional income transfers.

The environmental component of the inter-regional IO and SAM system consists of a set of direct emissions coefficients (physical amount of emissions per monetary unit of the relevant sectoral activity, here gross output/expenditure) for each production sector and final consumption group, focussing, in the present study, on just one pollutant – the main greenhouse gas, CO_2. Ideally the pollution coefficients should reflect region-specific polluting technology and energy use for each sector. We have carried out a separate study to construct a Scottish sectoral CO_2 emissions account from which Scottish-specific pollution coefficients could be derived (see Turner, 2003). However, we cannot at present use these results in the inter-regional system as there is no corresponding consistently-derived dataset for RUK. Therefore, we apply a set of average sectoral emissions intensities derived from the 1999 UK environmental accounts.[1] These coefficients are weighted to reflect differences in the composition of activity in Scotland and RUK, to the 10 sectors identified in Table 1 plus households.

We do, however, introduce some region-specific information, in the case of one particular, and very important, polluting process, namely electricity generation (part of the Electricity, Gas and Water supply (EGWS) sector), using Scottish- and RUK-specific data estimated as part of a regional air emissions inventory study (Salway *et al*, 2001). These estimates better reflect the greater use of renewable, and therefore 'cleaner', electricity generation techniques used in Scotland. The resulting set of direct emissions coefficients for the inter-regional environmental IO and SAM system is shown in Table 2. See Ferguson *et al* (2004) for fuller details.

5. Environmental attribution analysis for Scotland and RUK

The data problems outlined above mean that the quantitative results of any analyses using the Scotland-RUK environmental IO and SAM system should be regarded as provisional. Nonetheless, as explained in the introduction to this paper, we believe that there is still merit in using the framework for an illustrative attribution analysis to examine the nature and level of interdependence between regions of the UK, specifically in terms of environmental spillover effects, and the existence of an 'environmental trade balance'.

5. 1 "Conventional" 2-region IO attribution analyses

The first thing that we can do with the Scotland-RUK environmental IO system is to estimate direct CO_2 emissions generation by sector in each region, by multiplying the direct emissions coefficients against the gross sectoral outputs/expenditures from the inter-regional IO tables. The results of this calculation are shown in Table 3.

[1] The UK Environmental Accounts used here are those summarised in the 2001 Blue Book (National Statistics, 2001), which are consistent with the 1999 UK SUT used for the economic accounts and the Scottish 1999 IO tables (Scottish Executive, 2002). However, the UK Environmental Accounts are regularly updated and accessible at http://www.nationalstatistics.gov.uk/CCI/nscl.asp?ID=6805.

Insert Table 3 around here

The results in Table 3 identify the direct CO_2 generation in each sector and final consumption. However, an alternative attribution system is available. Through their purchases of goods and services from other sectors and regions, either for use as intermediate inputs to production or, in the case of households, for final consumption, the final demands for each sector contribute indirectly to pollution. We are particularly interested in measuring emissions embodied in inter-regional trade flows as, in general, the relative size of these emissions is important for the co-ordination of environmental policy delivered at the regional level. That is to say, we are interested in what share of pollution generation in RUK can be attributed to Scottish final consumption (and vice versa). A second issue is the CO_2 'trade balance' between Scotland and RUK - does Scotland import, directly or indirectly, more or less emissions than it exports to RUK? This is a potentially important element in the devolution settlement.

Our first attempt at estimating the extent of CO_2 "trade" between Scotland and RUK involves estimating equation (7) where the A matrix is a 2Ix2I, or 20x20 (where i=1,..,10 in each of the 2 regions) partitioned matrix where only the output of UK production sectors are treated as endogenous, and the partitioned matrix C of final consumption demands includes export demand from the rest of the world (ROW). That is, we begin with a convention Type I open economy attribution analysis.

Insert Table 4 around here

Table 4 shows the scale of the CO_2 "trade" (or "spillovers") that occur between Scotland and the rest of the UK. Of the total CO_2 generated in the UK directly or indirectly as a result of conventional Scottish final demand expenditures, just under 30% is generated outwith Scotland, that is in the RUK. A similar proportion of CO_2 generated in Scotland is to support, directly or indirectly, RUK final demand. Table 4 indicates the big differences in the extent of interregional CO_2 spillovers between these final demand types. These are highest proportionately for Scottish capital investment, where 1.6 tonnes of CO_2 is generated in RUK for each tonne in Scotland. Also note that Scottish exports to the rest of the world, which produce no direct CO_2 outwith Scotland, still generate sizeable amounts of CO_2 in RUK as a result of the indirect impacts of the production of intermediate inputs.

There is a negative CO_2 trade balance for Scotland, implying that the pollution generated in Scotland by production supporting RUK final demands is less than the pollution generated in

RUK by production supporting Scottish final demands. However, the Scottish CO_2 trade deficit is relatively small, accounting for less than 0.75% of total CO_2 generated in Scotland.

5.2 2-region IO attribution analysis in a neo-classical linear attribution system (NCLAS)

Note that the results in Table 4 do not take account of any CO_2 emissions embodied in imports from ROW. Further, this application of conventional Type I IO attribution analysis results in 20.5% of CO_2 emissions generated in RUK and 22.7% of those generated in Scotland being attributed to external, ROW, consumption demand. This is inconsistent with the common attempt to place human consumption decisions at the heart of environmental problems and the motivation underlying exercises to calculate the environmental impact of any one nation/region’s consumption, such as ecological footprints. However, as we have explained in Section 2, prohibitive data requirements mean that there is no feasible way of measuring, with any precision, the pollution content of imports from ROW.

We also argue that there is a conceptual problem in attempting to account for traded pollution by attributing the direct and indirect pollution generation (and/or resource use) embodied in the production of imported goods to consumption in the importing country. This is that such an attribution would apparently place the responsibility for pollution generation occurring in one legislative domain to decisions made in another legislative domain while self interest and international treaties (such as the Kyoto Protocol) generally require that governments take responsibility for pollution generation within their own territories.

In response to these problems we have developed the NCLAS method (McGregor *et al*, 2004a,b) based around standard environmental IO attribution analyses, which, whilst shifting the focus from production, as in conventional Type I analysis, to consumption. Formally, we treat the export sector as though it were a production sector that transforms exports to ROW into imports from ROW through an additional row and column in the A matrix. We also endogenise investment, as covering depreciation. However, while in the case of trade, regional exports are driven (proportionately) by national imports, we treat regional capital expenditure as being driven by regional depreciation, thus requiring two additional rows and two additional columns in the A matrix. Formally, we estimate equation (7) where the partitioned A matrix becomes a 23x23 matrix and the ROW terms that are added to the partitioned C matrix for the Type I analysis and capital formation drop out so that the only exogenous demands are private (household) and public (government) final consumption in each region.

In terms of the environmental attribution, adopting the NCLAS approach means that the pollution generation and resource use embodied in UK exports are essentially allocated *pro rata* to the sectors and final consumers in each region that import. From this viewpoint, the cost of imports, both in economic and environmental terms, is the cost and environmental damage associated with the exports that production sectors in each region have to provide to pay for UK imports.

Insert Table 5 around here

The results of the inter-regional IO NCLAS attribution are shown in Table 5. Compare the results in Table 5 with those of the conventional Type I IO analysis in Table 4. While the level of total CO_2 emissions generated in each region is unchanged, the allocation of these among Scottish and RUK final consumption demands changes dramatically with exports to ROW treated as endogenous. The measured CO_2 spillovers are now much larger. Over 43% of CO_2 associated with Scottish consumption is generated in RUK and 46% of the CO_2 produced in Scotland directly or indirectly for RUK final consumption.

The impact on the CO_2 trade balance between Scotland and RUK is considerable. Scotland now has a CO_2 balance of trade surplus, which stands at just over 2,1 million tonnes. This is over 4% of the total CO_2 production in Scotland. This reflects the fact that while Scotland runs a trade deficit with RUK, it runs a trade surplus with ROW. On the other hand, RUK runs a trade deficit with ROW. This carries the implication that a share of Scottish exports is contributing to financing RUK imports from ROW.

5.3 2-region SAM NCLAS attribution analysis

The NCLAS approach is closer than standard Type I (or Type II) IO analysis to the common environmental approach, which places domestic consumption at the centre of pollution attribution. However, the endogenisation of the final demand trade and investment sectors is rather crudely done in an IO framework. In McGregor *et al* (2004c) we extend the NCLAS approach in a social accounting matrix (SAM) framework for a single region environmental attribution analysis for Scotland to gain a fuller picture of the sources of household and government income used to finance final consumption, as well as giving a more comprehensive picture of the expenditures that these incomes finance. The final part of the current study is to extend this SAM-NCLAS analysis in the inter-regional framework for Scotland and the rest of the UK.

Insert Table 6 around here

The results for the SAM-NCLAS attribution shown in Table 6 are not dramatically different from the IO-NCLAS results in Table 5. The Scottish CO_2 trade surplus is increased and now stands at 5.5% of the total CO_2 generation in Scotland. There is also a reallocation of emissions among Scottish and RUK consumption demands.

Two main principles underlie the reallocation of emissions. First, consider the expenditures that are treated as exogenous in the IO-NCLAS analysis - i.e. private (households) and public (government) expenditures in Scotland and RUK. In the SAM additional exogenous expenditures by these local consumers are identified. This tends to have a positive impact for all private and public final consumption groups, though the impact is bigger for Scottish consumers (putting downward pressure of the size of Scotland's CO_2 trade surplus). Second, the inclusion of these additional elements of exogenous expenditures causes changes in the NCLAS multiplier values for the individual exogenous elements that are in both the IO and the SAM, with the general tendency for the latter to be lower than in the IO case (because there are now more elements of exogenous final demands driving the same amount of pollution). This second effect puts upward pressure on the size of Scotland's CO_2 trade surplus, which, here, more than offsets the downward pressure of the first effect.

6 Summary and Conclusions

In this paper we use an inter-regional input-output (IO) and social accounting matrix (SAM) environmental attribution framework to serve as a platform for sub-national environmental attribution and trade balance analysis. While the existence of significant data problems mean that the quantitative results of this study should be regarded as provisional, the inter-regional economy-environment SAM framework for Scotland and the rest of the UK (RUK) allows an illustrative analysis of some very important issues.

There are two key findings. The first is that there are large environmental spillovers between the regions of the UK. We report that around 45% of CO_2 generated in Scotland supports consumption in the RUK. A similar figure holds for the proportion of CO_2 generation that is required, directly or indirectly, to meet Scottish consumption that is produced in RUK. The second finding is that whilst Scotland runs an economic trade deficit with RUK, the environmental trade balance relationship for the main greenhouse gas, CO_2, runs in the opposite direction. In other words, the findings of this study suggest the existence of a CO_2 trade *surplus* between Scotland and the rest of the UK. This is in the order of 5% of the total CO_2 generation in Scotland.

There are two key implications. The first is that in terms of the devolution of responsibility for achieving targets for reductions in emissions levels, the size of pollution spillovers raises the question as to what extent controlling the level of Scottish emissions should be the responsibility of the Scottish Parliament. Scotland, as part of the union, is limited in the way it can control some emissions, particularly with respect to changes in demand elsewhere in the UK. This implies a need for policy co-ordination between national and regional government in the UK, rather than full devolution of responsibility for setting and achieving targets.

The second is that the existence of an environmental trade *surplus* between Scotland and the rest of the UK implies that Scotland is bearing a net loss in terms of pollutants as a result of inter-union trade. On the other hand, if activities such as electricity generation can be carried out using less polluting technology in Scotland relative to the rest of the UK, it is better for the UK as a whole if this type of relationship exists. Thus, the environmental trade balance is an important part of the devolution package.

All of the analysis and results reported here should of course be regarded as provisional. As we have explained in Section 4, there still exist considerable problems with the data requirements for constructing an inter-regional environmental IO/SAM system for the UK. For a more accurate and informative analysis we require a more robust set of analytical IO tables for the UK and better data on inter-regional trade flows. There is also a problem in terms of the absence of regional environmental data that report emissions at the sectoral level and relate these to energy supply and demand patterns implied by IO tables. That is to say, if useful analysis of the relationship between economic activity and environmental impacts is to be carried out, environmental accounting data need to be gathered and reported in a manner consistent with the economic accounts and, for inter-regional analysis, consistent procedures are required at the national and regional levels.

Finally, we should highlight the fact that all of the analyses in this paper have been discussed in the context of *accounting* for pollution flows in the single time period that the accounts relate to. If the focus is on *modelling* the impacts of any marginal change in activity - for example, resulting from changes in policy – a more flexible inter-regional computable general equilibrium approach, that models behavioural relationships in a more realistic and theory-consistent manner would be required.

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Table 1. Sectoral Breakdown of the Scot/RUKinter-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

Table 2. Output-CO_2 and expenditure-CO_2 pollution coefficients for UK, RUK and Scotland

	Tonnes of CO_2 per £1million output (and household final demand expenditure)		
Region Sector	UK	RUK	Scotland
PRIMARY	656	663	609
MANUFACTURING	304	312	224
ELEC, GAS & WATER SUPPLY	3077	3060	3222
CONSTRUCTION	40	40	40
WHOLESALE & RETAIL TRADE	59	59	59
TRANSPORT & COMMUNICATION	483	483	490
FINANCIAL INT & BUSINESS	33	32	33
PUBLIC ADMINISTRATION	120	120	120
EDUC, HEALTH & SOCIAL WORK	58	58	56
OTHER SERVICES	39	39	43
HOUSEHOLD FINAL CONSUMPTION	242	242	242

Table 3. Direct CO_2 Emissions Generated in UK, RUK and Scotland in 1999

	Tonnes, millions, of direct CO_2 emissions		
Region Sector	UK	RUK	Scotland
PRIMARY	30.9	27.0	3.9
MANUFACTURING	122.5	114.4	8.0
ELEC, GAS & WATER SUPPLY	145.0	128.7	16.3
CONSTRUCTION	4.4	4.0	0.4
WHOLESALE & RETAIL TRADE	14.0	13.1	0.9
TRANSPORT & COMMUNICATION	68.9	63.3	5.6
FINANCIAL INT & BUSINESS	12.8	12.0	0.9
PUBLIC ADMINISTRATION	8.9	7.9	1.0
EDUC, HEALTH & SOCIAL WORK	10.9	10.0	0.9
OTHER SERVICES	2.9	2.7	0.2
HOUSEHOLD FINAL CONSUMPTION	143.0	132.3	10.7
TOTAL	564.3	515.4	48.9
Direct contribution to UK emissions	100%	91.33%	8.67%

Table 4. The CO_2 Trade Balance Between Scotland and RUK (tonnes, millions) - Type I Input-Output

	Pollution supported by:								Total regional
	Scottish HH	Scottish Govt	Scottish Capital	Scot-ROW	RUK HH	RUK Govt	RUK Capital	RUK-ROW	emissions of CO_2
Pollution generated in:									
Scotland	21.3	3.6	1.4	8.8	9.1	0.9	1.5	2.3	48.9
RUK	7.1	1.7	2.3	3.1	332.5	33.0	33.0	102.7	515.4
Total (UK) emissions supported by:	28	5	4	12	342	34	35	105	564.3
Environmental trade balance:									
Scot pollution supported by RUK final demand	13.8								
RUK pollution supported by Scottish final demand	14.2								
Scotland's CO_2 trade surplus	-0.37								

Table 5. The CO_2 Trade Balance Between Scotland and RUK (tonnes, millions) - IO NCLAS

	Pollution supported by:				Total regional
	Scottish HH	Scottish Govt	RUK HH	RUK govt	emissions of CO_2
Pollution generated in:					
Scotland	22.7	3.9	19.7	2.7	48.9
RUK	16.9	3.3	443.7	51.4	515.4
Total (UK) emissions supported by:	39.6	7.2	463.4	54.1	564.3
Environmental trade balance:					
Scot pollution supported by RUK final demand	22.3				
RUK pollution supported by Scottish final demand	20.2				
Scotland's CO_2 trade surplus	2.1				

Table 6. The CO_2 Trade Balance Between Scotland and RUK (tonnes, millions) - SAM NCLAS

	Pollution supported by:				Total regional
	Scottish HH	Scottish Govt	RUK HH	RUK govt	emissions of CO_2
Pollution generated in:					
Scotland	22.8	3.8	19.3	3.0	48.9
RUK	16.5	3.1	440.1	55.7	515.4
Total (UK) emissions supported by:	39.3	6.9	459.4	58.6	564.3
Environmental trade balance:					
Scot pollution supported by RUK final demand	22.3				
RUK pollution supported by Scottish final demand	19.6				
Scotland's CO_2 trade surplus	2.7				

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