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The CO2 'trade balance' between Scotland and the rest of the UK: performing a multi-region environmental input-output analysis with limited data

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Abstract

In this paper we attempt an empirical application of the multi-region input-output (MRIO) method proposed by Turner, Lenzen, Wiedmann and Barrett (2007) in a recent issue of this journal in order to enumerate the CO2 pollution content of interregional trade flows between Scotland and the rest of the UK (RUK). We extend the analysis to account for direct emissions generation by households, as final consumers, and to a social accounting matrix (SAM), where a more comprehensive account of incomes and expenditures is possible. While the existence of significant data problems mean that the quantitative results of this study should be regarded as provisional, the interregional economy-environment IO and SAM framework for Scotland and RUK allows an illustrative analysis of some very important issues in terms of the nature and significance of interregional environmental spillovers within the UK and the existence of a CO2 'trade balance' between Scotland and RUK.

Keywords: multi-region input-output models; CO2 trade balance; environmental responsibility

1. Introduction

1.1 Policy context

Devolution[1] 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* interregional spillover effects.

In this paper we report on an initial attempt to generate such a framework by constructing an environmental interregional 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 interregional trade data for the UK; problems of consistency between economic and environmental, as well as 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 interregional economy-environment SAM framework for Scotland and RUK allows an illustrative analysis of some very important issues. Specifically, it allows us to investigate methods of 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. In particular, we focus on the extent to which a devolved authority like the Scottish

[1] Devolution is the term used in the UK for the form of decentralisation that involves the transfer of various discretionary powers and responsibilities to regional governments. Devolution may be contrasted with lesser levels of decentralisation: de-concentration, which is simply the spatial transfer of some administrative function that nonetheless remains within central government, and delegation, the assignment of some specific decision-making authority to a body outwith central government (McGregor and Swales, 2005, provide an analysis of the economics of devolution in the UK.)

Parliament can and should be responsible for contributing to national targets for reductions in emissions levels (e.g. the UK commitment to the Kyoto Protocol) when it is limited in the way it can control emissions, particularly with respect to changes in demand elsewhere in the UK.

Our results reflect the arguments of Munksgaard and Pederson (2001) in selecting between what they term the 'consumption accounting principle' and the 'production accounting principle' in the case of national economies that are exporters of CO2-intensive goods but are attempting to meet national targets in terms of domestic emissions generation. While there have been a number of analyses of the issue of greenhouse gas emissions embodied in international trade and whether emissions are attributable to producing or consuming nations (see for example, Wyckoff and Roop, 1994; Kondo et al., 1998; Munskgaard and Pedersen, 2001; Ferng, 2003; Bastianoni et al., 2004; Sánchez-Chóliz and Duarte, 2004; Mongelli et al., 2005; Hoekstra and Janssen, 2006; and Wiedmann et al, 2007, for a comprehensive review of MRIO applications) there has been less attention to emissions embodied in interregional trade within national economies. In the context of the UK regional economies a crucial issue is the devolution of responsibility for achieving targets for reductions in emissions levels under the UK commitment to the Kyoto Protocol. Our results have specific implications in terms of regional environmental losses/gains as a result of inter-union trade and the consequent importance of the CO2 trade balance as part of the devolution package. Focussing on the UK commitment to the Kyoto Protocol, and in the absence of appropriate data that would allow us fully to extend the interregional accounting framework to the rest of the world, we close our system by applying the 'production accounting principle' to trade between the UK and the rest of the world (ROW).

1.2 Application of the multi-region input-output technique[2]

Turner, Lenzen, Wiedmann and Barrett (2007), hereafter referred to as Turner *et al* (2007), provide an exposition of the basic Leontief (1970) environmental input-output method of attributing all pollution generation in a given economy to final consumption demand extended to a multiple region context where pollution and/or resource use is embodied in interregional trade flows.[3] For the purpose of simplicity, Turner *et al*'s (2007) exposition is given in terms of a 2-region world, but they explain that it is straightforward to extend to the multiple, or *N*-region case. Here we apply the 2-region framework to the empirical example of Scotland and the rest of the UK (RUK). However, while the UK is not a closed economy, we do not attempt to extend the multi-region input-output (MRIO) framework to include the UK's trading partners. There are two motivations for this.

First, the data requirements of constructing the MRIO system put forward by Turner *et al* (2007) to account for all of the countries that the UK directly and indirectly imports goods and services from are demanding. As explained by Turner *et al* (2007) for a very open economy like the UK, 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 the UK. Moreover, corresponding data on interregional trade flows at the sectoral/commodity level would also be required. This latter element is the key problem in informational terms. Over time, one would hope that development of databases such as that constructed by the Global Trade Analysis Project, GTAP, (see Hertel, 1997[4]) will help overcome this problem. The current GTAP database does include IO tables for many countries and attempts to report sectoral imports in each country

[2] Sometimes a distinction is drawn between interregional and multiregional input-output models (Miller and Blair, 1985, pp. 53-85). This distinction is based on the way in which the input-output accounts are constructed. Such a distinction is not relevant for this paper and the terms multiregional and interregional are used interchangeably.
[3] Turner, Lenzen, Wiedmann and Barrett's (2007) exposition is derived from an earlier version of the current paper, McGregor *et al* (2004a) and Miller and Blair (1985).
[4] More current information on the coverage of the GTAP database can be found at www.gtap.org.

broken down by commodities (but not by source country in a multi-lateral context, though the GTAP database does include bilateral trade data in some cases). However, a database in IO form linking individual sectors and consumers in different regions in a full global interregional IO table, as would be required to carry out a MRIO of the type proposed by Turner *et al* (2007) has not yet been constructed.

Turner *et al* (2007) and Wiedmann *et al* (2007) review how a number of studies have adopted simplifying assumptions to overcome the data problems that are inevitably encountered in using MRIO methods to calculate ecological footprints. We do not attempt such an approach here. While our treatment of trade between Scotland and RUK follows the ‘consumption accounting principle’ (Munksgaard and Pederson, 2001) that is strictly adhered to in ecological footprint analysis, in the case of trade between UK regions and ROW we apply Munksgaard and Pederson’s (2001) ‘production accounting principle’. The motivation for this is the focus of UK policymakers on their commitment to the Kyoto Protocol, where only territorial greenhouse gas emissions of a nation are accounted for and not the emission embodiments of trade with other nations (Task Force on National Greenhouse Gas Inventories, 1996). That is, we focus on the contribution of regions within the UK to meeting national targets under the Kyoto Protocol. The consumption focus is retained in that we attempt to attribute pollution generation within UK regions to consumption demand within the UK. However, in the case of external trade between UK regions and ROW, we close the system by endogenising trade with the production of exports, and associated *local* generation of pollutants, being solely attributed to the need to finance import demand. We also endogenise investment as offsetting the consumption of capital. This means that we are able to attribute all pollution generation within UK borders to private and public consumption demand at the regional level.

The remainder of the paper is structured as follows. In Section 2 we explain the theoretical model as applied to the case of the CO2 content of trade between Scotland and RUK. In

Section 3 we discuss in more detail the practical problems involved in constructing an interregional environmental accounting framework for the UK. In Section 4 we report the results of our CO2 attribution analyses for Scotland and RUK. Section 5 contains a summary and conclusions.

2. The accounting framework

2.1 The multi-region input-output framework in the 2-region case with a single pollutant

We apply the 2-region framework as derived by Turner *et al* (2007), but, in line with focussing on a carbon footprint in particular rather than an ecological footprint in general, we substitute the *K*x*N* matrix of resource-use coefficients, which tell us the amount of resource type *k* used in the production of one unit of output, x_i, in each production sector *i* in region *r*, with a 1x*N* vector of output-pollution coefficients for a single pollutant, CO2, $\mathbf{e}_\mathbf{r}^\mathbf{x}$, with elements e_i^r telling us the physical amount of CO2 directly generated per unit of output, x_i, produced by sector *i* in region *r*:

$$[1] \qquad \begin{pmatrix} p_{11}^y & p_{12}^y \\ p_{21}^y & p_{22}^y \end{pmatrix} = \begin{pmatrix} \mathbf{e}_\mathbf{1}^\mathbf{x} & \mathbf{0} \\ \mathbf{0} & \mathbf{e}_\mathbf{2}^\mathbf{x} \end{pmatrix} \begin{pmatrix} \mathbf{I} - \mathbf{A}_{\mathbf{11}} & -\mathbf{A}_{\mathbf{12}} \\ -\mathbf{A}_{\mathbf{21}} & \mathbf{I} - \mathbf{A}_{\mathbf{22}} \end{pmatrix}^{-1} \begin{pmatrix} \mathbf{y}_{\mathbf{11}} & \mathbf{y}_{\mathbf{12}} \\ \mathbf{y}_{\mathbf{21}} & \mathbf{y}_{\mathbf{22}} \end{pmatrix}$$

(where, in the present study, Scotland is region 1 and RUK is region 2, each with i=1,.., N=10 production sectors producing j=1,.., N=10 commodities).[5] The first subscript on each element

[5] While IO data are produced for both Scotland and the UK at a much higher level of sectoral disaggregation, problems of compatibility between the Scottish and UK data mean that the application here is carried out at a fairly high level of aggregation. See Section 3 for details.

of [1] identifies the producing region, r, and the second the consuming region, s. p_{rs}^{y} is a scalar telling us the amount of CO2 generated in production activities in region r to support region s final demand, for output produced in region r, $\mathbf{y_{rs}}$ (an Nx1 = 10x1 vector). $[\mathbf{I} - \mathbf{A}]^{-1}$ is the symmetric 2Nx2N (20x20) partitioned interregional Leontief inverse (multiplier) matrix, with elements b_{ij}^{rs} telling us the amount of output of each producing sector i in region r required per unit of final demand for the output of consuming sector j in region s.

In the current paper it is important to note that the description of a 2Nx2N (20x20) interregional Leontief inverse, where we have N=10 production sectors in each Scotland and RUK, is consistent with the conventional 'Type I' case where the A-matrix has elements a_{ij}^{rs} telling us the amount of output produced by each sector i in region r, x_{ij}^{rs}, required as input to production per unit of total input/output in consuming sector j in region s, X_{j}^{s}. Thus, each element of the A-matrix is formally defined as follows:

[2] $a_{ij}^{rs} = x_{ij}^{rs} / X_{j}^{s}$

In the conventional Type I case, the production sectors are those identified as production sectors in the IO accounts for the country in question. It is, however, possible to endogenise activities reported as final consumption sectors in the IO accounts – and , therefore, initially included in the partitioned matrix **Y** in the Type I case – by redefining the **A** and **Y** matrices. For example, it is common to carry out a Type II analysis, where household consumption is endogenised by subtracting household final consumption expenditure from each vector $\mathbf{y_{rs}}$, and adding an additional column and row of input-output coefficients to the **A**-matrix. In the additional row x_{ij}^{rs} will record use of region r household production (additional production sector, i) as inputs to production in sector j in region s and X_{j}^{s} will be the total input/output of sector j in region s (as above). In an IO account, household production is solely composed of the provision of labour services, so the additional row entries will be payments to labour services, or 'income from employment', divided by total input/output. In the case of households, where no labour is directly employed the coefficient will collapse to zero. In the additional column, x_{ij}^{rs} will record use of local inputs from each production sector, i, by the household sector, j (formerly recorded as final consumption) and X_j^s as the total input/output of households, which is given by total payments to labour/income from employment. Note that, in contrast to the conventional production sectors reported in the IO accounts, it will rarely be the case (if ever) that household input and output balance, as income from employment is unlikely to be the only source of household income that funds consumption expenditure. Strictly speaking, then, it would be appropriate to retain some household consumption expenditure as exogenously determined within the partitioned final consumption matrix **Y**. Only in a social accounting matrix (SAM), where a complete set of income and expenditure flows are reported, will household 'inputs' and 'outputs' balance.

In this paper we do not carry out a Type II analysis. The purpose of the above exposition is to familiarise/remind the reader of the standard approach to endogenising variables as later we close our 2-region system by endogenising trade with the rest of the world (ROW).

2.2 Extension to account for direct emissions generation by households as final consumers

If final consumers also directly generate emissions of CO2 these are determined using a 1xZ vector, $\mathbf{e}_\mathbf{r}^\mathbf{y}$, of coefficients giving the amount final expenditure-pollution coefficients for each final consumption group z in each region r, with each element e_z^r telling us the physical amount of CO2 directly generated per unit of final expenditure, f_z.[6] In the current study only one final consumption group, households (hh), is responsible for direct emissions generation, so z=1=hh, and this emissions generation takes place only in the home region, so we have

$$[3] \qquad \begin{pmatrix} p_1^{hh} & 0 \\ 0 & p_2^{hh} \end{pmatrix} = \begin{pmatrix} e_1^{hh} & 0 \\ 0 & e_2^{hh} \end{pmatrix} \begin{pmatrix} y_1^{hh} & 0 \\ 0 & y_2^{hh} \end{pmatrix}$$

If we sum the 2x2 partitioned **P** matrices derived in [1] and [3] we have all emissions in regions 1 and 2 attributed to final consumption demand in each region for the outputs of the 2 regions. The total emissions generated in region 1 (Scotland), p_1, are given by summing along the first row of each **P** matrix so that

$$[4] \qquad p_1 = p_{11}^y + p_{12}^y + p_1^{hh}$$

while the total emissions in the both regions of the UK that are supported by region 1 (Scottish) final consumption demand are given by summing down the first column of each **P** matrix so that

$$[5] \qquad p_1^y = p_{11}^y + p_{21}^y + p_1^{hh}$$

The corresponding calculations for RUK are carried out using the second row and column of the **P** matrix.

[6] We begin with Z=4 final consumption groups in each region: households, government final consumption, capital formation and ROW export demand. However, as we explain in Section 2.3, this is reduced to Z=2 when we endogenise trade and capital formation.

According to Munksgaard and Pedersen's (2001) method, Scotland's CO2 trade balance with RUK would be calculated as the difference between [4] and [5]. However, the distinction here is that the UK is not a closed economy, with the implication that [5] does not fully account for Scottish emissions under Munksgaard and Pedersen's (2001) consumption accounting principle.

2.3 Treatment of trade with the rest of the world

So far we have not considered either region's trade with the rest of the world (ROW) in our accounting framework. In the IO tables there is an NxZ matrix of final consumption, **Y,** for each region, within which there is an Nx1 vector $\mathbf{y_z}$ where z is ROW export demand ($\mathbf{y_{ROW}}$). In order to balance the system in [1] – i.e. account for all emissions of CO2 generated in each region r in p_r in the calculation of equation [4] for each region – export demand from the rest of the world must be included in the calculation somehow. In a full carbon footprint calculation using the MRIO system as derived by Turner *et al* (2007), each external region/nation that Scotland and/or RUK trade with would be included as an additional region r in [1], with additional sub-matrices in the partitioned interregional inverse $[\mathbf{I - A}]^{-1}$ and additional vectors of final consumption and emissions coefficients for each region. A less data demanding, but inevitably less accurate, alternative would be to introduce ROW as an aggregated third region representing some average production and polluting technology embodied in trade flows between the UK and ROW.

However, we have not adopted this approach for two reasons. Firstly, as noted above, data are not readily available to extend the UK framework in this way: in the MRIO approach derived by Turner *et al* (2007) that we apply here, this would require imports to Scotland and RUK broken down by commodity; only the former are available to us for the current exercise. Secondly, and we believe more importantly given our policy focus on responsibility for emissions generated within a national economy where responsibility for 'sustainability issues' is decentralised/devolved, the key policy focus in the UK is on the reduction in territorial emissions that are required under the Kyoto Protocol, rather than the environmental impact around the world of UK consumption. A potentially crucial point, in terms of the UK devolution (decentralisation) settlement, is whether any region within the UK is supporting consumption activity in other regions through generation of local emissions in excess of what is required to support that region's own consumption.

In order to focus on this issue we develop [1] to give what we will refer to as a trade endogenised linear attribution system (TELAS). This involves endogenising trade in much the same way as household final consumption is endogenised in a standard Type II analysis (outlined in Section 2.1 above; see also Miller and Blair, 1985). Instead of including ROW export demand for each region as a vector of final consumption demand, $\mathbf{y}_{\mathbf{ROW}}$, we create an additional UK production sector in the partitioned A-matrix, a Trade sector, *t*, which produces the imports required in the UK economy as a whole. The row entries for each (consuming) sector *j* in each (consuming) region *s* are that sector's imports from ROW, region *w*, m_{tj}^{ws} as a share of the total input/output of the (consuming) UK sector *j* X_j^{UK}:

[6] $a_{tj}^{ws} = m_{tj}^{ws} / X_j^{UK}$

The additional column entries are the outputs that must be produced for export to ROW (region *w*) via the trade sector, *t*, by each (producing) sector *i* in (producing) region *r*, x_{it}^{rw} per unit of unit of total imports required in the UK economy as a whole (intermediate and final consumption), M_j^{UK}:

[7] $a_{it}^{rw} = x_{it}^{rw} / M_j^{UK}$

The CO2 intensity of the output of the new UK trade sector, *t*, e_t^{UK}, is equal to zero, as no emissions are directly generated here (emissions directly generated in producing output for export demand are generated in the producing sectors and are, therefore, embodied indirectly in intermediate sales to the new trade sector.

Note that when we calculate (1) for the extended system with trade endogenised, this means that each individual (production or consumption) sector that imports from ROW will be attributed the pollution embodied in the share of total UK domestic export production required to finance these imports, as measured using e_t^{UK}. Because we are applying the production accounting principle at the national (UK) level, we do not attempt to estimate the pollution embodied in imports. That is, we do not attempt to measure pollution generated outside the UK to support UK consumption; rather we focus on pollution generated *within* the UK to support UK consumption. A second point is that the UK as a whole runs a trade deficit in goods and services with ROW, so that total imports in the UK IO table are greater than total exports (although Scotland actually runs a trade surplus, an issue which, as explained above, partly motivates the use of the TELAS technique). That is, similar to the point made in Section 2.1 with regard to endogenising households in a Type II analysis, inputs to and outputs from the Trade sector will not balance. This problem is overcome with extension to a social accounting matrix (SAM) analysis, where a full balance of payments is accounted for so that income and expenditure in the trade sector balance.

We also endogenise capital formation/investment as covering depreciation by defining a new Capital sector, *u*. 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 partitioned **A** matrix. In endogenising capital formation, the additional column entries in the partitioned **A** matrix are given by regional sectoral outputs produced to meet final consumption in the form of gross regional capital formation, x_{iu}^{rs}, divided by the total output of the (consuming) regional capital sector (total regional payments to capital or other value-added), which we label K_j^s so that

[8] $a_{iu}^{rs} = x_{iu}^{rs} / K_j^s$

The row entries are given by by sectoral payments to capital (other value-added) within each region, k_{uj}^{rs}, as a share of total sectoral inputs/output, X_j^s, so that

[9] $a_{uj}^{rs} = k_{uj}^{rs} / X_j^s$

(where *r*=*s*). As with the trade sector, the CO2 intensity of the output of each regional capital formation sector is equal to zero.

Formally, then, under TELAS we estimate equation [1] where the partitioned **A** matrix becomes a 23x23 matrix and the ROW terms that are included in the partitioned **Y** matrix in a standard 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.

The methodology of the TELAS framework was initially developed in McGregor *et al* (2004b) to attribute local pollution generation to local private and public final consumption focussing on Jersey as a small open single region economy. This basically involves adopting a neo-classical, resource-constrained, view of the operation of the open economy, where exports essentially finance imports (Dixit and Norman, 1980). 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, each individual importing sector is attributed the pollution embodied in the share of total 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 the current paper we extend the TELAS approach in the context of Scotland as a region of the UK. The key distinction in the interregional UK case is that the argument favouring the production accounting principle (appropriate in analysis relating to territorial emissions targets like the Kyoto Protocol) over the consumption responsibility principle (required in ecological footprint calculations) is not valid in the case of interregional 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 using the consumption accounting principle, by augmenting the Scottish input-output table with an input-output 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 interregional flow of imports and exports. Such an approach is appropriate given that the two regions are part of the same, albeit devolved (decentralised), legislative system.

3. 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 interregional environmental input-output accounts for Scotland and RUK with a single environmental variable, CO2 generation. This involves two steps. The first is the generation of the interregional input-output economic accounts in the format required for multiplier/attribution analyses, namely a symmetric and domestic flows matrix in producer prices that balances inputs and outputs at the sectoral level and provides us with the partitioned **A** matrix for calculation of the 2-region system in equation (1). The second is the creation of matching CO2 average production and consumption coefficients – i.e. the **e** vectors of 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 to allow us to derive $\mathbf{A}_{11}$ and the vectors $\mathbf{y}_{11}$ and $\mathbf{y}_{12}$ in (1). Here we use the 1999 tables (Scottish Executive, 2002). However, corresponding analytical tables have not been produced for the UK since 1995 (National Statistics, 2002) to allow us to derive the other intra-regional sub-matrices of **A** and the remaining **y** vectors. 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, primary input requirements and final demand expenditures from the SUT and use these along with the elements of the 1995 UK **A** matrix and **y** vectors to mechanically update the 1995 tables to estimate a 1999 industry-by-industry domestic flows matrix in basic prices. This involves assuming that the technology (input composition) implied by the elements, a_{ij}^{UK}, of the UK 1995 **A** matrix, and y_{iz}^{UK}, of the UK matrix of final consumption expenditures also apply to the year 1999 and using a RAS balance programme to balance the 1999 tables to the aggregates given by the 1999 SUT. (See Allan *et al*, 2004, or Ferguson *et al*, 2004, for full details on the process of updating).

The second main data problem for constructing the interregional economic IO accounts is the absence of information on interregional trade flows at an appropriate level of sectoral disaggregation to allow us to derive the $\mathbf{A_{rs}}$ submatrices and $\mathbf{y_{rs}}$ vectors (where $r \neq s$, i.e. $\mathbf{A_{12}}$ and $\mathbf{A_{21}}$, and $\mathbf{y_{12}}$ and $\mathbf{y_{21}}$). In the case of Scottish imports from RUK (sector-by-sector) – i.e. the $\mathbf{A_{21}}$ submatrix and $\mathbf{y_{21}}$ vector, where Scotland is region 1 and RUK is region 2 - 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 in order to derive $\mathbf{A_{12}}$ and $\mathbf{y_{12}}$. We do this by making the (very simple, but transparent) 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 interregional 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). This problem may occur for several reasons, including consistency of accounting methods, quality of data etc at the UK and Scottish levels. However, a more obvious problem is the possibility of error in the methods used to estimated components of the Scotland-RUK interregional IO tables for 1999. As explained above, we have assumed that the technology embodied in the 1995 UK **A** and **Y** matrices applies in 1999 and we have had to use RAS balancing techniques to balance our estimated UK IO table for 1999. This may lead to some elements of the estimated 1999 UK table being smaller than they should be (hence the negative result when the actual 1999 table for Scotland and estimated interregional trade matrices are subtracted). Similarly, the UK entries may be overestimated, but the resulting errors do not reveal themselves as clearly.

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. Moreover, as discussed by Lenzen *et al* (2004), over-aggregation at the sectoral (as well as spatial) level is likely to result in significant errors in IO multiplier values. At this stage, however, we focus on only a limited sectoral breakdown in order to work through the key issues for constructing an interregional 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 interregional SAM framework involves the introduction of additional and extended accounts for the following:

- The two (primary) factors of production – labour and other value added (capital) – where the income side of the account is given by the IO table, and all items on the expenditure side (distribution of factor payments) are additional SAM data
- Net product and production taxes – again the income side of the account is given by the IO table, and the expenditure side (consisting solely of the flow of indirect tax income to government) is an additional item reported in the SAM.
- Three domestic institutional transactors – households, government and corporate. The latter is a new account on both the income and expenditure side, showing income transfers to and from the aggregate production sector (goods and services transactions are

given for each of the 10 production sectors in each of the two regions by the IO table). In the household and government accounts, the IO table informs the expenditure side in terms of purchases goods and services, with additional entries for income transfers to other institutional transactors and the foreign and capital accounts. The income accounts are additional SAM data.

- The foreign sector – ROW. There are two sets of income and expenditure for ROW: (a) goods and services imported/exported by Scotland and RUK (the current account); (b) income transfers between ROW and the local (Scottish and RUK) institutional transactors and the local capital account (balance of payments). (a) is given by the IO table, while (b) is additional SAM data.
- The capital account. The Regional Gross Domestic Fixed Capital Formation (GDFCF) and Stocks columns of the IO table give the expenditure side of the capital account (investment), while the income side (savings) is additional SAM data.

The income-expenditure accounts are reported directly in the SAM with each account. Each account consists of a row of recording elements of income and a column recording elements of expenditure. The only transactors for whom the income-expenditure account is shown across multiple columns are firms, referred to collectively as 'corporate'; the production section of the corporate account is disaggregated by sector, while the income transfer section is only shown for the aggregate corporate sector. The SAM-TELAS is then estimated using equation (1), where, with the additional elements/accounts identified above, the partitioned **A** matrix becomes a 32x32 matrix.

Full details (including the IO and SAM matrices themselves) are given in Allan *et al* (2004) and Ferguson *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 *interregional* income transfers. For example, wage income earned in Scotland by RUK residents should be represented as an interregional transfer between Scottish and RUK households. Similarly profit income generated in Scotland by RUK-owned firms is represented as an interregional transfer between the Scottish and RUK corporate accounts. However, neither the Scottish Executive nor the UK Office for National Statistics collect or report data on such transfers. This type of problem is analogous to and illustrative of the fact that only Gross *Domestic* but not Gross *National* (or regional) Product is reported for Scotland (and the other component regions of the UK). Due to the lack of published data, we have to estimate these entries based on what appropriate data are available from component elements of the regional and national accounts relating to household incomes and expenditures, company ownership etc.

The environmental component of the interregional 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, CO2. Ideally the pollution coefficients should reflect region-specific polluting technology and energy use for each sector. However, a full set of region-specific data in appropriate format (i.e. reported for the SIC classified sectors/activities in the IO accounts are not currently available for the UK). Therefore, we apply a set of average sectoral emissions intensities derived from the 1999 UK environmental accounts.[7] 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 (the only final consumption group for which direct emissions are reported).

[7] 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.

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 reported for IPCC classified activities (Salway *et al*, 2001). These estimates better reflect the greater use of renewable, and therefore 'cleaner', electricity generation techniques used in Scotland (Turner, 2003). The resulting set of direct emissions coefficients for the interregional environmental IO and SAM system is shown in Table 2. See Ferguson *et al* (2004) for fuller details.

INSERT TABLE 2 AROUND HERE

4. CO2 attribution analysis for Scotland and the rest of the UK

The data problems outlined above mean that the quantitative results of any analyses using the Scotland-rest of UK (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 a CO2 'trade balance'.

4.1 "Conventional" two-region input-output attribution analyses

The first thing that we can do with the Scotland-RUK environmental IO system is to estimate direct CO2 emissions generation by sector in each region, by multiplying the direct emissions coefficients ($\mathbf{e}_\mathbf{r}^\mathbf{x}$ and e_r^{hh}) against the gross sectoral outputs and expenditures ($\mathbf{x}_\mathbf{r}$ and y_r^{hh}) from the interregional IO tables. The results of this calculation are shown in Table 3.

Insert Table 3 around here

The results in Table 3 identify the direct CO2 generation in each sector and final consumption group. 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 interregional 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 CO2 '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 CO2 "trade" between Scotland and RUK involves estimating equation [1] where the **A** matrix is a $2N$x$2N$, or 20x20 (where i=1,..,10 in each of the 2 regions) partitioned matrix where only the outputs of UK production sectors are treated as endogenous, and the partitioned matrix **Y** of final consumption demands includes export demand from the rest of the world (ROW). That is, we begin with a conventional Type I open economy attribution analysis.

Insert Table 4 around here

Table 4 shows the scale of the CO2 "trade" (or "spillovers") that occur between Scotland and the rest of the UK. Of the total CO2 generated in the UK directly or indirectly as a result of conventional Scottish final demand expenditures, just under 30% is generated in RUK (i.e. not in Scotland). 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 just 0.8% of total CO_2 generated in Scotland.

4.2 Two-region input-output attribution analysis in a trade endogenised linear attribution system

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 2.3, current data constraints mean that there is no feasible way of measuring, with any precision, the pollution content of imports from ROW.

We also argue that if the key policy focus is on meeting the UK's commitments under the Kyoto Protocol 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. Such an attribution, under what Munksgaard and Pedersen (2001) identify as a 'consumption principle' would place the responsibility for pollution generation occurring in one legislative domain to decisions made in another legislative domain. However international treaties such as the Kyoto Protocol generally require that governments take responsibility for pollution generation within their own territories – i.e. encouraging adoption of what Munksgaard and Pedersen (2001) identify as a 'production accounting principle'.

As explained in Section 2.3, in response to these problems we adopt the trade endogenised linear attribution system (TELAS) method (McGregor *et al*, 2004b) in the case of external trade with ROW and investment. This allows us to focus private (household) and public (government) final consumption as the only exogenous drivers of economic activity and consequent pollution generation.

In terms of the environmental attribution, adopting the TELAS 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 Tables 5 and 6 around here

The results of the interregional IO TELAS 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 capital formation and exports to ROW treated as endogenous. Endogenising capital formation has little overall impact. In Table 6 we show the impact of endogenising capital, but keeping trade with ROW exogenous. The CO_2 attributable to all the remaining elements of final consumption rises as what was attributed to capital formation is redistributed, but the impact on inter-regional demands is limited in absolute terms and there is no net change on the CO_2 trade balance. The large majority of the increase in emissions attributable to inter-regional demands in comparing the Type I and TELAS in Tables 4 and 5 respectively results from endogenising the trade sector.[8] 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 (see Table 7). 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 and, when this is taken into consideration in the TELAS analysis, there is a qualitative impact on the CO_2 trade balance between Scotland and RUK.

Insert Table 7 around here

4.3 Two-region trade endogenised linear attribution system attribution analysis using a social accounting matrix framework

[8] We are indebted to an anonymous referee for suggesting isolating the impacts of trade sector and capital endogeneity.

The TELAS approach is closer than standard Type I (or Type II) IO analysis to approaches such as ecological footprint analyses, which place 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 particular, as noted above, inputs and outputs do not balance in the new Trade and Capital sectors of the TELAS IO framework. In McGregor *et al* (2004b) we apply the TELAS 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 (and the positive and negative savings that allow all income and expenditure accounts in the SAM to balance). The final part of the current study is to extend this SAM-TELAS analysis in the interregional framework for Scotland and the rest of the UK.

Insert Table 8 around here

The results for the SAM-TELAS attribution shown in Table 8 are not dramatically different from the IO-TELAS results in Table 5. The Scottish CO2 trade surplus is increased and now stands at 5.5% of the total CO2 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-TELAS 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 CO2 trade surplus). Second, the inclusion of these additional elements of exogenous expenditures causes changes in the

TELAS 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 CO2 trade surplus, which, here, more than offsets the downward pressure of the first effect.

5. Summary and Conclusions

In this paper we use an interregional 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 interregional 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 CO2 generated in Scotland supports consumption in the RUK. A similar figure holds for the proportion of CO2 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, CO2, runs in the opposite direction. In other words, the findings of this study suggest the existence of a CO2 trade *surplus* between Scotland and the rest of the UK. This is in the order of 5% of the total CO2 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 3, there still exist considerable problems with the data requirements for constructing an interregional 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 interregional 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 interregional 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 interregional 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-CO2 coefficients (production sectors) and household final expenditure-CO2 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 CO2 Emissions Generated in UK, RUK and Scotland in 1999

	Tonnes, millions, of direct CO2 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: Scottish HH	Scottish Govt	Scottish Capital	Scot-ROW	RUK HH	RUK Govt	RUK Capital	RUK-ROW	Total regional emissions of CO_2
Pollution generated in:									
Scotland	21.3 (43.6%)	3.6 (7.4%)	1.4 (2.9%)	8.8 (18%)	**9.1 (18.6%)**	**0.9 (1.8%)**	**1.5 (3.1%)**	**2.3 (4.7%)**	48.9 (100%)
RUK	**7.1 (1.4%)**	**1.7 (0.3%)**	**2.3 (0.4%)**	**3.1 (0.6%)**	332.5 (64.5%)	33 (6.4%)	33 (6.4%)	102.7 (19.9%)	515.4 (100%)
Total (UK) emissions supported by	28.4 (5%)	5.3 (0.9%)	3.7 (0.7%)	11.9 (2.1%)	341.6 (60.5%)	33.9 (6%)	34.5 (6.1%)	105 (18.6%)	564.3 (100%)
Environmental trade balance:									
Scot pollution supported by RUK final demand	**13.8**	(=9.1+0.9+1.5+2.3)							
RUK pollution supported by Scot final demand	**14.2**	(=7.1+1.7+2.3+3.1)							
Scotland's CO_2 trade surplus	-0.4								

Table 5. The CO2 Trade Balance Between Scotland and RUK (tonnes, millions) - IO TELAS

	Pollution supported by: Scottish HH	Scottish Govt	RUK HH	RUK govt	Total regional emissions of CO_2
Pollution generated in:					
Scotland	22.7 (46.5%)	3.9 (7.9%)	**19.7 (40.2%)**	**2.7 (5.4%)**	48.9 (100%)
RUK	**16.9 (3.3%)**	**3.3 (0.6%)**	443.7 (86.1%)	51.4 (10%)	515.4 (100%)
Total (UK) emissions supported by:	39.6 (7%)	7.2 (1.3%)	463.4 (82.1%)	54.1 (9.6%)	564.3 (100%)
Environmental trade balance:					
Scot pollution supported by RUK final demand	**22.3**	(=19.7+2.7)			
RUK pollution supported by Scottish final demand	**20.2**	(=16.9+3.3)			
Scotland's CO_2 trade surplus	2.1				

Table 6. The CO2 Trade Balance Between Scotland and RUK (tonnes, millions) - IO with capital formation endogenous

	Pollution supported by:						Total regional
	Scottish HH	Scottish Govt	Scot-ROW	RUK HH	RUK govt	RUK-ROW	emissions of CO2
Pollution generated in:							
Scotland	21.9 (44.7%)	3.7 (7.6%)	9.2 (18.7%)	**10.3 (21%)**	**1.1 (2.3%)**	**2.7 (5.6%)**	48.9 (100%)
RUK	**8.6 (1.7%)**	**2.0 (0.4%)**	**3.9 (0.8%)**	352.7 (68.4%)	36.8 (7.1%)	111.4 (21.6%)	515.4 (100%)
Total (UK) emissions supported by:	30.5 (5.4%)	5.8 (1%)	13.1 (2.3%)	362.9 (64.3%)	37.9 (6.7%)	114.1 (20.2%)	564.3 (100%)
Environmental trade balance:							
Scot pollution supported by RUK final demand	**14.2**	(=10.3+1.1+2.7)					
RUK pollution supported by Scottish final demand	**14.6**	(=8.6+2.0+3.9					
Scotland's CO2 trade surplus	-0.4						

Table 7. Regional trade balances for 1999 (goods and services, £million)

	Scotland		**RUK**	
Sector	Exports to RUK	Exports to ROW	Exports to Scotland	Exports to ROW
PRIMARY	1,673	2,066	1,063	9,803
MANUFACTURING	10,744	16,909	19,611	122,875
ELEC, GAS & WATER SUPPLY	1,296	0	301	73
CONSTRUCTION	171	16	558	162
WHOLESALE & RETAIL TRADE	1,288	524	942	25,253
TRANSPORT & COMMUNICATION	3,352	803	2,149	11,501
FINANCIAL INT & BUSINESS	3,813	1,394	5,412	29,505
PUBLIC ADMINISTRATION	122	6	5	643
EDUC, HEALTH & SOCIAL WORK	362	183	246	932
OTHER SERVICES	1,321	332	1,078	3,768
Total exports	24,143	22,231	31,366	204,515
Imports	31,366	18,708	24,143	225,033
Trade balance (Exports minus imports)	-7,223	3,522	7,223	-20,517

Table 8. The CO2 Trade Balance Between Scotland and RUK (tonnes, millions) - SAM TELAS

	Pollution supported by:				Total regional
	Scottish HH	Scottish Govt	RUK HH	RUK govt	emissions of CO_2
Pollution generated in:					
Scotland	22.8 (46.7%)	3.8 (7.8%)	**19.3 (39.4%)**	**3.0 (6.1%)**	48.9 (100%)
RUK	**16.5 (3.2%)**	**3.1 (0.6%)**	440.1 (85.4%)	55.7 (10.8%)	515.4 (100%)
Total (UK) emissions supported by:	39.3 (7%)	6.9 (1.2%)	459.4 (81.4%)	58.6 (10.4%)	564.3 (100%)
Environmental trade balance:					
Scot pollution supported by RUK final demand	**22.3**	(=19.3+3.0)			
RUK pollution supported by Scottish final demand	**19.6**	(=16.5+3.1)			
Scotland's CO_2 trade surplus	2.7				