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CONSTRUCTION OF A MULTI-SECTORAL INTER-REGIONAL IO AND SAM DATABASE FOR THE UK

BY

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Construction of a multi-sectoral inter-regional IO and SAM database for the UK*

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1. Introduction

The purpose of this paper is to explain the construction of the input-output (IO) and social accounting matrix (SAM) databases for the inter-regional computable general equilibrium (CGE) model of the UK developed as part of the project 'An Analysis of National and Devolved Economic Policies' undertaken as part of the ESRC Devolution and Constitutional Change research programme.

We identify four main regions of the UK: Scotland, Wales, Northern Ireland and England. However, in Section 2, we begin by constructing a set of two-region accounts where we focus on Scotland, Wales or Northern Ireland with the other aggregate 'region' labelled 'rest of the UK' or RUK. Then, in Section 3, we extend to a three-region framework where we identify Scotland, Wales and RUK. Finally, in Section 4, we extend further to construct the full 4-region IO and SAM.

The main problems we encounter relate to data availability, in particular the absence of recent analytical IO tables and inter-regional trade data for the UK, but also the absence of any form of IO accounts for Northern Ireland. Another key issue is problems of consistency between regional and national data. These problems are discussed in more detail at appropriate points throughout the paper and summarised in the conclusions in Section 5.

2. Two-region IO and SAM accounts

This section outlines the data requirements and methods used to generate two-region IO tables and SAM. The basic approach is then extended to the multi-region case. We begin with the IO tables, which are then augmented with information on income flows between the main aggregate transactors to construct the SAM.

2.1 Data requirements for the inter-regional IO table

Insert Figure 1a

Figure 1a shows the schematic structure of the 2-region IO framework (for the example of Scotland-RUK). The columns show the inputs of production sectors and expenditures by final consumers in each of the two regions and ROW export demand. The rows show the destination of output in each production sector in the two regions and of imports from ROW

and primary inputs. It is useful to consider the data requirements in terms of a set of use matrices, so that to construct an inter-regional IO framework for Scotland (or any other UK region) and RUK we ideally require (all for a common base year):

1. A set of symmetric (i.e. product-by-product, PxP, or industry-by-industry, IxI) analytical IO tables (reported in basic/producer prices) for the national (UK) economy for the chosen base year. This gives us a matrix M_{UK}^{UK}, showing local intermediate and final consumption of UK production (superscripts denote the producing region and subscripts to denote the consuming region.) It also gives us the primary input matrix F_{UK} and the column vector of external final consumption demand from the rest of the world (ROW) for UK production (exports to ROW), $c_{i(ROW)}^{UK}$.

2. A compatible set regional (Scottish) IO tables (i.e. for the same base year and sectoral breakdown). This gives us the matrix M_S^S of Scottish intermediate and final consumption of Scottish production – the local demand matrices in Figure 1a - as well as the primary input matrix F_S and a column vector of Scottish exports to ROW, $c_{i(ROW)}^{S}$ (and subtracting these from F_{UK} and $c_{i(ROW)}^{UK}$ respectively gives us F_{RUK} and $c_{i(ROW)}^{RUK}$). However Scottish consumption of RUK goods and services is given in a single row vector of imports, m_S^{RUK}, and RUK consumption of Scottish goods and services is given in a single column vector of exports, $c_{i(RUK)}^{S}$.[1]

3. To determine the matrix, M_S^{RUK}, of Scottish intermediate and final consumption of the RUK production – the Scottish imports from RUK matrices in Figure 1a - we need data that disaggregate the imports vector m_S^{RUK} in the Scottish IO table in terms of the i=1,..,I RUK production sectors.

4. Similarly, to determine the matrix, M_{RUK}^S, of RUK intermediate and final consumption of the Scottish production, we need data that disaggregate the exports vector $c_{i(RUK)}^{S}$ in the Scottish IO table in terms of the i=1,..,I production sectors and z=1,..,Z final consumption groups in RUK.

[1] In the Scottish IO tables, tourist expenditure is separately identified in a separate export vector.

2.2 The UK (national) IO table

Our first problem is that analytical IO tables are not produced for the UK on a regular basis, with only annual PxI Supply-Use Tables (SUT) reported in purchaser prices being publicly available. That is to say, there are problems in even establishing the UK Use matrices, M_{UK}^{UK} and F_{UK} and the aggregate ROW export demand vector, $c_{i(ROW)}^{UK}$.

The most recent set of analytical IO tables for the UK were produced for 1995 (National Statistics, 2002), a year for which Scottish and Welsh IO tables are not available. In order to convert the UK SUT for any year to analytical IO format, data are required on commodity taxes, distribution margins and sectoral imports. This allows production of a PxI IO table, which can then be converted to PxP or IxI format using the make matrix. However, due to confidentiality constraints, the ONS do not make the commodity tax, distribution margin and make matrixes public so we are unable to make the required conversions. Therefore, the option we have chosen at this time is to take information on gross industry outputs and final demand expenditures from the 1999 SUT and use these to mechanically roll forward the 1995 IO tables forward to estimate a UK industry-by-industry domestic flows matrix in basic prices for 1999, which is the most recent year for which Scottish IO tables are available.[2]

However, there is a problem with this approach that we have not yet overcome. The control total data that are suitable for rolling forward the 1995 analytical tables are the column totals of the 1999 SUT, which give industry gross outputs. However, only PxI and PxP tables are available for 1995. We cannot roll forward the PxP tables because the SUT only give product gross outputs in purchaser prices and do not distinguish imports and locally produced goods. Therefore, what we have done in the first instance is roll forward the 1995 PxI tables, and then used a mechanical balancing programme to produce an IxI table.[3] This means that we are allowing the programme to randomly reallocate products to industries, rather than systematically reallocating the off-diagonal entries of the make matrix (of which we have no knowledge). This is obviously unsatisfactory and we hope to find alternative data to allow something more systematic.

[2] The 1999 Scottish IO tables (Scottish Executive 2002), are consistent with the version of the 1999 UK SUT reported in the 2001 Blue Book (National Statistics, 2001). (Note, though, that there may be some differences in accounting conventions at the regional and national levels.) As we explain below, Welsh IO tables are available for 2000 rather than 1999. However, due to the greater degree of compatibility between the Scottish and UK national accounts, we choose our base year on the basis of the availability of Scottish IO tables. Note also that since the work reported here was carried out, Scottish IO tables for 2000 have actually become available. We intend to update the whole UK inter-regional framework to the base year of 2000 in future work.

[3] We apply software that is based on the RAS procedure originated by Stone (1961).

2.3 Two-region IO table for Scotland-RUK

The second data requirement for construction of a Scotland-RUK IO table is an industry-by-industry regional IO table for Scotland in analytical and consistent format with the national IO table. This directly gives us the Scotland-Scotland use matrix, M_S^S, which we split into the (IxI) matrix of local intermediate demands from Scottish production sectors, X_S^S, and the (IxZ) matrix of local consumption demand by Scottish final demand groups, $C_{i(z,S)}^S$. It also gives us the matrix F_S of Scottish use of primary inputs (value added and net product and production taxes), which we split into $F_{(i,S)}$ and $F_{(z,S)}$ for intermediate and final consumption respectively. Finally it gives us the vector of Scottish exports to ROW, $c_{i(ROW)}^S$. All of these elements directly enter the Scotland-RUK inter-regional IO table (see Figure 1b). The RUK elements, $c_{i(ROW)}^{RUK}$, $F_{(i,RUK)}$ and $F_{(z,RUK)}$ can also be determined by subtracting Scottish exports to ROW and primary input use from the corresponding elements from the UK IO table.

Insert Figure 1b

However, no published data are available to allow us to determine the inter-regional trade matrices M_S^{RUK}, which we split into the (IxI) sub-matrix X_S^{RUK} of imports from RUK to Scottish intermediate consumption demand, and the (ZxI) sub-matrix $C_{i(z,S)}^{RUK}$ of imports from RUK to Scottish final consumption demand, and M_{RUK}^S, which we split into the sub-matrics X_{RUK}^S and $C_{i(z,RUK)}^S$ of Scottish exports to, respectively, RUK intermediate and final consumption demand. Therefore we must estimate these matrices.

In the case of M_S^{RUK}, the Scottish Executive has kindly given us permission to use experimental (and unpublished) information on Scottish sectoral imports from RUK 1999. These data are consistent with the row vector of Scottish imports from RUK, m_S^{RUK}, from the 1999 industry-by-industry Scottish IO table. However, these data are reported in terms of RUK *products* imported by Scottish *industries* and final demand sectors – i.e. PxI, rather than the symmetric PxP or IxI. In the first instance, we have attempted to overcome this by adjusting the row totals (total imports to Scotland of each RUK product) of the Px(I+Z)

imports matrix provided by the Scottish Executive using the ratio of the output of each RUK industry to the corresponding product output (taken as the difference between UK product outputs from the estimated PxI table for 99 – see Section 2.2 – and Scottish product outputs from the PxP version of the 1999 Scottish IO table) to convert the row totals from commodity to industry outputs. We then use the RAS mechanical balancing programme to adjust the matrix to the revised row totals. Again, as with the conversion of the estimated 1999 UK IO table from PxI to IxI format in Section 2.2, this means that we are allowing the programme to randomly reallocate products to industries. It would, of course be preferable to do this more systematically using make matrix data, were this publicly available.

Together the matrices M_S^S, taken directly from the Scottish IO table, and M_S^{RUK}, estimated as described above, give us the Scottish-UK Use matrix, M_S^{UK}. The RUK-UK use matrix, M_{RUK}^{UK}, can be calculated by subtracting the Scottish-UK Use matrix from the UK local use matrix, M_{UK}^{UK}. However, for the inter-regional framework it is necessary to split the RUK-UK Use matrix, M_{RUK}^{UK}, into the sub-matrices M_{RUK}^{RUK} $(= X_{RUK}^{RUK} + C_{i,(z,RUK)}^{RUK})$ and M_{RUK}^{S} $(= X_{RUK}^{S} + C_{i(z,RUK)}^{S})$ that identify RUK intermediate and final consumption of, respectively, local (RUK) and imported Scottish goods and services.

The problem is that no are no data available to identify M_{RUK}^{S} – imports to RUK industries and final consumers from Scottish production sectors. The Scottish IO tables tell us the value of exports to RUK from each Scottish industry in the column vector $c_{i(RUK)}^{S}$. What is missing is the *destination* of these exports in terms of which RUK production or final demand sectors purchase them, either as intermediate inputs or as final consumption goods. Our next step, then, is to attempt to *estimate* the RUK-Scotland Use matrix, M_{RUK}^{S}, using what data we do have from the Scottish and UK IO tables (including the aggregate RUK-UK Use matrix, M_{RUK}^{UK}).

The method we have applied to identify M_{RUK}^{S} is to take the ratio of exports to RUK from each Scottish sector, i, to total RUK use of UK sector i outputs. We then apply this to each RUK production and final demand sector's use of UK sector i outputs. This means we are assuming that, in using goods and services from UK sector i for intermediate or final consumption, each RUK sector makes the same proportionate use of Scottish or RUK outputs.

For example, in the case of Primary commodities (see the 10-sector breakdown in Table 1 below), the ratio of Scottish produced commodities to total RUK use is

$$\frac{\text{Scottish Primary exports to RUK (Scottish IO table)}}{\text{Total RUK use of UK Primary commodities (Primary row total, RUK use)}}$$

$$= 0.0527$$

Therefore, we assume that each RUK production sector, i, and final consumption sector, z, purchases 5.3% of the UK-produced Primary inputs it uses from Scotland. When we sum along each row of the resulting matrix, the totals are equal to the RUK exports entries from the Scottish IO table (i.e. the elements of the column vector $c^{S}_{i(RUK)}$). However, in order to balance the Scottish rows in the inter-regional IO table across M^{S}_{S} and M^{S}_{RUK} there is one further adjustment in the Scotland-RUK case. The Scottish IO tables identify an additional type of export demand: tourist expenditure by visitors from RUK and ROW. Therefore, we must add (estimated) RUK tourist expenditure in Scotland to the RUK households column.

Once we have estimated RUK-Scotland Use matrix, M^{S}_{RUK}, we take this away from the RUK-UK use matrix, M^{UK}_{RUK} to get the unbalanced RUK-RUK Use matrix, M^{RUK}_{RUK}. This matrix is slightly unbalanced because of the adjustment made above in allocating tourist expenditure by RUK residents in Scotland to the household vector of M^{S}_{RUK} ($C^{S}_{i(z,RUK)}$). This is because the Scottish IO tables are unique in the UK in identifying tourist expenditure as a separate category of final consumption demand. In the UK IO tables local tourist expenditure (i.e. UK residents visiting other UK regions) is allocated to households, and in Wales, RUK tourist expenditure is allocated to RUK exports. In allocating tourist expenditure by RUK households in Scotland to $C^{S}_{i(z,RUK)}$ a minor imbalance is introduced because of the differences in accounting conventions so we need to make some adjustments to balance the system. First of all, we need to add the imports from RUK to RUK tourist expenditure recorded in the Scottish imports matrix to the RUK household expenditure column in $C^{RUK}_{i(z,RUK)}$. Then we take the resulting matrix and use the RAS programme to balance it to the row and column totals required to balance the M^{RUK}_{RUK} use matrix – i.e. the row/column total from the UK IO table minus the row/column total in the Scottish IO table for each production and final demand sector.

2.4 Two-region IO table for Wales-RUK

For the Wales-RUK case corresponding data components were available – i.e. the estimated UK IO table for 1999, region-specific analytical Welsh IO tables and data on imports-by-commodity. However, the latter two are available for 2000 rather than 1999 (the previous set of tables are for 1996). Therefore, we had to estimate the 1999 Welsh IO table and imports-by-commodity data by rolling back the corresponding 2000 data constructed by WERU (Bryan *et al*, 2004). We did this using control total data on sectoral outputs, primary inputs and final demand expenditures provided by WERU.

The Wales-RUK IO tables are constructed by following the same process as outlined above for Scotland-RUK. There is one difference, though. As noted above, tourist expenditure is not identified as a separate category of final demand in the Welsh IO tables. Therefore, the additional stages to balance the M_{RUK}^{RUK} use matrix are not required. That is to say, M_{RUK}^{RUK} is derived by simply subtracting M_{RUK}^{W} from M_{RUK}^{UK} without any further adjustments or RAS application.

In using the Welsh IO tables as a component in our inter-regional UK framework, however, we must be aware of potential problems of compatibility and consistency with the UK and Scottish tables. The basic issue is that while the UK national IO accounts and Scottish regional tables are both based on the same survey carried out by the Office for National Statistics, the Annual Business Inquiry (ABI), WERU do not have access to this source in constructing the Welsh IO tables. Instead, WERU conducts an independent industry survey for the production side of the table. In estimating final demands, use is made of data on the purchasing patterns of Welsh Households from the Family Expenditure Survey published by ONS, and for other categories of final demand adjusted UK IO data are used. Fuller details are given in Bryan *et al* (2004). However, the key point here is that, unlike the case of Scotland, the Welsh IO tables are constructed without the co-operation of the UK Office for National Statistics.

2.5 Two-region IO table for NI-RUK

In the case of Northern Ireland, the situation is somewhat worse, in that no official (or, to our knowledge, unofficial) IO tables are available. Therefore we have had to estimate an analytical IO table for Northern Ireland (NI) in 1999 in a format consistent with the Scottish and Welsh regional and UK national tables above. Full details on the construction/estimation

of the NI table are given in the Appendix. Here it is sufficient to state that we took what control total data were available and used the input coefficients from the Welsh IO for 1999 (aggregated to 3 sectors) to estimate the 4 quadrants of the IO matrix for NI in 1999.

To construct the NI-RUK 2-region IO we adopt the same method as described in Section 2.3 for Scotland-RUK (and Wales-RUK), with one exception. No data on RUK imports-by-commodity are available for NI. Therefore, we derive the matrix M_{NI}^{RUK} using coefficients from the corresponding Welsh matrix, M_{W}^{RUK}, to determine the commodity composition of RUK imports in the NI IO. Thereafter we follow the steps as outlined in Section 2.3 to determine the RUK use matrices for the NI-RUK case.

2.6 Sectoral breakdown

Both the Scotland-RUK and Wales-RUK 2-region IO tables have initially been constructed at the 10 sector/commodity breakdown shown in the first box in Table 1. However, in the case of Wales-RUK, the 10-sector IO table has negative entries in RUK GDFCF in the 'Electricity, gas and water supply' and 'Education, health & social work' sectors. This is because of differences in accounting conventions: the Welsh IO records entries for output to GDFCF in these sectors, while the (estimated) UK IO table does not. Therefore we identify an alternative 8-sector aggregation in the second box of Table 1. This is the sectoral breakdown at which the 3-region (Scotland-Wales-RUK) IO table is constructed in Section 3 below.

However, the inter-regional CGE modelling framework that uses the inter-regional IO and SAM tables as its core database only identifies 3 production sectors/commodities. The 3-sector breakdown is identified in the bottom box in Table 3. Because we have to entirely estimate the inter-sectoral transactions in the Northern Ireland IO table, we limit the sectoral breakdown of this and the NI-RUK IO framework to the 3-sector breakdown required for the model.

All of the inter-regional IO tables constructed for this project are available on request from the corresponding author.

2.7 Two region SAMs

As with a single region SAM (e.g. Turner, 2002) we construct an inter-regional SAM using data from the inter-regional IO tables (above) and from income-expenditure accounts for the two regions in question.

Before discussing the income transfer data in the income-expenditure accounts, note that one adjustment is required to the IO data in the SAM framework used for the AMOSUK model. In the inter-regional IO tables we record net product (commodity) and production taxes in a single row (in the primary inputs/value added block). In the SAM we split this so that in each region commodity taxes paid on goods imported from the other region are paid to a net commodity tax account (and subsequently the government account) in the exporting region.

In the case of net commodity taxes paid on regional exports (from Scotland/Wales/NI) to RUK, the inter-regional IO tables give an aggregate figure. In the absence of better information, we split this across RUK production and final demand sectors according to the distribution of exports to RUK (imports from Scotland/Wales/NI). For net commodity taxes on regional imports *from* RUK, we have to strip these out of the existing net product *and* production taxes in the inter-regional IO table. The residual is then allocated to Scottish/Welsh/NI payments to the own-region commodity tax account. Note that this process means that the income to Scottish/Welsh/NI government from commodity taxes is lower than in the single region SAM, with the difference being reallocated through RUK government transfers to Scottish/Welsh/NI government. The final set of net commodity tax entries are from RUK producers and consumers to the RUK commodity tax account. These are determined the commodity tax entries for RUK producers and consumers minus the payments (above) to the Scottish/Welsh/NI commodity tax account relating to Scottish/Welsh/NI exports to RUK.

The remaining SAM entries, recording income transfers between the aggregate/institutional transactors, are determined using the income-expenditure account method. The intra-regional entries are identical to what they would be in a single region SAM. Inter-regional transfers are also recorded in single region income-expenditure accounts, as transfers to or from RUK in the single region household, government and corporate accounts. In the inter-regional SAM these transfers are recorded as intra-agent UK transfers – e.g. Scottish households to RUK households, Scottish (Welsh) government to RUK government etc. There are no inter-agent UK transfers (i.e. no Scottish household to RUK government etc) in the inter-regional SAM (note that the opposite is true in the case of intra-region transfers, where there are no intra-agent transfers), except in the case of the capital account.

Following the method adopted so far, payments to the Scottish/Welsh/NI capital account from RUK should flow from RUK capital to Scottish/Welsh/NI capital and correspond to the 'transfers from RUK' entry in the single region capital income account. This is the way these transfers are recorded in the inter-regional SAM attribution analyses in Allan *et al* (2004) and McGregor *et al* (2004). However, the AMOS model identifies variables for payments to capital in the other region by households, government and corporate. Therefore, here, for example, we split the RUK to Scottish/Welsh/NI capital entry over RUK households, government and corporate spending according to the distribution of total savings by these transactors. This is offset in the RUK capital account when these amounts are reallocated out of the corresponding entries in the Scottish/Welsh/NI capital row.

The remaining intra-UK income transfers are between RUK transactors. As the definition of RUK differs across the different 2-region and 3- and 4-region cases we have to construct an RUK income-expenditure account for each case. We do this by constructing a set of income-expenditure accounts (and SAM) for the UK and taking all RUK-RUK entries as the difference between the corresponding UK and other region income-expenditure account entries. All inter-regional transfers are already determined from the other region income-expenditure accounts.

The final income transfer entries in the inter-regional SAM are those to and from ROW. In the case of Scotland/Wales/NI these are taken from the single region income-expenditure accounts. In the case of RUK these are equal to the UK SAM entries minus those for the other regions.

As with the inter-regional IO tables, all the SAM accounts constructed for this project are available on request from the corresponding author.

3. Three-region IO and SAM accounts

3.1 The 3-region IO

Figure 2a shows the schematic structure of the 3-region IO framework (Scotland-Wales-RUK). All but the inter-regional trade flows and the RUK-RUK use matrix are determined from the existing UK, Scottish and Welsh single region IO tables and/or the Scot-RUK and Wales-RUK 2-region tables:

The Scottish Use Matrices (column entries)

The Scottish local intermediate and final demand matrices, X_S^S and $C_{i(z,S)}^S$ respectively in Figure 2b, which combine to give the Scotland-Scotland use matrix, M_S^S, are given by the 1999 Scottish IO table and correspond to their counterparts in the 2-region system in Figures 1a and 1b. Similarly, the Scottish primary expenditure matrices, $F_{(i,S)}$ and $F_{(z,S)}$, are also given by the Scottish IO table and correspond to their counterparts in the 2-region system. However, the Scottish imports from the rest of the UK matrices for the 3-region case – i.e. imports from Wales, X_S^W and $C_{i(z,S)}^W$, and from RUK, X_S^{RUK} and $C_{i(z,S)}^{RUK}$ - need to be separated in the existing imports from RUK matrix, M_S^{RUK} in Figure 1b (2-region Scotland-RUK case), where the latter is derived from the experimental commodity-by-industry data supplied by the Input-Output team at the Scottish Executive.

The Welsh Use Matrices

Similarly, the Welsh local intermediate and final demand matrices and the primary expenditure matrices are given by the estimated 1999 Welsh IO table and correspond to their counterparts in the 2-region Wales-RUK system. However, the Welsh imports matrices – imports from Scotland, X_W^S and $C_{i(z,W)}^S$, and from RUK, X_W^{RUK} and $C_{i(z,W)}^{RUK}$ in Figure 2b - need to be separated in the existing imports from RUK matrix, M_W^{RUK} in Figure 1b (2-region Wales-RUK case), where the latter is derived from the experimental commodity-by-industry data supplied by WERU.

The RUK Use Matrices

Unlike the Scottish and Welsh cases, we cannot take the RUK local intermediate and final demand matrices - where $M_{RUK}^{RUK} = X_{RUK}^{RUK} + C_{i,(z,RUK)}^{RUK}$ - from the existing 2-region systems. This is because RUK is defined differently in each of the 2-region cases and in the 3-region case. As in the 2-region case outline in Section 2, we can determine the total RUK-UK use matrix, M_{RUK}^{UK} at this stage, but need to determine inter-regional trade flows first, with M_{RUK}^{RUK} being the residual (i.e. $M_{RUK}^{RUK} = M_{RUK}^{UK} - M_{RUK}^{S} - M_{RUK}^{W}$).

However, the RUK primary expenditure matrices, $F_{(i,RUK)}$ and $F_{(z,RUK)}$, can be determined from the existing single and 2-region IO data, as the residual after taking the Scottish and Welsh entries away from those in the UK IO table – i.e. $F_{RUK} = F_{UK} - F_S - F_W$.

The ROW Use Matrices

The vectors of Scottish and Welsh exports to ROW, $c^S_{i(ROW)}$ and $c^W_{i(ROW)}$ respectively in Figure 2b, are given by the Scottish and Welsh IO tables for 1999 and correspond to their counterparts in the 2-region system. The vector of RUK exports to ROW, $c^{RUK}_{i(ROW)}$ can also be determined from the existing single and 2-region IO data, as the residual after taking the Scottish and Welsh entries away from those in the UK IO table – i.e. $c^{RUK}_{i(ROW)} = c^{UK}_{i(ROW)} - c^S_{i(ROW)} - c^W_{i(ROW)}$. Finally the vector of ROW primary expenditures in the UK, F_{ROW}, is given by the corresponding entries in the UK IO table.

The unshaded cells in Figure 2b indicate all the matrices we can derive directly from the single and 2-region IO frameworks as described above. The grey shaded cells indicate the matrices that need to be derived separately. We do this in 5 steps:

<u>1. Scottish imports from Wales and RUK</u>

First, we complete the set of Scottish Use matrices. This involves separating the matrices X^W_S, $C^W_{i(z,S)}$, X^{RUK}_S and $C^{RUK}_{i(z,S)}$ from the estimated matrix of Scottish imports from the rest of the UK in the 2-region Scotland-RUK table (i.e. M^{RUK}_S in Figure 1b). The method we have applied to do this is to take the ratio of output production in Wales for each sector i to total Welsh plus RUK sector i output (Welsh plus RUK sector i output corresponds to sector i RUK output in the Scotland-RUK 2-region framework). We then apply this ratio to each Scottish production and final demand sector's use of Welsh plus RUK imports (i.e. imports from RUK in the 2-region case, given by M^{RUK}_S in Figure 1b). This means that, in using imported UK sector i goods and services, each Scottish sector makes the same proportionate use of Welsh or RUK outputs, based on the total output shares of the Welsh and RUK sector. For example, in the case of Primary commodities, the ratio of Welsh produced commodities to total Primary production in the rest of the UK (Wales+RUK) is

$$\frac{\text{Welsh Primary sector gross output}}{\text{Welsh Primary sector gross output plus RUK Primary sector gross output}}$$

$= 0.0529$

Therefore, we assume that each Scottish production sector, i, and final consumption sector, z, purchases 5.3% of its UK imports of Primary goods and services from Wales and the remaining 94.7% from RUK. Doing this for all I=8 imported goods and services gives us the matrix M_S^W, which in turn is split into X_S^W and $C_{i(z,S)}^W$ in Figure 2b. Then, by subtracting M_S^W from the 2-region version of M_S^{RUK}, or by subtracting M_S^W plus M_S^S from the total Scottish-UK use matrix, M_S^{UK}, we get the new (3-region version) matrix M_S^{RUK} of Scottish imports from RUK.

2. Welsh imports from Scotland and RUK

The set of Welsh Use matrices – M_W^S, M_W^W and M_W^{RUK} - which form the Welsh column entries in Figures 2a and 2b - is determined by following the same steps as outlined above for Scotland.

3. Scottish exports to RUK

Note from Figure 2a that, reading along the rows of the 3-region IO, the estimation of the matrix M_W^S in Step 2 gives us Scottish exports to Wales. From the single/2-region IO tables we already have Scottish output going to Scottish producers and consumers, M_S^S, and Scottish exports to ROW, $c_{i(ROW)}^S$. Therefore, the residual matrix in the Scottish row block is the exports to RUK, or the RUK-Scotland use matrix, M_{RUK}^S. This can be determined by one of two methods. In the first instance, we attempted to calculate M_{RUK}^S as indicated in Figure 2b. That is, we subtract the Wales-Scottish use matrix, M_W^S, from the Scotland to RUK exports matrix from the 2-region Scotland-RUK system. This appeal of this method is that the 3-region framework is numerically consistent with both the Scotland-RUK and Wales-RUK 2-region systems in that the former is simply a more disaggregated version of the latter. However, it results in several negative entries in the inter-regional trade matrix X_{RUK}^S. This is due to the general problem highlighted already in this paper: inconsistency in accounting

methods and data sources at the national and regional levels in the UK. This problem is compounded by the fact that we have had to estimate the Welsh and UK IO tables for 1999 (by rolling back/forward analytical tables constructed for other years) and the inter-regional trade flows matrices (using experimental imports-by-commodity data for Scotland and Wales).

Therefore, we use a second method to estimate the residual matrix M^{S}_{RUK} in the Scottish output rows. This is consistent with the method used to estimate M^{S}_{RUK} in the 2-region case (see Section 2.3), where we take the ratio of exports to RUK from each Scottish sector, i, to total RUK use of UK sector i outputs and apply this to each RUK production and final demand sector's use of UK sector i outputs. The difference in the 3-region case is that the vector of Scottish exports to RUK, $c^{S}_{i(RUK)}$, is not taken directly from the Scottish IO table. Instead we are taking account of the estimated data on Welsh use of Scottish commodities with M^{S}_{W} *before* we enact this assumption regarding Scottish exports to the rest of the UK (England and Northern Ireland). Therefore the ratio for calculating exports from each Scottish sector i to RUK in the 3-region case (see Section 2.3) to each production sector i and final consumption sector z becomes

$$\frac{\text{Sector i exports to RUK (Scottish IO table) minus sector i exports to Wales}}{\text{Total RUK use (England and NI) use of UK sector i commodities}}$$

4. Welsh exports to RUK

The RUK-Wales Use matrix, M^{W}_{RUK}, is estimated using the same process as explained for Scottish export to RUK in Step 3. Again, using the first method, which means that the 3-region framework is numerically consistent with the 2-region Wales-RUK IO table – i.e. where we subtract the Scotland-Wales use matrix, M^{W}_{S} (see Step 1) from the Wales to RUK exports matrix from the 2-region Wales-RUK system. However, as is the case with Scottish exports to RUK in Step 3, this results in negative entries in the resulting residual matrix, M^{W}_{RUK}. Therefore we adopt the second method, which, while it is not numerically consistent with the 2-region system, it is consistent in terms of the method used to estimate exports to RUK (where RUK is defined differently due to the identification of Scotland as a third trading region).

5. The RUK-RUK use matrix

Once Steps 1-4 are completed, Figure 2a and 2b show that only one matrix in the 3 region IO framework remains to be calculated. As in the two-region case, this balancing matrix is the RUK-RUK use matrix, M_{RUK}^{RUK}. In steps 3 and 4 we have determined the matrices M_{RUK}^{S} and M_{RUK}^{W} showing RUK imports from the other UK regions. Therefore, we can calculate M_{RUK}^{RUK} as the residual of the RUK-UK use matrix (i.e. $M_{RUK}^{RUK} = M_{RUK}^{UK} - M_{RUK}^{S} - M_{RUK}^{W}$).

This completes and balances the 3-region IO table (note that no RASing is required as we are simply splitting down matrices already determined in the single and two-region IO tables). As with the 2-region tables, the 3-region IO table is available on request from the corresponding author.

3.2 The 3-region SAM

As in the single and 2-region case the 3-region SAM takes data from the 3-region IO table and from income-expenditure accounts for the each of the 3-regions. Here we need to: (a) split RUK transfers in the Scottish and Welsh income-expenditure accounts into transfers to and from RUK and Wales in the Scottish case and RUK and Scotland in the Welsh case; (b) create a new RUK income-expenditure account for the 3 region framework.

As in the 2-region case, before discussing the income transfer data in the income expenditure accounts one adjustment is required to the IO data in the SAM framework used for the AMOSUK model. We need to split the single net product and production tax row in the 3-region IO table to allow taxes paid on goods and services imported from other UK regions to be recorded as going to the net commodity tax and government accounts in the exporting region. However, we have already separated net commodity taxes on domestic purchases from aggregate UK imports in the 2-region case for the Scotland-RUK and Wales-RUK cases. Therefore, all that we have to do here is separate these according to the split in imports determined in steps 1 and 2 in Section 3.1 above. Then the net commodity taxes paid on Scottish and Welsh exports to RUK are determined as in the 2-region case – i.e. according the distribution of exports from Scotland and Wales to RUK, rather than on the distribution of imports. The product and production taxes paid by RUK in RUK are the residual entries required to balance the RUK to UK P&P taxes minus all the above.

The remaining SAM entries, recording income transfers between the aggregate/institutional transactors are again determined using the income-expenditure account method. Basically the Scotland-Scotland and Wales-Wales entries are taken from the 2-region income-expenditure accounts. However, here we need to split transfers to and from RUK in the Scottish and Welsh accounts into Wales and RUK in the Scottish case and Scotland and RUK in the Welsh case. Note that we only split the RUK transfer entries in the case of the household and corporate accounts. In the case of inter-governmental transfers (remember that all inter-regional transfers, except capital, are intra-agent flows), we assume that these will between the devolved administrations of Wales and Scotland and central government located in England (the main part of RUK, along with Northern Ireland in the 3-region framework). For the split in the RUK transfers in the household accounts, we base this on the expenditure entries in the Scottish and Welsh accounts, which are estimated transfers of wage income. Therefore, we estimate the income from Scotland and Wales to the Welsh and Scottish income accounts respectively based on the share of RUK wage income that is generated in Scotland and Wales. Transfers to Scottish and Welsh households also include dividends etc but here we assume these come from RUK. The split in inter-regional transfers in the corporate accounts is done on the basis of regional shares in the generation of other value-added.

In the case of the capital account, as in the single and 2-region cases, positive income transfers from any one region into the capital account of another are not allocated as capital-to-capital intra-agent transfers. Instead they are reallocated from the own-region capital account entries for households, government and corporate based on the distribution of savings across these transactors in the income-expenditure account of the home-region.

As in the 2-region case the remaining intra-UK income transfers are between RUK transactors. To determine these entries we again use the income-expenditure accounts constructed for the UK national economy and take the RUK-RUK entries as the residual after subtracting the corresponding Scottish and Welsh entries from each RUK one. All inter-regional transfers are already determined from the Scottish-RUK and Welsh-RUK transfers in the 3-region versions of the Scottish and Welsh income-expenditure accounts.

The final income transfer entries in the 3-region SAM are those to and from ROW. For Scotland and Wales, these correspond to the 2-region entries in each of these cases and the RUK entries will again be the residuals after subtracting the Scottish and Welsh entries from those in the (national) UK income expenditure accounts.

The 3-region income-expenditure accounts and SAM are available from the corresponding author on request.

4. Four-region IO and SAM accounts

4.1 The 4-region IO

Constructing the 4-region IO involves extending the framework illustrated in Figure 2a to that shown in Figure 3a. The additional data/estimation requirements are identified in Figure 3b. Note that the 4-region database is limited to the 3-sector breakdown in the bottom box in Table 1 (the sectoral breakdown that the 4-region CGE model is specficied for).

The unshaded cells in Figure 3b indicate all the matrices that have already been determined through the single and 3-region IO frameworks. The grey shaded cells indicate the matrices that need to be derived separately. These are the Northern Ireland (NI) use matrices from the other 3 UK regions and the England use matrices (the 'residual' region RUK is redefined as 'England' in the 4-sector tables). We follow the same basic approach as described in Section 3.1 for the 3-region IO tables and estimate these matrices in 7 steps:

<u>1. Scottish imports from NI and RUK</u>

The 3-region tables give us Scottish imports from Wales and from RUK, where the latter includes England and NI. For the 4-region framework we have to separate imports from NI and England – i.e. identify the matrices M_S^{NI} and M_S^{E} for the Scottish use columns in Figure 3b. We adopt the same method as reported in to separate imports to Scotland from Wales from other RUK in the construction of the 3-region tables in Section 3.1 above. That is, we take the ratio of output production in NI for each sector i to total NI plus England sector i output (or 3-region RUK sector i output). We then apply this to each Scottish production and final demand sector's use of NI plus RUK imports (i.e. imports from RUK in the 3-region case). Therefore, because we use the same method to derive M_S^{W} in Section 3.1, in using imported UK sector i goods/services, Scottish production and final demand sectors make the same proportionate use of Welsh, NI or RUK outputs, based on the total output shares of the Welsh, NI and RUK sectors. For example, in the case of Primary commodities, in the 4-region calculation the ratio of NI produced commodities to total Primary production in the rest of the UK (NI+England) is

$$\frac{\text{NI Primary sector gross output}}{\text{NI Primary sector gross output plus England Primary sector gross output}}$$

$$= 0.0364$$

Therefore, we assume that each Scottish production sector, i, and final consumption sector, z, purchases 3.6% of its (3-region) RUK imports of Primary goods and services from NI and the remaining 94.7% from England. Doing this for all i=3 imported goods and services gives us the matrix M_S^{NI}, which in turn is split into X_S^{NI} and $C_{i(z,S)}^{NI}$ in Figure 3b. Then, by subtracting M_S^{NI} from the 3-region version of M_S^{RUK}, or by subtracting M_S^{NI} plus M_S^W plus M_S^S from the total Scottish-UK use matrix, M_S^{UK}, we get the matrix M_S^E of Scottish imports from England.

2. Welsh imports from NI and RUK

We employ exactly the same method to derive Welsh imports from NI and England, i.e. the matrices M_W^{NI} and M_W^{RUK} in Figure 3b. The 3-region table gives us Welsh imports from Scotland, M_W^S, which are derived as explained in Section 3.1 using the output share method. Therefore we employ this method again to split NI from other RUK imports in the manner described above for Scotland.

3. NI imports from Scotland, Wales and RUK

Again we employ the output share method explained in steps 1&2 and section 3.1 above. The only difference is that in the case of NI we are starting with the 2-region case. we identify imports from Scotland and from Wales – M_{NI}^S and M_{NI}^W – using the output share method and take imports from England as the residual – i.e. subtract M_{NI}^S plus M_{NI}^W from the 2-region version of M_{NI}^{RUK}.

4. Scottish exports to England

Figure 3b shows that once we have estimated NI imports from Scotland – i.e. matrix M_{NI}^S – the Scottish rows are balanced with the estimation of the exports to England, matrix M_E^S. As

in the 3-region case, we begin by calculating M_E^S as a residual matrix, by subtracting M_{NI}^S from the 3-region version of M_{RUK}^S. However, once again this results in the problem of negative entries. The alternative is to adopt the second approach outlined in Section 3.1, where we take the residual vector of exports to the rest of the UK after M_W^S and M_{NI}^S have been accounted for and distributing this across English production sectors. This is done using the ratio of total exports to England from each Scottish sector, i, to total English use of UK sector i outputs and apply this to each English production and final demand sector's use of UK sector i outputs.

5. Welsh exports to England

Welsh exports to England, M_E^W, in the 4-region table are calculated in exactly the same way as outlined in Step 4. Again, the first method gives rise to the negative entry problem. Unless we choose to make ad hoc adjustments to get rid of these, the second method, which is consistent with the 2- and 3-region frameworks in terms of method, is used.

6. NI exports to England

The only difference in estimating the matrix M_E^{NI} of exports from NI to England is that we are starting with the 2-region case for NI so, if we choose the first method outline above, we either need to subtract both M_S^{NI} and M_W^{NI} (estimated in Steps 1 and 2) from the 2-region version of M_{RUK}^{NI}. However, again this gives rise to the negative entry problem, so the second method is adopted.

7. The England-England use matrix

As in the 3-region case, the schematic illustration of the 4-region IO table in Figure 3b that shows that after Steps 1-6 only one matrix remains to be calculated. This is the RUK-RUK use matrix, M_{RUK}^{RUK}. In steps 4-6 we have determined the English Use matrices, M_E^S, M_E^W and M_E^{NI} showing English imports from the other three UK regions. Therefore, we can calculate M_E^E as the residual of the England-UK use matrix (i.e. $M_E^E = M_E^{UK} - M_E^S - M_E^W - M_E^{NI}$).

4.2 The 4-region SAM

As in the single, 2-region (Section 2) and 3-region (Section 3) cases, the 4-region SAM takes data from the 4-region IO table (Section 4.1), the NI-RUK 2-region SAM (Section 2.5) and from income-expenditure accounts for each of the 4 regions. Here we need to: (a) split RUK transfers in the Scottish, Welsh and Northern Ireland single region income-expenditure accounts into transfers to and from the other 3 regions in each case; (b) create a new RUK income-expenditure account for the 4-region case.

The approach taken is analogous to that explained in Section 3.2 for the 3-region SAM. We begin by reallocating the existing net product and production tax row in the 4-region IO table to allow taxes paid on goods and services to be recorded as going to the net commodity tax and government accounts in the exporting region. As in the 3-region case for all except England (which takes the place of RUK as the 'balancing region') we do this on the basis of import shares, with the balancing entries in the Scottish, Welsh and NI rows being determined by the distribution of exports to England from each of the other regions. Net P&P taxes paid by England in England are the residual entries required to balance England to UK P&P taxes minus all of the above.

The outstanding SAM entries, recording income transfers between the aggregate/institutional transactors are determined using the income-expenditure account method. All intra-regional transfers except the capital accounts and the England-England case, along with primary input expenditures and flows to ROW link back to the 4-region IO, the 3-region SAM (Scottish and Welsh entries) or the NI-RUK 2-region SAM. The additional income-expenditure account data needed here are (a) inter-regional transfers and (b) intra-regional English transfers (i.e. the residual after stripping NI out of RUK in the 3-region case).

As in the 3-region case, we only split transfers to and from England in the Scottish, Welsh and NI accounts down by the other 3 regions in the case of the household and corporate accounts. In the case of inter-governmental transfers (remember that all inter-regional transfers, except capital, are intra-agent flows), we assume that these will be between the devolved administrations of Wales and Scotland and central government located in England.

For the split in the English transfers in the household accounts, we adopt the same approach as for RUK in the 3-region case (roughly speaking, on the basis of outflows of wage income from each region). However, note, that in the absence of actual data, this is quite tricky and extremely ad hoc. For the split in inter-regional transfers in the corporate account, this is done on the basis of regional shares in the generation of other value added.

In the case of the capital account, as in the single, 2- and 3-region cases, positive income transfers from any one region into the capital account of another are not allocated as capital-to-capital intra-agent transfers. Instead they are reallocated from the own-region capital account entries for households, government and corporate based on the distribution of savings across these transactors in the income-expenditure account of the home-region.

As with RUK in the 3-region case, the remaining intra-UK income transfers are between English transactors. To determine these entries we again use the income-expenditure accounts constructed for the UK national economy and take the England-England entries as the residual after subtracting the corresponding NI entries from each RUK one in the 3-region version.

As noted in Sections 2 and 3, all of the components of the 4-region SAM are available from the corresponding author on request.

5. Summary and conclusions

This paper has explained the methods used to develop a set of 2-region, 3-region and 4-region IO and SAM accounts as the core database of the inter-regional computable general equilibrium (CGE) model of the UK developed as part of the project 'An Analysis of National and Devolved Economic Policies' undertaken as part of the ESRC Devolution and Constitutional Change research programme.

The main problems are in terms of data availability. First, a major issue is the absence of regularly produced analytical IO tables for the UK. The most recent set of tables are for the year 1995 (National Statistics, 2002) and according to National Statistics there are no plans at this time to produce analytical tables for any subsequent year. UK IO data is produced regularly, but in the form of supply and use tables (SUT), the latter of which report all (domestic and import) transactions in commodity-by-industry terms at purchaser prices. In order to convert these to the format required for modelling (separately identifying domestic and import transactions in symmetric, commodity-by-commodity or industry-by-industry format at basic prices) we require data from the make matrix and other data on commodity tax rates, distribution margins etc. However, none of these data are publicly available. Therefore, the best we have been able to do is estimate a UK IO table for 1999 by mechanically rolling forward the 1995 tables using control total data from the 1999 SUT.

The second major problem is with regional IO data. Only Scotland has regularly published IO tables that use the same survey data source as used in UK IO accounts. Wales does produce IO tables on a semi-regular basis by the Welsh Economic Research Unit at Cardiff Business School. WERU do not have access to the same survey data used in UK and Scottish IO accounting, relying instead on a separate survey carried out specifically for constructing the Welsh IO tables. This raises the issue of consistency with other regional and national IO data for the UK. However, the situation is even worse in terms of the English regions and Northern Ireland where no IO accounts exist whatsoever. Therefore we have had to estimate a table for Northern Ireland based on some region-specific data for aggregates but Welsh technical coefficients to determine inter-sectoral transactions.

The third major problem is the absence of an official data on inter-regional trade at the sectoral level and on income transfers within the UK. We have been able to draw on experimental (and unpublished) data provided by the Scottish Executive and WERU on imports-by-commodity from elsewhere in the UK to Scotland and Wales respectively that is consistent with the IO tables in these regions. However, even if these data were to become official they do not help us quantify trade linkages in the other direction (i.e. Scottish and Welsh exports to other UK regions) or for the more regionally disaggregated level of analysis we are attempting in the current project.

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Table 1. Sectoral breakdown for the UK inter-regional framework

10 sector

Production sectors		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

8 sector

Production sectors		IOC
1	PRIMARY & UTILITIES	1-7, 85-87
2	MANUFACTURING	8-84
3	CONSTRUCTION	88
4	WHOLESALE & RETAIL TRADE	89-92
5	TRANSPORT & COMMUNICATION	93-99
6	FINANCIAL INT & BUSINESS	100-114
7	PUBLIC ADMIN., EDUC., HEALTH & SOCIAL WORK	115-118
8	OTHER SERVICES	119-123

3 sector

Production sectors		IOC
1	MANUFACTURING	8-84
2	NON-MANUFACTURING TRADED	1-7, 85-87, 89-114, 119-123
3	NON-MANUFACTURINT NON-TRADED	88, 115-118

Figure 1a. Schematic Structure of the Scottish/RUK Inter-Regional Input-Output Table

		SCOTLAND		RUK		ROW
	Input to Output from	Intermediate demand Scot sector i=1..10	Final demand Scot sector z=1..4	Intermediate demand RUK sector i=1….10	Final demand RUK sector z=1..4	ROW export demand
SCOT	Scot sector i. ↓ 10	ixi Scottish local int. demand matrix	ixz Scottish local fin. dem matrix	ixi RUK imports from Scot	ixz RUK imports from Scot	ix1 Scottish exports to ROW (tourist and g&S)
RUK	RUK sector i. ↓ 10	ixi Scot imports from RUK matrix	ixz Scot imports from RUK matrix	ixi RUK local int. demand matrix	ixz UK local fin. dem matrix	1xi RUK exports to ROW
Primary Inputs	ROW imp, prod/ comm tax, VA	5xi Scot primary exp	5xz Scot primary exp	5xi RUK primary exp	5xz RUK primary exp	5x1 ROW primary exp

Figure 1b. Actual structure and data sources for the Scottish/RUK Inter-Regional Input-Output Table

		Scotland		RUK		ROW
	Input to Output from	Intermediate demand Scot sector i=1..10	Final demand Scot sector z=1..4	Intermediate demand RUK sector i=1….10	Final demand RUK sector z=1..4	ROW export demand
SCOT	Scot sector i. ↓ 10	X^{S}_{S} (Scot IO table)	$C^{s}_{i(z,S)}$ (Scot IO table)	X^{S}_{RUK} Estimated matrix M^{S}_{RUK}	$C^{s}_{i(z,RUK)}$ Estimated matrix M^{S}_{RUK}	$c^{s}_{i(ROW)}$ (Scot IO table)
RUK	RUK sector i. ↓ 10	X^{RUK}_{S} Estimated matrix M^{RUK}_{S}	$C^{RUK}_{i(z,S)}$ Estimated matrix M^{RUK}_{S}	X^{RUK}_{RUK} (RUK use minus M^{S}_{RUK})	$C^{RUK}_{i(z,RUK)}$ (RUK use minus M^{S}_{RUK})	$c^{RUK}_{i(ROW)}$ (UK IO minus Scot IO)
Primary Inputs	ROW imp, prod/ comm tax, VA	$F_{(i,S)}$ (Scot IO table)	$F_{(z,S)}$ (Scot IO table)	$F_{(i,RUK)}$ (UK IO minus Scot IO)	$F_{(z,RUK)}$ (UK IO minus Scot IO)	$F_{(ROW)}$ (UK IO table)

Figure 2a. Schematic Structure of the Scot/Wales/RUK Inter-Regional Input-Output Table

		SCOTLAND		WALES		RUK		ROW
	Input to Output from	Intermediate demand Scot sector i=1..8	Final demand Scot sector z=1..4	Intermediate demand Welsh sector i=1..8	Final demand Welsh sector z=1..4	Intermediate demand RUK sector i=1…8	Final demand RUK sector z=1..4	ROW export demand
SCOT	Scot sector i. ↓ 8	ixi Scottish local int. demand matrix	ixz Scottish local fin. dem matrix	ixi Wales imports from Scot	ixz Wales imports from Scot	ixi RUK imports from Scot	ixz RUK imports from Scot	ix1 Scottish exports to ROW (tourist and g&S)
WALES	Welsh sector i. ↓ 8	ixi Scot imports from Wales matrix	ixz Scot imports from Wales matrix	ixi Welsh local int. demand matrix	ixz Welsh local fin. dem matrix	ixi RUK imports from Wales	ixz RUK imports from Wales	1xi Wales exports to ROW
RUK	RUK sector i. ↓ 8	ixi Scot imports from RUK matrix	ixz Scot imports from RUK matrix	ixi Welsh imports from RUK matrix	ixz Welsh imports from RUK matrix	ixi RUK local int. demand matrix	ixz UK local fin. dem matrix	1xi RUK exports to ROW
Primary Inputs	ROW imp, prod/ comm tax, VA	5xi Scot primary exp	5xz Scot primary exp	5xi Welsh primary exp	5xz Welsh primary exp	5xi RUK primary exp	5xz RUK primary exp	5x1 ROW primary exp

Figure 2b. Actual structure and data sources for the Scot/Wales/RUK Inter-Regional Input-Output Table

		SCOTLAND		WALES		RUK		ROW
	Input to / Output from	Intermediate demand Scot sector i=1..10	Final demand Scot sector z=1..4	Intermediate demand Welsh sector i=1..10	Final demand Welsh sector z=1..4	Intermediate demand RUK sector i=1….10	Final demand RUK sector z=1..4	ROW export demand
SCOTS	Scot sector i. ↓ 10	X^S_S Scot-RUK (Scot IO)	$C^S_{i(z,S)}$ Scot-RUK (Scot IO)	X^S_W Estimated matrix M^S_W (step 2)	$C^S_{i(z,W)}$	X^S_{RUK} Scot-RUK IO M^S_{RUK} minus M^S_W (step 3)	$C^S_{i(z,RUK)}$	$c^s_{i(ROW)}$ Scot-RUK (Scot IO)
WALES	Welsh sector i. ↓ 10	X^W_S Estimated matrix M^W_S (step 1)	$C^W_{i(z,S)}$	X^W_W Wales-RUK (Wales IO)	$C^W_{i(z,W)}$ Wales-RUK (Wales IO)	X^W_{RUK} Wales-RUK IO M^W_{RUK} minus M^W_S (step 4)	$C^W_{i(z,RUK)}$	$c^W_{i(ROW)}$ Wales-RUK (Wales IO)
RUK	RUK sector i. ↓ 10	X^{RUK}_S Estimated matrix M^{RUK}_S (step 1)	$C^{RUK}_{i(z,S)}$	X^{RUK}_W Estimated matrix M^{RUK}_W (step 2)	$C^{RUK}_{i(z,W)}$	X^{RUK}_{RUK} RUK use M_{RUK} minus (M^S_{RUK} + M^W_{RUK}) (step 5)	$C^{RUK}_{i(z,RUK)}$	$c^{RUK}_{i(ROW)}$ UK IO - Scot IO - Wales IO
Primary Inputs	ROW imp, prod/ comm tax, VA	$F_{(i,S)}$ Scot-RUK (Scot IO)	$F_{(z,S)}$ Scot-RUK (Scot IO)	$F_{(i,W)}$ Wales-RUK (Wales IO)	$F_{(z,W)}$ Wales-RUK (Wales IO)	$F_{(i,RUK)}$ UK IO - Scot IO - Wales IO	$F_{(z,RUK)}$ UK IO - Scot IO - Wales IO	$F_{(ROW)}$ UK IO

Figure 3a. Schematic Structure of the Scot/Wales/NI/England 4-region Inter-Regional Input-Output Table

		SCOTLAND		WALES		NORTHERN IRELAND		England		ROW
	Input to / Output from	Intermediate demand Scot sector i=1..3	Final demand Scot sector z=1..4	Intermediate demand Welsh sector i=1..3	Final demand Welsh sector z=1..4	Intermediate demand NI sector i=1..3	Final demand NI sector z=1..4	Intermediate demand England sector i=1….3	Final demand England sector z=1..4	ROW export demand
SCOTS	Scot sector i. ↓ 3	ixi Scottish local int. demand matrix	ixz Scottish local fin. dem matrix	ixi Wales imports from Scot	ixz Wales imports from Scot	ixi NI imports from Scot	ixz NI imports from Scot	ixi England imports from Scot	ixz England imports from Scot	ix1 Scottish exports to ROW (tourist and g&S)
WALES	Welsh sector i. ↓ 3	ixi Scot imports from Wales matrix	ixz Scot imports from Wales matrix	ixi Welsh local int. demand matrix	ixz Welsh local fin. dem matrix	ixi NI imports from Wales matrix	ixz NI imports from Wales matrix	ixi England imports from Wales	ixz England imports from Wales	1xi Wales exports to ROW
NI	NI sector i. ↓ 3	ixi Scot imports from NI matrix	ixz Scot imports from NI matrix	ixi Welsh imports from NI matrix	ixz Welsh imports from NI matrix	ixi NI local int. demand matrix	ixz NI local fin. dem matrix	ixi England imports from NI	ixz England imports from NI	1xi NI exports to ROW
ENGLAND	England sector i. ↓ 3	ixi Scot imports from England matrix	ixz Scot imports from England matrix	ixi Welsh imports from England matrix	ixz Welsh imports from England matrix	ixi NI imports from England matrix	ixz NI imports from England matrix	ixi England local int. demand matrix	ixz UK local fin. dem matrix	1xi England exports to ROW
Primary Inputs	ROW imp, prod/ comm tax, VA	5xi Scot primary exp	5xz Scot primary exp	5xi Welsh primary exp	5xz Welsh primary exp	5xi NI primary exp	5xz NI primary exp	5xi England primary exp	5xz England primary exp	5x1 ROW primary exp

Figure 3b. Actual structure and data sources for the Scot/Wales/NI/England 4-region Inter-Regional Input-Output Table

		SCOTLAND		WALES		NORTHERN IRELAND		England		ROW
	Input to / Output from	Intermediate demand Scot sector i=1..3	Final demand Scot sector z=1..4	Intermediate demand Welsh sector i=1..3	Final demand Welsh sector z=1..4	Intermediate demand NI sector i=1..3	Final demand NI sector z=1..4	Intermediate demand England sector i=1….3	Final demand England sector z=1..4	ROW export demand
SCOTS	Scot sector i. ↓ 3	X^S_S 3-reg (Scot IO)	$C^S_{i(z,S)}$ 3-reg (Scot IO)	X^S_W Estimated matrix M^S_W (step 3)	$C^S_{i(z,W)}$	X^S_{NI} Estimated matrix M^S_{NI} (step 3)	$C^S_{i(z,NI)}$	X^S_E 3-reg IO M^S_{RUK} minus M^S_{NI} (step 4)	$C^S_{i(z,E)}$	$c^s_{i(ROW)}$ 3-reg (Scot IO)
WALES	Welsh sector i. ↓ 3	X^W_S Estimated matrix M^W_S (3-reg)	$C^W_{i(z,S)}$	X^W_W 3-reg (Wales IO)	$C^W_{i(z,W)}$ 3-reg (Wales IO)	X^E_S Estimated matrix M^E_S (step 3)	$C^E_{i(z,S)}$	X^W_E 3-reg IO M^W_{RUK} minus M^W_{NI} (step 5)	$C^W_{i(z,E)}$	$c^W_{i(ROW)}$ 3-reg (Wales IO)
NI	NI sector i. ↓ 3	X^{NI}_S Estimated matrix M^{NI}_S (step 1)	$C^{NI}_{i(z,S)}$	X^{NI}_W Estimated matrix M^{NI}_W (step 2)	$C^{NI}_{i(z,W)}$	X^{NI}_{NI} NI-E (NI IO)	$C^{NI}_{i(z,NI)}$ NI-E (NI IO)	X^{NI}_E 2-reg NI-E IO M^{NI}_{RUK} minus (M^{NI}_S + M^{NI}_W) (step 6)	$C^{NI}_{i(z,E)}$	$c^{NI}_{i(ROW)}$ NI-E (NI IO)
ENGLAND	England sector i. ↓ 3	X^E_S Estimated matrix M^E_S (step 1)	$C^E_{i(z,S)}$	X^E_W Estimated matrix M^E_W (step 2)	$C^E_{i(z,W)}$	X^E_{NI} Estimated matrix M^E_{NI} (step 3)	$C^E_{i(z,NI)}$	X^E_E E use M^{UK}_E minus (M^S_E + M^W_E + M^{NI}_E) (step 7)	$C^E_{i(z,E)}$	$c^E_{i(ROW)}$ UK IO - Scot - Wales - NI
Primary Inputs	ROW imp, prod/ comm tax, VA	$F_{(i,S)}$ 3-reg (Scot IO)	$F_{(z,S)}$ 3-reg (Scot IO)	$F_{(i,W)}$ 3-reg (Wales IO)	$F_{(z,W)}$ 3-reg (Wales IO)	$F_{(i,NI)}$ NI-E (NI IO)	$F_{(z,NI)}$ NI-E (NI IO)	$F_{(i,E)}$ UK IO - Scot - Wales - NI	$F_{(z,E)}$ UK IO - Scot - Wales - NI	$F_{(ROW)}$ UK IO

APPENDIX

Construction of a 3 sector input-output table of the Northern Ireland economy, (1999)

For our four-region UK IO/SAM database we require an Input-Output table for Northern Ireland. Due to the absence of a survey-based IO accounts for this region, we have had to estimate a table in a format consistent with the UK, Scottish and Welsh analytical IO tables for 1999. To do this we collected Northern Ireland specific published estimates of data where possible, focussing on particular on control totals for each row and column in the table. For the column coefficients, we used the technical coefficients from our Welsh table. We then balanced the unbalanced table using our RAS balancing program. We constructed our table at the three-sector level[4], with six final demand categories[5] and five primary input categories[6]. We explain the data sources and the methods we used for each of the control totals below.

Data sources used

Primary Inputs

- *Imports from the Rest of the UK and Imports from the Rest of the World*

To estimate these imports we used the ratio between exports and imports from the Welsh Input-Output table, and used this ratio alongside our estimates of Northern Ireland exports (calculated below).

We calculate the ratio of exports to imports for Wales from each geographical zone (Rest of the UK and Rest of the World). For the Rest of the UK, the ratio of Welsh exports to imports is 0.9309, while for the Rest of the World this ratio is 0.6505. We then divide our estimates of Northern Ireland exports to these areas by these ratios. This process gives us total NI imports from the Rest of the UK of £7,968.58million, and total NI imports from the Rest of the World of £7,643.52million.

[4] The three sectors are Manufacturing, non-Manufacturing traded, and non-Manufacturing, non-traded. These were chosen due to the programming needs for our four region inter-regional model. See Section 2.6.

[5] The Final Demand categories are Households, General Government, Gross Domestic Fixed Capital Formation, Change in Inventories, Exports to Rest of the UK, and Exports to Rest of the World.

[6] The Primary Inputs categories are Imports from the Rest of the UK, Imports from the Rest of the World, Net production and commodity taxes, Compensation of employees and Gross Operating Surplus.

- *Net production and commodity taxes*

We estimate net production and commodity taxes by using estimated figures at the UK level. Figures (National Statistics, 2004) at the UK level show that Estimate Net production and Commodity taxes for 1999 were 13.36% of UK GVA (we take this to be the sum of Compensation of Employees plus Gross Operating Surplus). We take this same share of Northern Ireland Gross Value Added (£17,003million), giving us a figure for Net Production and Commodity Taxes of £2,272.3million.

- *Compensation of Employees*

This figure comes from Table 2 in National Statistics (2001a).

- *Gross Operating Surplus*

This is the difference between Compensation of Employees (£10,502million) figure from Table 2 of National Statistics (2001a) and Northern Irish Gross Value Added for 1999 (£17,003million), also from Table 2 National Statistics (2001a). Thus, this value of Gross Operating Surplus for Northern Ireland in 1999 is £6,547million.

Final Demands

- *Households*

The control total for Household expenditure comes from the Table 12.11 of "Regional Trends" (National Statistics, 2004a), and reports that households in Northern Ireland spent £14,009million in 1999.

- *General Government*

To estimate General Government expenditure in Northern Ireland we used the ratio between the Total Government Expenditure figures for 1999 from the Scottish and Welsh Income and Expenditure Accounts and the IO Government expenditure from the Scotland (Scottish Executive, 2002) and Wales input-output tables for 1999. This ratio was 1.93 for Scotland and 1.87 for Wales for our base year. We divided Total Government Expenditure from the

Northern Ireland Income and Expenditure Account (£12,621.8m) by the average of these two figures (1.90) to estimate total IO Government expenditure.

Aggregate/Total Government Expenditure for the SAM is estimated as the sum of three elements: Total Identifiable Expenditure (£9945.25m), Estimated Non-Identifiable Expenditure (£1084.93m) and Other Estimated Expenditure (£1591.57m). These three elements are obtained from Public Expenditure Statistical Analysis 2001-02 (HM Treasury, 2001). Estimated Non-Identifiable Expenditure uses Northern Ireland's population share of the UK (2.8%) of Total Non-Identifiable Expenditure, while the value for Other Estimated Expenditure uses the Northern Ireland share of Total Identifiable Expenditure (3.8%). This gives us a total figure for Northern Ireland General Government expenditure of £6,640.7million for 1999.

- *Gross Domestic Fixed Capital Formation (GDFCF) and Change in Inventories*

Our control totals estimates for GDFCF and Change in Inventories come from a combination of National Statistics (2003) and the single-region IO tables for Scotland (Scottish Executive, 2002) and Wales (Bryan *et al*, 2004).

Table 4 in National Statistics (2003) provides Total Gross Fixed Capital Formation for Scotland, Wales and Northern Ireland. We then add together the total GDFCF and the total Change in Inventories for both the Scotland and Wales IO tables. The Scottish IO for 1999 gave a total GDFCF and Change in Inventories of £11,428million, against the National Statistics (2003) value of £13,111m. The Welsh IO table for 1999 total for these categories was £4859m, while the National Statistics (2003) value was £6,319m.

The National Statistics (2003) values are on average 22.38% lower than the IO figures, thus to obtain the Northern Ireland total for GDFCF and Change in Inventories, we reduced the published value from National Statistics (2003) by this amount. This gave us a total of £3,176m.

We then split this total for Northern Ireland between GDFCF and Change in Inventories. We calculated the share from the Scottish and Welsh IO tables, and used the average of these shares for each final demand category. Thus, 1.77% of this total went to the Change in Inventories total (£56.16million), while 98.23% went to the GDFCF total (£3120.05million).

- *Exports to the Rest of the UK and Exports to the Rest of the World*

Export figures come from a combination of published sources and IO tables for other regions. The published report by the Northern Ireland Department of Enterprise, Trade and Investment (DETI, 2002) gave the value of exports by the Northern Irish Manufacturing sector for our years around our base year of 1999. We take the average of export figures for 1998/9 and 1999/00 to get values of manufacturing exports to the Rest of the UK of £3,248million, and £3,732million of manufacturing exports to the Rest of the World.

We then calculated for Scotland the percentage that manufacturing exports represents of total exports to these two areas. These were 43.79% and 75.06% for the Rest of the UK and the Rest of the World respectively. We used these same shares to estimate total exports for Northern Ireland of £7,417.9million to the Rest of the UK and £4,972.0million to the Rest of the World.

The six Final Demand categories totalled £36,215.8million. This was more than the £34,887.3million total of the Primary Input categories. For our RAS balancing program it is necessary that these two values are equal to each other, thus we had to make a decision about how to change the totals to make them equate with each other. We decided, given our stronger confidence in the data sources used for the Primary Input totals, to keep those totals unchanged and decrease the Final Demand categories to equal £34,887.3million. Thus, we scaled these six categories to this new total – maintaining each totals share of the total – and we had the Final Demand equating the Primary Input totals.

Sectoral data

Sectoral control totals on Gross Inputs for our three-sector aggregation mainly come from turnover estimates (DETI, 2003). This survey covers a large sample of businesses in Northern Ireland, but omits three important groups of sectors – "Agriculture, Fishing and Forestry", "Banking and Financial Intermediation/Insurance activities" and "Public Administration, Education, Health and Social Work". These sectors needed to be estimated and then added to the published sectoral estimates.

- *Manufacturing*

This total figure for turnover comes from (DETI, 2003), and shows that Gross Input in the Manufacturing sector, SIC 92 classification sector D (matching with IOC 8-84), was £12,477million in 1999.

- *Non-manufacturing, traded*

The total figure for turnover in this sector is also based on NIABI survey data (DETI, 2003), but the "Agriculture, Forestry and Fishing" and "Banking and Financial Intermediation /Insurance Activities" sectors are omitted from that survey needed to be estimated and added onto the survey estimates. We estimated turnover values for these sectors by taking the Welsh values for Gross Inputs for these sectors and dividing these by the Gross Inputs for the Welsh Manufacturing sector. We then took this ratio for the two sectors and multiplied it by the total Northern Ireland Gross Input figure obtained above (£12,477million) to get Northern Irish estimates of Turnover in these sectors.

This method assumes that each of the two sectors above is the same proportion of the manufacturing sector in both Wales and Northern Ireland. For the "Agriculture, Fishing and Forestry" sector we assume the NI sector is 5.63% of the size of Manufacturing Gross Inputs, while the "Banking and Financial Intermediation /Insurance Activities" sector is assumed to be 10.17% of the Manufacturing sector.

Adding these estimates to those published in the NIABI results for 1999, we get a total Gross Input figure of £23,531.5million.

- *Non-manufacturing, non-traded*

Similar to the entries above, non-manufacturing non-traded sectors are generally provided by the NIABI survey (DETI, 2003). A much larger area of economic activity is missing from this sector than for the sectors added above, since the Public sector is missing from the NIABI sample. This omits sectors 115-118 from the survey, which contain "Public Administration, Education, Health and Social Work" sectors.

Using the same method as the sectors estimated above, we assume that the turnover of Public sector in Northern Ireland is same proportion of Manufacturing in Northern Ireland as the Welsh public sector is of Manufacturing in Wales. Thus, we assume the turnover of the Northern Ireland public sector is 55.33% of the Northern Ireland Manufacturing sector.

Adding this estimate to those published in the NIABI results (DETI, 2003) for 1999, we get a total Gross Turnover (Input) figure of £10,814.9million.

Balancing procedure

We use the column control totals to create an unbalanced table at the three-sector level using the coefficients for each column from a three-sector aggregation of the Welsh 1999 IO table. This table is then balanced to the column totals, for the three sectors gross inputs and final demand categories, and row totals, for the three sectors gross output and primary inputs categories described above using the RAS balancing program. This process thus gave us a three sector balanced Input-Output table for Northern Ireland for 1999.

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