THE SURREY ENVIRONMENTAL LIFESTYLE MAPPING (SELMA) FRAMEWORK:

DEVELOPMENT AND KEY RESULTS TO DATE

by

A. Druckman and T. Jackson

RESOLVE Working Paper 08-08

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Abstract

The Surrey Environmental Lifestyle MApping (SELMA) Framework has been developed in order to underpin work undertaken within the ESRC Research Group on Lifestyles, Values and Environment (RESOLVE) with quantitative estimates of the environmental impacts of UK lifestyles. SELMA takes the consumption perspective, and at its core is an Environmental Input-Output model which attributes all resource use and associated emissions that arise along supply chains to final consumers. SELMA can attribute resource use at a national UK level or, through incorporation of the Local Area Resource Analysis (LARA) model, at the level of local neighbourhoods, or to typical segments of UK households. SELMA is applicable to a wide variety of types of resource use and associated emissions. Many of its applications to date focus on carbon dioxide emissions arising from energy use, although it has also been applied to fossil energy resources, commodity flows and waste arisings.

This is a technical Working Paper designed to give an overview of the design of SELMA to date. It should be viewed as a report on SELMA's development at the time of writing (October 2008), and the reader should bear in mind that SELMA will be subject to further developments. This paper builds on previous descriptions of the development of SELMA, and in particular it covers the incorporation of a quasi-multi-regional input-output (QMRIO) model into SELMA, and also the integration of LARA with the QMRIO model.

In this paper we report high level results of estimated CO_2 emissions for the UK from the consumption perspective at the national level produced by the QMRIO model, and compare these to results obtained by other studies.

As a technical working paper this document makes no attempt to present the motivation or background for studies using SELMA, nor does it provide discussion of conclusions that may be drawn from SELMA's findings. For these the reader is referred to Druckman and Jackson (2007; 2008a; 2008b; 2009), Druckman et al (2008a; 2008b) Jackson et al (2006; 2007) and Bradley et al (2006).

Key Words: Input-output analysis; carbon footprint; household consumption; socio-economic segmentation.

1. Introduction

This Working Paper presents the development to date of the Surrey Environmental Lifestyle MApping (SELMA) framework. SELMA is subject to on-going development and this paper describes its current status and some results obtained from the framework as it stands at the time of writing (October 2008).

SELMA is a framework that accounts for resource use (such as energy use) and associated emissions (such as carbon dioxide) from the consumption perspective. In this paper we largely refer to the application of SELMA for modeling CO_2 emissions, but the reader is asked to bear in mind that it is equally applicable to other environmental stressors, such as other greenhouse gases or waste.

In accounting from the consumption perspective we include CO_2 emissions from energy used directly in homes (for space heating, lighting, hot water and so on), for personal transportation, and also from energy used upstream in the production of goods and services purchased by UK households (Bastianoni et al. 2004; Bin and Dowlatabadi 2005; Druckman et al. 2008a; Jackson and Papathanasopoulou 2008; Jackson et al. 2006; Munksgaard and Pedersen 2001; Nijdam et al. 2005; Peters and Hertwich 2006; Peters 2008; Weber and Matthews 2008; Wiedmann et al. 2008b). The upstream CO_2 emissions are referred to as "embedded". An important aspect of the consumption perspective is that it takes account of all emissions incurred in support of household consumption within the UK, whether they occur in the UK or abroad. This contrasts with the production perspective, which accounts for emissions produced within UK territorial boundaries, regardless of where consumption of final goods and services occurs. The difference between the two approaches is the CO_2 embodied in trade.

The importance of accounting from the consumption perspective is shown by the difference in carbon dioxide emissions from energy use when accounted for by the different perspectives. When accounting from the production perspective, SELMA estimates that emissions are almost the same in 2004 as they were in 1990. However, when estimated from the consumption perspective we find that they have risen 12% or more over the time period (see Results section).

One of the reasons that consumption accounting is not used more widely is that accounting for CO_2 emissions embedded in consumption uses Environmental Input-Output (EIO) modelling. This is a highly data-intensive technique for which there are significant difficulties in compiling robust datasets (Peters et al. 2007), and this is particularly the case for the UK[1]. Furthermore, in order to take account of CO_2 embedded in goods and services produced abroad to support UK consumption, a Multi-Regional Input-Output model (MRIO) is ideally required. MRIO models present even greater data challenges than conventional EIO models, and are often limited in the number of sectors (Huppes et al. 2006; Tukker et al. 2006; Turner et al. 2007). To overcome this difficulty we have developed a quasi-multi-regional input-output (QMRIO) model which attempts to estimate CO_2 emissions due to imported goods and services with maximum accuracy while retaining the greatest possible number of sectors. The QMRIO model is described in this Working Paper.

SELMA has the capability to model CO_2 emissions at various different levels. In Druckman et al (2008a) and Jackson et al (2006; 2007) total UK consumption is considered, which includes resource use due to UK household, Government and capital investment expenditure. In Druckman and Jackson (2009), SELMA is used to consider CO_2 emissions due to UK household expenditure alone, excluding Government and fixed capital investment expenditure, as this is considered more relevant for drawing direct policy implications with regard to households. Through integration of the Local Area Resource Analysis (LARA) model within SELMA, SELMA is also able to consider CO_2 emissions for different types (segments) of households and also for households in specific local geographical areas (see Druckman and Jackson (2008a; 2009) and Druckman et al (2008b)). This Working Paper gives details of the integration of LARA with the QMRIO model.

[1] The latest comprehensive dataset available as a basis for EIO for the UK is for 1995 (Druckman et al. 2008a; ONS 2006). It is possible to use Supply and Use Tables which have been published annually up to 2004 for some of the information required (Lenzen et al. 2004; Wiedmann et al. 2008b).

The paper is organised as follows. The methodologies used in SELMA are presented in Section 2. This covers development of the QMRIO model (Section 2.1), integration of LARA within SELMA (Section 2.2), and the methodology for mapping CO_2 emissions to high level functional uses (Section 2.3). In the Results section (Section 3) we present national level UK CO_2 emissions estimated using the QMRIO model. We compare these results with national level results reported according to UNFCCC (as used for Kyoto reporting) and the UK Environmental Accounts which both take the production perspective. We also compare the QMRIO results with those obtained in other studies. In the final section we discuss the future development of SELMA.

As a technical working paper this document makes no attempt to present the motivation or background for studies using SELMA, nor does it provide discussion of conclusions that may be drawn from SELMA's findings. For these the reader is referred to Druckman and Jackson (2007; 2008a; 2008b; 2009), Druckman et al (2008a; 2008b) and Jackson et al (2006; 2007).

2. Methodology

SELMA incorporates two discrete sub-models which were developed separately and can be used as stand-alone tools. The first is an Environmental Input-Output (EIO) model which is used to estimate indirect (embedded) resource use and associated emissions at the national UK level. The second is the Local Area Resource Analysis (LARA) model, which estimates household expenditure, direct resource use and associated emissions at a highly socio-economically disaggregated level. Integration of the EIO model with LARA enables estimation of both direct and indirect resource use and emissions attributable to households in specific local neighbourhoods and to typical types (segments) of UK households.

2.1 Consumption accounting at the national level

In accounting from the consumption perspective at the national level SELMA accounts for two broad categories of emissions:

a) CO_2 embedded in goods and services purchased by households (including Not For Profit Institutions Serving Households (NPISH)), Government and capital investment;

b) CO_2 due to direct fuel use by households for household and personal transport use.

Estimating CO_2 emissions due to direct household fuel use and personal transportation is relatively straightforward using data sources described in Appendix 1. Estimation of embedded CO_2 is the subject of the next section.

2.1.1 The quasi-multi-regional input-output (QMRIO) model

In this study accounting for emissions embedded in expenditure by households, Government and capital investment is carried out using a Quasi-Multi-Regional Input-Output (QMRIO) model. Input-output is a well established technique (Leontief 1986; Miller and Blair 1985) and therefore only a brief description of the basic model is given here. Our model is based on the two-region model developed by Proops et al (1993) and Jackson et al (2007). Detailed explanation is provided in Jackson et al (2007) and is therefore not repeated here.

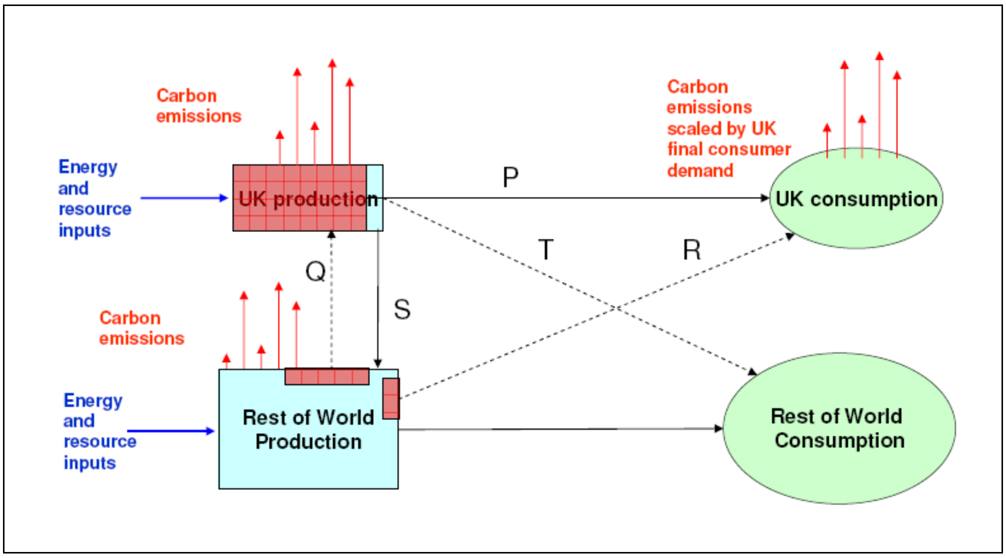

Figure 1: A two-region CO_2 attribution model. Source Jackson et al (2006)

Figure 1 gives a diagrammatic presentation of the underlying two-region model on which the QMRIO model is based. Derivation of the two-region model is described in Jackson et al (2007) and given by equations 1-3 [2].

$$\mathbf{c}^{P} = \mathbf{u}^{1'}(\mathbf{I} - \mathbf{A}^{1})^{-1}\hat{\mathbf{y}}^{11} \quad (1)$$

$$\mathbf{c}^{Q} = \mathbf{u}^{2'}(\mathbf{I} - \mathbf{A}^{2})^{-1}\mathbf{B}^{21}(\mathbf{I} - \mathbf{A}^{1})^{-1}\hat{\mathbf{y}}^{11} \quad (2)$$

$$\mathbf{c}^{R} = \mathbf{u}^{2'}(\mathbf{I} - \mathbf{A}^{2})^{-1}\hat{\mathbf{y}}^{21} \quad (3)$$

[2] In the equations ^ signifies diagonalisation and ′ denotes transposition.

where

$\mathbf{c^P}$ is the CO_2 associated with the flow P of goods produced in the UK to meet final demand in the UK;

$\mathbf{c^Q}$ is the CO_2 associated with the flow Q of goods produced in the Rest of the World to meet intermediate demand in the UK for goods destined for final demand in the UK;[3]

$\mathbf{c^R}$ is the CO_2 associated with the flow R of goods produced in the Rest of the World to meet UK final demand;

$\mathbf{u^n}$ is the vector of CO_2 coefficients for region *n*;

$\mathbf{y^{n1}}$ is the vector of final demand for commodities produced in region *n* and consumed in region 1 (the UK);

I is an identity matrix;

$\mathbf{A^n}$ is the 'A-matrix' of intra-regional technical coefficients for region *n*. $(\mathbf{I}\text{-}\mathbf{A})^{-1}$ is known as the 'Leontief Inverse';

$\mathbf{B^{n1}}$ is the imports use coefficients matrix for imports from region *n* to region 1. This is often referred to as the Imports Use Matrix.

An important shortcoming of most two-region models is the assumption that imported goods have the same production recipe and energy use structure as those produced in the UK (Lenzen et al. 2004). This assumption, known as the 'domestic technology assumption', is described by the following equation:

$$\mathbf{u^{2'}(I - A^2)^{-1} = u^{1'}(I - A^1)^{-1}} \quad (4)$$

In the QMRIO we modify this assumption so that the CO_2 intensity of imported goods more accurately represents the intensity of each of our importing partners, which are divided into 12 world regions. Figure 2 gives a diagrammatic representation of the parameters used to characterise production in the 13 regions in the QMRIO model (region 1 is the UK). The diagram shows that imports from region *n* are characterised by the vector of relative CO_2 intensity of region *n* compared to region 1 ($\mathbf{u^{n1}}$), and the vector of the proportion of total imports from region *n* to region 1 ($\mathbf{p^{n1}}$). The industry structure of all regions is represented by the UK A-Matrix. Details of the derivation of equations in 2 and 3 terms of $\mathbf{u^{n1}}$ and $\mathbf{p^{n1}}$ for a 13-region economy gives are given in Appendix 2. Equation 1 remains unchanged as it does not involve imports. The QMRIO model is given by equations 5 to 7 below.

[3] Note that for accounting purposes this flow must exclude the goods required to produce the demand for exports back to the Rest of the World.

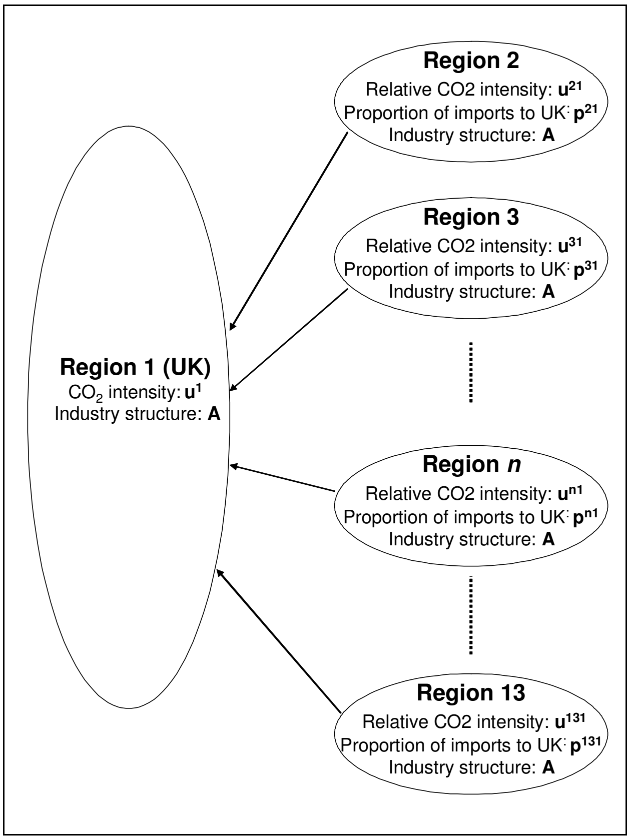

Figure 2. Parameters used for modelling a *n*-region QMRIO model

$$\mathbf{c^P} = \mathbf{u}^{\mathbf{1}'}(\mathbf{I} - \mathbf{A}^{\mathbf{1}})^{-1}\hat{\mathbf{y}}^{\mathbf{11}} \quad (5)$$

$$\mathbf{c^Q} = \sum_{n=2}^{n=13}\left(\hat{\mathbf{u}}^{\mathbf{n1}}\mathbf{u}^{\mathbf{1}}\right)'(\mathbf{I} - \mathbf{A})^{-1}\left(\mathbf{P}^{\mathbf{n1}}.\mathbf{B}^{\mathbf{imp}}\right)(\mathbf{I} - \mathbf{A})^{-1}\hat{\mathbf{y}}^{\mathbf{11}} \quad (6)$$

$$\mathbf{c^R} = \sum_{n=2}^{n=13}\left(\hat{\mathbf{u}}^{\mathbf{n1}}\mathbf{u}^{\mathbf{1}}\right)'(\mathbf{I} - \mathbf{A})^{-1}\hat{\mathbf{y}}^{\mathbf{imp}}\hat{\mathbf{p}}^{\mathbf{n1}} \quad (7)$$

where $\mathbf{B}^{\mathbf{imp}}$ is the Imports Use Matrix for imports to the UK from all regions.

The data requirements for the QMRIO model are substantial. Economic datasets are obtained from the Supply and Use Tables (ONS 2006). The most recent authorised versions of the Leontief Inverse and Imports Use Matrices for the UK are for 1990 (in SIC80) and for 1995 (in SIC92)[4]. For the early years of the study (1990-1992/3) we would ideally like to use the 1990 Leontief Inverse and Imports Use matrices. However, Supply and Use Tables for

[4] Defra has commissioned updated Structural Input-Output Tables for years 1992-2004 as a stop-gap while the ONS are unable to produce authorised updated versions (Wiedmann et al. 2008b). These tables are not a replacement for authorised versions as they have been produced with limited source data. However, they are expected to be more appropriate for modelling more recent years and their incorporation into future versions of SELMA is under consideration.

1991 are not available, and the 1992 Supply and Use Table is only available in SIC92. Therefore 1990 is modelled in SIC80 using the 1990 Leontief Inverse and Imports Use matrices and years 1992-2004 are modelled in SIC92 using the 1995 Leontief Inverse and Imports Use matrices. For further details of the methodology, assumptions and implications the reader is referred to Druckman et al (2008a).

Annual UK energy use and CO_2 emissions data are obtained from the UK Environmental Accounts in 93 sector format (ONS 2008) which are mapped onto the SIC80 and SIC92 classifications (ONS and Gazley (personal communication) 2008). Other details are as explained in Druckman et al (2008a) and are therefore not repeated here.

The data for 12 world regions from which the UK receives imports are taken from the GTAP version 6 (2001) dataset (Dimaranan 2006). These data are aggregated from 87 regions to 13 regions based on those used by Wilting (2008) as shown in Appendix 3. Due to problems found with the GTAP CO_2 emissions data (see, for example, Peters and Hertwich (2008)), CO_2 emissions for selected countries (Australia[5], China[6], Japan[7], USA[8], and various EU countries[9]) are overwritten with data kindly provided by Glen Peters. Use of 2001 data assumes that the relative CO_2 intensity and proportion of imports are constant for all years at 2001 levels. The GTAP data are in 57 sectors which are mapped onto the SIC80 and SIC92 classifications.

[5] Australian Bureau of Statistics. Energy and greenhouse gas emissions accounts, Australia 1992-93 to 1997-98. ABS Catalogue No. 4604.0, 2001.
[6] Glen P. Peters, Christopher Weber, and Jingru Liu. Construction of Chinese energy and emissions inventory. IndEcol Report 4/2006, Norwegian University of Science and Technology, 2006.
[7] K. Nansai, Y. Moriguchi, and S. Tohmo. Compilation and application of Japanese inventories for energy consumption and air pollutant emissions using input-output tables. *Environmental Science and Technology*, 37(9):2005{2015, 2003.
[8] Gorgyi Cicas, Chris Hendrickson, A. Horvath, and H. Scott Matthews. A regional version of a U.S. economic input-output life-cycle assessment model. *International Journal of Life Cycle Assessment*, 12(6):367{374, 2007.
[9] Eurostat. Environmental accounts - satellite accounts to the national accounts. On-line database: Accessed: 14 December, 2007, Eurostat: Statistical Office of the European Communities, 2007. Countries covered: Austria, Belgium, Bulgaria, Denmark, Estonia, Finland, France, Germany, Hungary, Ireland, Italy, The Netherlands, Poland, Portugal, Slovenia, Spain, Sweden, Switzerland, United Kingdom, and Norway which was assumed to be Rest of EFTA in the GTAP data.

In work carried out to date the QMRIO model has been run for years 1990-2004[10] for energy use and associated CO_2 emissions. The result is a time-series of total energy use and CO_2 emissions attributable to UK households (including NPISHs), Government and capital investment.

2.2 Socio-economic disaggregation using LARA

Of particular interest in RESOLVE is the CO_2 attributable to households. There is an argument that all government and fixed capital expenditure is made in support of households, and SELMA has the ability to attribute CO_2 due to these expenditures to households. This has been done in some studies using SELMA (see Jackson et al (2006; 2007) and Carbon Trust (2006)). In order to be able to draw more direct policy implications from the results it was not done in Druckman and Jackson (2009).

We now focus on modelling CO_2 emissions attributable to different types (segments) of UK households using LARA. LARA is a highly socio-economically disaggregated model that can be used as a stand-alone tool for estimating direct resource use and emissions, or integrated within SELMA to estimate indirect (embedded) resource use and emissions. LARA is a top-down model that uses expenditure data from Expenditure and Food Survey (ONS various years) and household data from the 2001 Census (National Statistics 2005). Its geographical basis is neighbourhoods of 124 households on average. A brief description of LARA's methodology is included in Appendix 4 and further details given elsewhere (see Druckman and Jackson (2007; 2008a) and Druckman et al (2008b)).

In the following text we show how LARA is integrated with the QMRIO model to estimate the total (direct and indirect) CO_2 attributable to each Supergroup. In this analysis we account for four broad categories:

i) CO_2 emissions embedded in goods and services purchased by households (this analysis excludes NPISH, Government and capital investment);
ii) CO_2 emissions due to direct fuel use by households;
iii) CO_2 emissions due to personal vehicle use;

[10] Excluding 1991 as explained above.

iv) CO_2 emissions due to personal aviation.

The choice of these categories reflects the end uses that we are interested in from a policy perspective, with our focus being on household consumption. In the category of direct fuel use by households, we include electricity use. Electricity is not, in itself, a fuel: it is an energy carrier, and emissions from its production arise upstream, for example, at the power plants where coal, gas or nuclear fuel are burnt. CO_2 emissions from the electricity used by households are, technically, embedded. However, it is separated from the category of embedded emissions and included as a direct household CO_2 because this is how it is commonly perceived by consumers, and it is subject to direct household decisions concerning use and savings.

Personal transportation is an important contributor to CO_2 emissions, and in the following analysis we choose two categories, as defined above, again, selected with a view to policy relevance. Emissions due to personal vehicle use are those directly due to petrol and diesel consumption, whereas those due to personal aviation occur upstream: they have been separated from the general category of embedded emissions due to their significance for emissions reduction policy. [11]

In this study LARA is applied to each of the 175,434 Output Areas in England and Wales. The results from this study can be reported for each of these small geographic areas. However, in order to draw wider conclusions we use group the outputs from LARA into seven segments (known as Supergroups) of typical types of households, using the UK National Output Area Classification (ONS 2005; Vickers and Rees 2007; Vickers et al. 2005). The main characteristics of each of these seven Supergroups, which have names such as 'Prospering Suburbs' and 'Constrained by Circumstances', are given in Appendix 5.

A schematic diagram showing the use of LARA in this study is shown in Figure 3. On the left-hand side data inputs to LARA are shown. Outputs from LARA used in this study are in

[11] Energy use and emissions due to personal travel by trains and ferries is not separated into a category of its own because the per capita levels from these modes of transport are generally lower, and these modes are not so relevant for carbon reduction strategies.

terms of CO_2 emissions (namely mean CO_2 emissions due to direct fuel use by households and vehicle use for each Supergroup) and expenditures. Estimation by LARA of CO_2 emissions due to direct household fuel use by households in Supergroups has been carried out previously (see Druckman and Jackson (2008a)), and results from that study are used here[12]. This methodology has been repeated to estimate mean CO_2 due to personal vehicle use for each Supergroup.

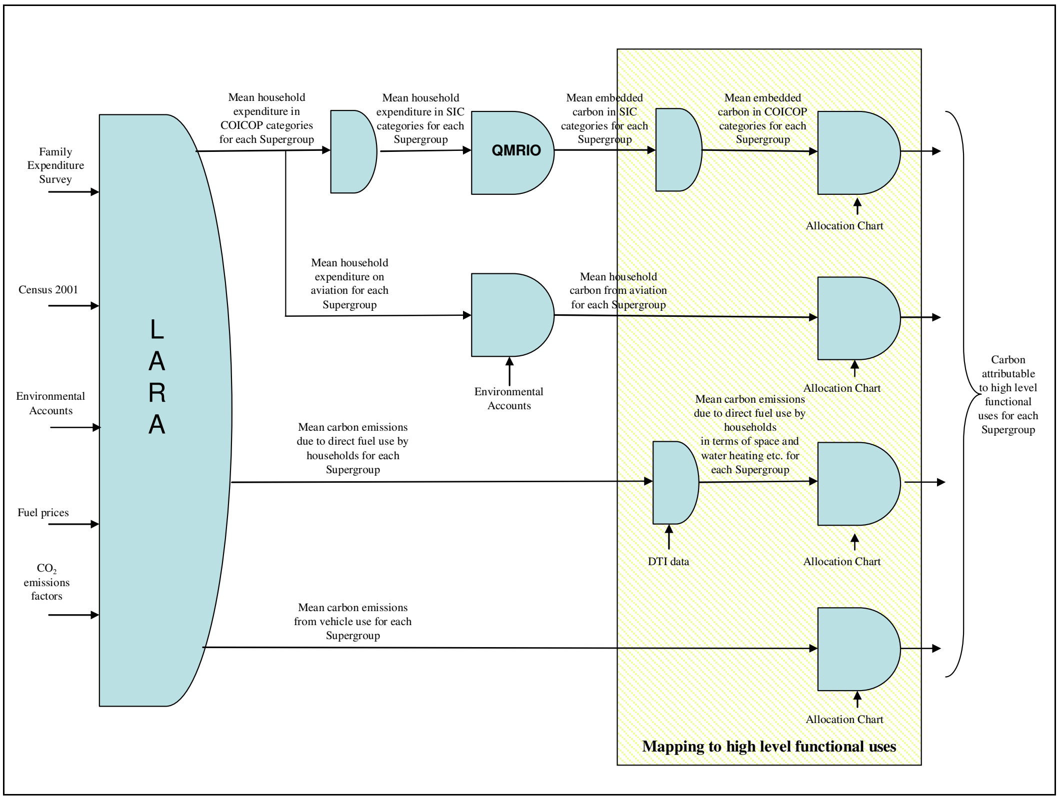

Figure 3. A flow diagram to show estimation of CO_2 emissions attributable to Supergroups using LARA, and allocation to high level functional uses

CO_2 due to personal aviation is estimated using expenditure information on aviation by each Supergroup from LARA. Data on CO_2 emissions from aviation are obtained from Environmental Accounts Sector 70. This includes emissions from business travel (as intermediate demand) as well as personal aviation emissions (as household final demand).

[12] Adjustments were required due to use of different data sources in the two studies. First, different estimates of the number of households in UK are used: Druckman and Jackson {, 2008 #943} used an estimate based on Expenditure and Food Survey whereas this study uses figures from DCLG (2008). The DCLG estimate is believed to be more accurate although the actual number of households, is, in fact, unknown. Second, figures for total energy use by UK households for Druckman and Jackson (2008a) were obtained from Energy Trends (DTI various years) whereas this study uses figures from DUKES (2006) Table 5.2.

We assume that the mix of short- and long-haul flights, and price paid, is the same for these two types of demand. We therefore use proportionality based on the monetary value of flights purchased by businesses and households from the Supply and Use Tables (ONS 2006) in order to estimate mean CO_2 emissions due to personal aviation for UK households. We then use expenditure results from LARA to estimate mean CO_2 emissions due to personal aviation for each Supergroup.

Embedded emissions for each Supergroup are calculated using expenditure data from LARA, and this is the subject of the following text.

2.2.1 Preparation of expenditure data from LARA for use in QMRIO model

In essence the methodology for estimating embedded CO_2 for each Supergroup is simple: embedded emissions for each Supergroup is estimated by running the QMRIO model, as given in equations 20-22, with household demand for the seven different Supergroups estimated using LARA. However, the results from LARA cannot be directly used in the QMRIO model, as they are in terms of 247 COICOP[13] categories in Purchasers' prices based on the UK Family Expenditure Survey (ONS various years), whereas the QMRIO model requires household final demand in terms of 122 SIC[14] categories in Basic prices. Another difficulty is that UK household expenditure based on the Expenditure and Food Survey differs from that published in the Supply and Use Tables for a number of reasons: different sources of data are used (ONS 2007); the Supply and Use Tables include imputed rents[15]; and the time periods covered are different[16].

The following procedure is used to prepare the expenditure data from LARA for use in the QMRIO model. Our first step is to find the ratio of expenditure in each SIC category above UK mean household expenditure for each Supergroup in Purchasers' prices. The basis of the conversion from COICOP to SIC is Table 4 ('Households final consumption expenditure by

[13] COICOP stands for Classification of Individual Consumption According to Purpose (UN 2005).
[14] Standard Industrial Classification.
[15] People living in dwellings they own are considered to be selling housing services to themselves. The rents recorded in the national accounts therefore include both the actual rents paid by tenants and imputed rents in the case of owner-occupiers. In most countries, this is the largest imputed item in households' consumption. The amount of the imputed rent is measured by the rents paid for comparable housing in a similar part of the country. http://caliban.sourceoecd.org/vl=5879620/cl=31/nw=1/rpsv/una/Chapter5.htm. Imputed rent accounts for approximately 10% of household expenditure in 2004 according to Table 4.
[16] The national accounts use a calendar year whereas the Family Spending is based on the Expenditure & Food Survey is carried out annually covering April to March.

COICOP heading') in the Supply and Use Tables (ONS 2006). Table 4 is given in only 41 COICOP categories so for the most important sectors in terms of CO_2 emissions (for example, food and transport), the conversion is carried out at a more disaggregated COICOP level by manually matching sectors. Information is required for 'Actual rentals for housing' and 'Imputed rentals for housing' for use in Table 4. Naturally, the Family Expenditure Survey does not, being a survey, give information on imputed rentals, although it does give information on actual rentals. Therefore imputed rental information cannot be estimated using LARA, and hence national average values for both these categories are used.

The next step is to estimate mean household expenditure in Purchasers' prices in SIC according to the Supply and Use Tables. This is done by dividing national household expenditure as given in the Supply and Use Tables by the estimated number of households in the UK[17]. This is then converted to Basic prices using the methodology explained in Druckman et al (2008a). We then assume that the ratio of expenditure on each SIC category above UK mean household expenditure for each Supergroup in Basic prices is the same as that in Purchaser' prices, and hence estimate final demand for each Supergroup for use in the QMRIO equations.

Figure 3 also shows how carbon emissions are allocated to high level functional uses, and this is the subject of the next section, which commences with an explanation of the reasoning underlying the choice of high functional categories.

2.3 Mapping carbon emissions to high level functional uses

As discussed above, one of the aims of SELMA is to attribute CO_2 emissions to high level functional uses. Expenditures reported in the Expenditure and Food Survey (ONS various years) are in COICOP[18] categories (UN 2005). These categories are designed to identify the 'functional uses' on which people spend their money, such as Education, Health and Transport. When considering the CO_2 emissions involved in supporting UK lifestyles these COICOP categories are not ideal, and therefore we select different high level functional use

[17] This estimation is based on data from DCLG (2008).
[18] COICOP is Classification of Individual Consumption According to Purpose.

categories for the purposes of this study, as used previously by Jackson et al (2006; 2007), and Carbon Trust (2006). The rationale for this selection is in part to reflect the range of material, social and psychological needs that are associated with modern lifestyles (Jackson 2005; Jackson and Marks 1999). Some of these are basic functional needs for material subsistence, protection and health. Others are associated more with social needs such as communication and education. Others cover a range of social and psychological motivations for leisure, relaxation, and interacting with friends and family. We therefore use the following categories:

- Space heating
- Household
- Food & catering
- Clothing & footwear
- Health & Hygiene
- Recreation & Leisure
- Education
- Communications
- Commuting

The procedures used for mapping carbon emissions to these high level functional uses are shown diagrammatically in Figure 3. The Allocation Chart referred to in the diagram is given in Appendix 6. We first consider how embedded emissions are allocated to these categories. As shown in Figure 3 the results from the QMRIO model are in SIC categories, and therefore the first task is to convert these industrial classifications to COICOP. This conversion is carried out using Table 4 ('Households final consumption expenditure by COICOP heading') of the Supply and Use Tables (ONS 2006). We then use the Allocation Chart shown in Appendix 6 as a basis for mapping the COICOP classification onto high level functional uses.

Results from LARA for direct household CO_2 emissions by each Supergroup are simply in terms of type of fuel used (gas, electricity and other fuels), but give us no information about the *uses* for which these fuels are purchased. For this purpose we use information from DTI concerning the amount of each type of fuel used for 'Space heating', 'Water heating', 'Cooking' and 'Lighting and appliances'[19]. Electricity use for 'Lighting and appliances' is further disaggregated into use for Lighting, Cold appliances (refrigerators and freezers),

[19] Source: http://www.dti.gov.uk/energy/statistics/publications/energy-consumption/domestic-tables/page18071.html Accessed Oct 06.

Cookers, Brown appliances (such as televisions and computers), Wet appliances (such as dishwashers) and Miscellaneous[20]. Information on these allocations is, to the knowledge of the authors, not available for different types of households based on their socio-economic characteristics, and therefore mean estimates for the UK are applied to all Supergroups. These categories are then allocated to high level functional uses as shown in Appendix 6.

CO_2 emissions due to personal vehicle use are mapped onto high level functional uses based on information published by the DfT on personal travel by purpose as shown in the Allocation Chart (Appendix 6) [21]. Again, UK mean figures are applied for each Supergroup due to lack of socio-economically disaggregated data. Personal aviation is allocated to recreation and leisure, assuming that the number of people who privately purchase flights for the purposes of commuting is negligible (see Section 5).

3. National level results

The major aim of this technical Working Paper is to provide details of the methodology employed in SELMA to date. Some results obtained using the framework as described in this paper for household expenditure only are presented in Druckman and Jackson (2009). In this section we take the opportunity to present results for the framework applied to total national UK consumption which have not been published elsewhere to date. These results include CO_2 emissions attributable to households (including NPISHs), Government and capital expenditure.

As explained in Druckman and Jackson (2008a), the convention used for accounting for CO_2 emissions radically changes the conclusions that can be drawn about the UK's progress towards its emissions reduction targets. In that study[22] it was shown that according to the UNFCCC reporting convention, carbon emissions fell by 5.6% between 1990 (the Kyoto base year) and 2004. When calculations are based on figures produced in the UK Environmental Accounts, which additionally account for aviation and shipping emissions (excluded from

[20] Source http://www.dti.gov.uk/energy/statistics/publications/energy-consumption/domestic-tables/page18071.html Accessed Oct 06.

[21] Sources: Trips and distance per person per year by trip purpose (http://www.dft.gov.uk/stellent/groups/dft_transstats/documents/page/dft_transstats_612468.hcsp Accessed Oct06); Allocation of shopping trips to purpose is based on DfT (2007).

[22] Druckman and Jackson (2008a) use the domestic technology assumption.

the UNFCCC convention), progress towards the Kyoto target appears to be wiped out, with carbon emissions having risen by 0.3% over the time period. More significantly, Druckman and Jackson's 2008 study found that when emissions were estimated according to the consumption perspective using an earlier version of SELMA that used the domestic technology assumption, CO_2 was estimated to have risen by 8% over the same time span. The study also found that the UK's carbon trade balance had risen from 1% in 1990 to 8% in 2004.

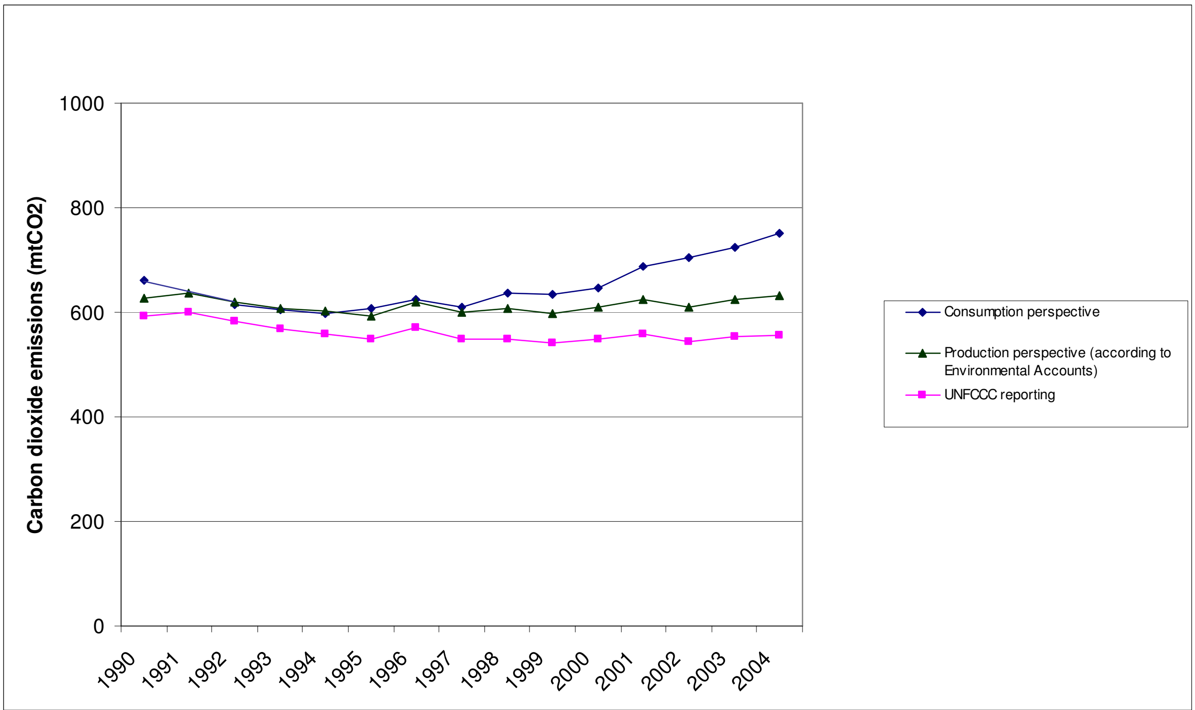

Figure 4. Trends in UK carbon dioxide emissions from different accounting perspectives

The graph in Figure 4 shows estimates of these results found using the QMRIO model within SELMA[23]. The figures for UNFCCC reporting and reporting according to the Environmental Accounts are the same as in Druckman and Jackson (2008a). The QMRIO model attempts to estimate the emissions embedded in imports with improved accuracy over use of the domestic technology assumption, and, as predicted in the sensitivity analysis in Druckman and Jackson (2008a), estimates using the QMRIO model are higher. Figure 4 shows that according to the consumption perspective CO_2 emissions increased by around 14% between 1990 and 2004, with the carbon trade balance rising from 5% to 19% over the time period.

[23] As discussed above data were not available for 1991 and therefore the line between 1990 and 1992 is interpolated.

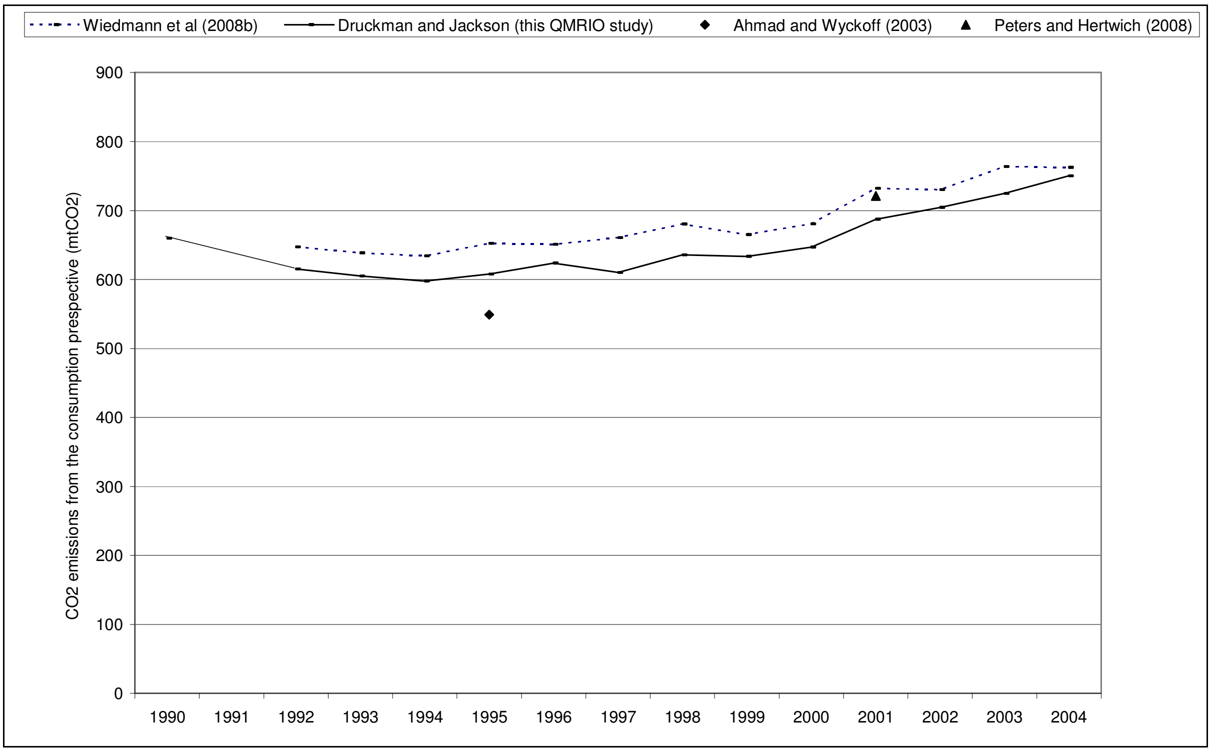

Figure 5. Comparison of results with MRIO studies of UK

In the next part of this Working Paper we compare the results obtained by our study using the QMRIO model within SELMA with results from other recent studies of the UK.

Figure 5 compares our results with those from multi-regional studies of the UK by Wiedmann et al (2008b) (for 199-2004), Ahmad and Wyckoff (2003) (for 1995) and Peters and Hertwich (2008) (for 2001). Wiedmann et al's (2008b) estimates are higher than those from other studies, whereas Ahmad and Wyckoff (2003) give the lowest estimate. Our QMRIO model is predicted to under-estimate CO_2 emissions due to use of the UK Leontief Inverse for all world regions, and comparison with the other studies generally confirms this. The trends shown by Wiedmann et al (2008b) and our QMRIO study agree well. Both studies show the effects of the "dash for gas" [24] and economic downturn in the early 1990s. Following this period emissions are estimated by both studies to have risen fairly steadily.

The variation in results from different EIO models is due to the myriad assumptions that are required in developing any model, whether it be single- or two- region, quasi-multi regional

[24] See Druckman and Jackson (2009)

or multi-regional. Of particular interest is comparison of the time-series results from our study with the time-series results from Wiedmann et al (2008b). One of the salient differences (apart from quasi- versus multi-regional) between the QMRIO model in this study and Wiedmann et al's study is that the QMRIO study is based on the official, authorised edition of the Input Output Tables for 1995 as published by the ONS[25] whereas Wiedmann et al have updated the UK Input-Output Tables using information from the Supply and Use Tables. The difficulties, assumptions required, and implications of using the 1995 tables in the QMRIO model are discussed in Druckman et al (2008a). As documented in Wiedmann et al's report, the process of updating the tables was done under conditions of incomplete data (being based on the Supply and Use Tables rather than the full dataset of transactions in the economy) and also necessitated many assumptions concerning, for example, imports and conversion from Purchasers' to Basic prices.

Other differences between our QMRIO study and Wiedmann et al's (2008b) study include:

- The QMRIO model excludes Sector 123 (Private households with employed persons) which, in monetary terms, accounts for around 3% of total final demand. This sector was included in Wiedmann et al's study and will be included in future versions of SELMA. Omission of this sector is another reason why the QMRIO results as shown in Figure 5 are lower than estimates by Wiedmann et al.
- The QMRIO model uses a more recent version of the Environmental Accounts than Wiedmann et al's study.
- In the QMRIO study special attention is paid to modelling CO_2 emissions associated with the emissions arising from the electricity production and distribution sector. In order to take account of the different losses and tariffs in supplying industry and domestic final demand, the carbon intensity coefficient for this sector is modified to represent supply to industry (Druckman et al. 2008a). CO_2 emissions due to direct domestic energy use is then estimated from figures on domestic electricity consumption taken from the Digest of United Kingdom Energy Statistics (Department of Trade and Industry 2006).

[25] This statement applies to years 1992-2004. Estimates for 1990 are based on the official, authorised 1990 Input-Output Table published by the ONS, as described earlier.

Wiedmann et al. carried out an uncertainty analysis (see Wiedmann et al (2008a)) on their results. Their analysis, however, was unable to model some uncertainties due to many of the fundamental assumptions in their model. Examples of this include the assumptions made during the conversion from Purchasers' to Basic prices; uncertainties due to aggregation/disaggregation of sectors between the numerous datasets used; and uncertainties due to conversion from US dollars into British pounds (which was based on Purchasing Power Parities) for use in calculating CO_2 intensities for the non-UK regions (Wiedmann et al. 2008b). Other uncertainties not included in the uncertainty analysis, are, for example, use of technical coefficients for OECD Europe countries that includes the UK but excludes the Netherlands (ibid). That being said, estimates from the QMRIO are within the ±2 relative standard error uncertainty range estimated by Wiedmann et al (2008a).

In summary, it can be concluded that the QMRIO figures agree well with those from the other MRIO studies. Due to use of the UK Leontief Inverse for all world regions, the QMRIO model is expected to under-estimate CO_2 emissions, and comparison with estimates from other models generally confirms this. The trends shown by the QMRIO model agree well with those found by Wiedmann et al. The advantage of our QMRIO over MRIO models is that the data requirements are substantially lower, and it has greater transparency.

4. Future development of SELMA

This Working Paper has presented the methodology used within SELMA to date. Of course, SELMA can be developed and enhanced indefinitely. In the discussion that follows we look at some specific developments under consideration.

The current version of SELMA uses a QMRIO model based on the 1995 Structural Input-Output Tables for all years 1995 onwards. As mentioned earlier, Defra has commissioned updated Structural Input-Output Tables for years 1992-2004 as a stop-gap while the ONS are unable to produce authorised updated versions. These tables are not a replacement for authorised versions as they have been produced with limited source data (Wiedmann et al. 2008b). However they may be more appropriate for modelling more recent years than basing our analysis on the 1995 table as has been done in SELMA to date, and incorporation of these tables into future versions of SELMA is under consideration.

A particular element of SELMA that needs revision is its limited ability to explore in detail the differences between how CO_2 emissions due to direct energy use are attributable to high level functional uses for each Supergroup. This is because at the moment we do not have information for each Supergroup concerning, for example, the purpose of their personal vehicle use or the relative quantities of electricity that is used for powering, say, household appliances, lighting, and brown goods such as computers and televisions. This is a subject for further research, and will be important in targeting specific carbon reduction schemes at different sectors of society.

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Appendix 1. Direct household fuel use, personal vehicle use and personal aviation

Data for direct household use of gas, oil coal and other fuels are obtained from the Environmental Accounts Sector 92 (ONS 2008) for each year. Energy and carbon emissions due to domestic electricity use is estimated using data supplied by AEA Energy & Environment from the UK Greenhouse Gas Inventory 2007 NAEI and the Digest of UK Energy Statistics 2006 (DUKES) (Department of Trade and Industry 2006). Data on personal vehicle use are obtained from the Environmental Accounts Sector 93.

Appendix 2

In this Appendix we give details of the derivation of the QMRIO model presented in equations 6 and 7 [26]. These are derived from equations 2 and 3. Specifically, we show how expressions for equations for $\mathbf{c^Q}$ and $\mathbf{c^R}$ in terms of $\mathbf{u^{n1}}$ and $\mathbf{p^{n1}}$ are derived. For simplicity we consider a 2 sector 3 region economy. We look at equation 3 first, as this is more straight forward. Equation 3 may be written as

$$\mathbf{c^R} = \mathbf{u}^{2'}(\mathbf{I} - \mathbf{A})^{-1}\hat{\mathbf{y}}^{\mathbf{21}} + \mathbf{u}^{3'}(\mathbf{I} - \mathbf{A})^{-1}\hat{\mathbf{y}}^{\mathbf{31}} \tag{8}$$

Let

$$\mathbf{y^{imp}} = \mathbf{y^{21}} + \mathbf{y^{31}} \tag{9}$$

where $\mathbf{y^{imp}}$ is the total imports from all regions to the UK. $\mathbf{y^{imp}}$ can be written for the two sector economy as

$$\mathbf{y^{imp}} = \begin{pmatrix} y_1^{imp} \\ y_2^{imp} \end{pmatrix} \tag{10}$$

Now let **P** be a matrix of the proportion of imports (in monetary terms) to Region 1 from Regions 2 and 3 for each sector. In this matrix, for example, p_1^{21} is proportion of imports from Region 2, sector 1.

$$\mathbf{P} = \begin{pmatrix} p_1^{21} & p_1^{31} \\ p_2^{21} & p_2^{31} \end{pmatrix} \tag{11}$$

So

$$\hat{\mathbf{y}}^{\mathbf{21}} = \begin{pmatrix} y_1^{imp} p_1^{21} & 0 \\ 0 & y_2^{imp} p_2^{21} \end{pmatrix} = \begin{pmatrix} y_1^{imp} & 0 \\ 0 & y_2^{imp} \end{pmatrix} \begin{pmatrix} p_1^{21} & 0 \\ 0 & p_2^{21} \end{pmatrix} = \hat{\mathbf{y}}^{\mathbf{imp}} \hat{\mathbf{p}}^{\mathbf{21}} \tag{12}$$

Substitute for $\mathbf{y^{21}}$ and $\mathbf{y^{31}}$ in equation (8)

[26] Equation 5 is the same as equation 1.

$$\mathbf{c^R} = \mathbf{u}^{2'}(\mathbf{I} - \mathbf{A})^{-1}\hat{\mathbf{y}}^{\mathbf{imp}}\hat{\mathbf{p}}^{\mathbf{21}} + \mathbf{u}^{3'}(\mathbf{I} - \mathbf{A})^{-1}\hat{\mathbf{y}}^{\mathbf{imp}}\hat{\mathbf{p}}^{31} \tag{13}$$

We now need to write this in terms of relative CO_2 intensities $\mathbf{u^{21}}$ and $\mathbf{u^{31}}$ instead of absolute CO_2 intensities $\mathbf{u^2}$ and $\mathbf{u^3}$. We define the vector of relative CO_2 intensity for Region 2 ($\mathbf{u^{21}}$) as the CO_2 intensity of each sector in Region 2 divided by the CO_2 intensity of that sector in Region 1. In matrix algebra this is called element by element division and written as $./$ in the equations. The relative CO_2 intensity of Region 2 can be written as

$$\mathbf{u^{21}} = \left(\mathbf{u}^2./\mathbf{u^1}\right) \tag{14}$$

We now need to express $\mathbf{u^2}$ in terms of $\mathbf{u^{21}}$. This can be done simply by algebraic manipulation:

$$\mathbf{u}^2 = \left(\mathbf{u}^1./\mathbf{u}^1\right)\ \mathbf{u}^2 = \left(\mathbf{u}^2./\mathbf{u}^1\right)\ \mathbf{u}^1 \tag{15}$$

and therefore

$$\mathbf{u}^2 = \hat{\mathbf{u}}^{\mathbf{21}}\mathbf{u^1} \tag{16}$$

and

$$\mathbf{u}^3 = \hat{\mathbf{u}}^{\mathbf{31}}\mathbf{u^1} \tag{17}$$

Substituting into equation (13) gives

$$\mathbf{c^R} = \left(\hat{\mathbf{u}}^{\mathbf{21}}\mathbf{u^1}\right)'\ (\mathbf{I} - \mathbf{A})^{-1}\hat{\mathbf{y}}^{\mathbf{imp}}\hat{\mathbf{p}}^{\mathbf{21}} + \left(\hat{\mathbf{u}}^{\mathbf{31}}\mathbf{u^1}\right)'\ (\mathbf{I} - \mathbf{A})^{-1}\hat{\mathbf{y}}^{\mathbf{imp}}\hat{\mathbf{p}}^{\mathbf{31}} \tag{18}$$

Hence, for a 13 region economy equation 3 can be written as

$$\mathbf{c^R} = \sum_{n=2}^{n=13}\left(\hat{\mathbf{u}}^{\mathbf{n1}}\mathbf{u^1}\right)'\ (\mathbf{I} - \mathbf{A})^{-1}\hat{\mathbf{y}}^{\mathbf{imp}}\hat{\mathbf{p}}^{\mathbf{n1}} \tag{19}$$

We now derive an expression for $\mathbf{c^Q}$ in terms of $\mathbf{u^{n1}}$ and $\mathbf{p^{n1}}$ for a 3 region 2 sector economy.

We can write equation (2) as

$$\mathbf{c^Q} = \mathbf{u}^{2'}(\mathbf{I} - \mathbf{A})^{-1}\mathbf{B^{21}}(\mathbf{I} - \mathbf{A})^{-1}\hat{\mathbf{y}}^{\mathbf{11}} + \mathbf{u}^{3'}(\mathbf{I} - \mathbf{A})^{-1}\mathbf{B^{31}}(\mathbf{I} - \mathbf{A})^{-1}\hat{\mathbf{y}}^{\mathbf{11}} \tag{20}$$

Let $\mathbf{B^{imp}}$ be the Imports Use Matrix for imports to the UK from all regions, such that

$$\mathbf{B^{imp}} = \mathbf{B^{21}} + \mathbf{B^{31}}.$$

If we make matrices $\mathbf{P^{21}} = \begin{pmatrix} p_1^{21} & p_1^{21} \\ p_2^{21} & p_2^{21} \end{pmatrix}$ and $\mathbf{P^{31}} = \begin{pmatrix} p_1^{31} & p_1^{31} \\ p_2^{31} & p_2^{31} \end{pmatrix}$

and we assume equal ratios of imports into all sectors, then

$$\mathbf{B^{21}} = \mathbf{P^{21}}.\mathbf{B^{imp}} \tag{21}$$

$$\mathbf{B^{31}} = \mathbf{P^{31}}.\mathbf{B^{imp}} \tag{22}$$

By substituting in equation (20) using equations 16, 17, 21 and 22 we get

$$\mathbf{c^Q} = \left(\hat{\mathbf{u}}^{\mathbf{21}}\mathbf{u^1}\right)'(\mathbf{I - A})^{-1}\left(\mathbf{P^{21}.B^{imp}}\right)(\mathbf{I - A})^{-1}\hat{\mathbf{y}}^{\mathbf{11}} + \left(\hat{\mathbf{u}}^{\mathbf{31}}\mathbf{u^1}\right)(\mathbf{I - A})^{-1}\left(\mathbf{P^{31}.B^{imp}}\right)(\mathbf{I - A})^{-1}\hat{\mathbf{y}}^{\mathbf{11}} \quad (23)$$

Therefore for a 13 region economy equation 2 can be written as

$$\mathbf{c^Q} = \sum_{n=2}^{n=13}\left(\hat{\mathbf{u}}^{\mathbf{n1}}\mathbf{u^1}\right)'(\mathbf{I - A})^{-1}\left(\mathbf{P^{n1}.B^{imp}}\right)(\mathbf{I - A})^{-1}\hat{\mathbf{y}}^{\mathbf{11}} \quad (24)$$

The QMRIO model is hence given by equations 1, 24 and 19, which are summarised below for convenience.

$$\mathbf{c^P} = \mathbf{u^{1'}}(\mathbf{I - A^1})^{-1}\hat{\mathbf{y}}^{\mathbf{11}} \quad (25)$$

$$\mathbf{c^Q} = \sum_{n=2}^{n=13}\left(\hat{\mathbf{u}}^{\mathbf{n1}}\mathbf{u^1}\right)'(\mathbf{I - A})^{-1}\left(\mathbf{P^{n1}.B^{imp}}\right)(\mathbf{I - A})^{-1}\hat{\mathbf{y}}^{\mathbf{11}} \quad (26)$$

$$\mathbf{c^R} = \sum_{n=2}^{n=13}\left(\hat{\mathbf{u}}^{\mathbf{n1}}\mathbf{u^1}\right)'\,(\mathbf{I - A})^{-1}\hat{\mathbf{y}}^{\mathbf{imp}}\hat{\mathbf{p}}^{\mathbf{n1}} \quad (27)$$

Appendix 3. QMRIO Regions (adapted from Wilting (2008)).

World region		GTAP Region	
Number	Name	GTAP 6 code	Description
1	UK	43	UK
2	North America	21	Canada
		22	United States
		23	Rest of N. America
3	Central and South America	23	Mexico
		25	Colombia
		26	Peru
		27	Venezuela
		28	Rest of Andean Pact
		29	Argentina
		30	Brazil
		31	Chile
		32	Uruguay
		33	Rest of South America
		43	Central America
		35	Rest of FTAA
		36	Rest of the Caribbean
4	Oceania	1	Australia
		2	New Zealand
		3	Rest of Oceania
5	Japan and New Industrializing Economies	5	Hong Kong
		6	Japan
		7	Korea
		8	Taiwan
		13	Singapore
6	South East Asia	10	Indonesia
		11	Malaysia
		12	Philippines
		14	Thailand
		15	Vietnam
		16	Rest of South East Asia
7	China and East Asia	4	China
		9	Rest of East Asia
8	South Asia	17	Bangladesh
		18	India
		19	Sri Lanka
		20	Rest of South Asia
9	Middle East	71	Turkey
		72	Rest of Middle East
10	Former Soviet Union	69	Russian Federation
		70	Rest of Former Soviet Union
11	Eastern Europe	54	Rest of Europe
		55	Albania
		56	Bulgaria
		57	Croatia
		58	Cyprus
		59	Czech Republic
		60	Hungary
		61	Malta
		62	Poland
		63	Romania
		64	Slovakia
		65	Slovenia
		66	Estonia
		67	Latvia
		68	Lithuania
12	OECD Europe	37	Austria
		38	Belgium
		39	Denmark
		40	Finland
		41	France
		42	Germany
		44	Greece
		45	Ireland
		46	Italy
		47	Luxembourg
		48	Netherlands
		49	Portugal
		50	Spain
		51	Sweden
		52	Switzerland
		53	Rest of EFTA
13	Africa	73	Morocco
		74	Tunisia
		75	Rest of North Africa
		76	Botswana
		77	South Africa
		78	Rest of South African CU
		79	Malawi
		80	Mozambique
		81	Tanzania
		82	Zambia
		83	Zimbabwe
		84	Rest of SADC
		85	Madagascar
		86	Uganda
		87	Rest of Sub-Saharan Africa

Appendix 4. LARA Methodology

This Appendix contains a brief overview of LARA's methodology. For more detailed explanations the reader is referred to Druckman and Jackson (2007; 2008a), and Druckman et al (2008b).

As explained in the main text, LARA estimates expenditure, resource use and emissions for households in small local areas based on their socio-economic characteristics. This is achieved by combining two national level datasets: the UK Family Expenditure Survey (ONS various years) and the 2001 Census (National Statistics 2005). The geographical basis of LARA is Output Areas (OAs) as defined by the UK Census 2001. These are areas of approximately 124 households, on average, that are as socio-economically homogenous as possible. Households are categorised into Household Categories (HoCs), which are defined in terms of type of dwelling, tenure, age and economic status of the household representative[27]. We find the socio-economic characteristics of households in each OA from the Census, and we estimate typical household expenditure by people with matching characteristics from the Family Expenditure Survey. The mean household expenditure E^{kl} in local area *l*, on commodity *k* is estimated using the equation

$$E^{kl} = \sum_{i=1}^{i=N} p_i^l e_i^k \tag{28}$$

where

p_i^l = proportion of households in local area *l*, that are members of HoC *I;*
e_i^k = average annual household expenditure commodity on *k*, of households in HoC *I;*
i = HoC number, such that *i*=1 to N, where N= total number of HoCs (N=45).

Equation 11 shows LARA in terms of expenditure, and this is used as a basis for final demand in the QMRIO model in order to estimate embedded CO_2 attributable to household expenditure in local neighbourhoods.

[27] Each household has a designated Household Reference Person (HRP) who, for a person living alone is that person, or for more than one person, is chosen on the basis of their economic activity, followed by age (ONS 2001).

In this paper, particular attention is paid to direct household energy use and personal vehicle use. For these commodities there are wide price variations across different areas of the UK and also prices vary during the sample period of one year. In order to take these variations into account, appropriate price information (according to the time in the year the sample was taken and the household's regional location) is allocated to each sample household in the Expenditure Survey in order to estimate quantity of fuel purchased, or associated carbon emissions[28]. Therefore, for these categories LARA is run in terms of physical quantities, and E^{kl} and e_i^k in Equation 11 represent the consumption of fuel or CO_2 emissions instead of expenditures.

[28] Matrices of price information were kindly supplied by the Centre for Alternative Energy http://www.cse.org.uk/ .

Appendix 5. Selected characteristics of OAC Supergroups

	Blue Collar Communities	City Living	Countryside	Prospering Suburbs	Constrained by Circumstances	Typical Traits	Multicultural
Variables distinctively above national average	• Age 5-14 • Rent (public) • Terraced housing • Lone parent households	• Age 25-44 • Population density • Rent (private) • Flats • No central heating	• Age 45+ • Detached housing • Rooms per household • 2+ car households	• Age 45-64 • Detached housing • Rooms per household • 2+ car households • Two adults no children • Households with non-dependant children	• Age 65+ • Single pensioner households • Rent (Public) • Flats • People room • Unemployment	*Typical traits is characterised by its 'averageness'. This Supergroup has few values which are high or low in comparison to the other groups.*	• Age 0-15 • Born outside UK • Population density • No central heating • People per room • Flats • Unemployment • Rent (public and private)
Variables distinctively below national average	• Rent (private) • Flats	• Ages 0-14 • Rooms per household	• Population density • Flats • People per room • Single person household	• No central heating • Terraced housing • Flats • Single person household • Rent (private and public)	• Two adults no children • Rent (private) • Detached housing • Rooms per household • 2+ car household		• Age 45+ • Single pensioner households • Detached housing

Source: Vickers et al (2005), ONS (2005) and Druckman and Jackson (2008a)

Appendix 6. Allocation table for high level functional uses.

COICOP categories plus direct use of domestic fuels	CIOCOP category	High level functional uses: Household	Recreation & Leisure	Space Heating	Food & Catering	Commut-ing	Health & Hygiene	Clothing & Footwear	Education	Commun-ications	Total[1]
Food & Non-alcoholic drink	1.1, 1.2, 11.1				100%						100%
Alcohol & Tobacco	2.1, 2.2		100%								100%
Clothing & Footwear	3.1, 3.2							100%			100%
Housing	4.1, 4.2, 4.3, 5.5, 5.6,	100%									100%
Water Supply & Other Misc Services	4.4						75%	25%			100%
Furnishings & Other Household	5.1, 5.2, 5.4	100%									100%
Household Appliances	5.3	25%	25%		25%		13%	13%			100%
Health & Hygiene	6.1, 6.2, 6.3, 12.1						100%				100%
Transport Services (indirect)	7.1, 7.2, 7.3	1%	40%		5%	37%	7%	6%	4%		100%
Post & Communication	8.1, 8.2, 8.3									100%	100%
Recreation & Entertainment	9.1 – 9.4		100%								100%
Books & Newspaper	9.5								100%		100%
Other Personal Effects	12.3							100%			100%
Holidays excl dir personal aviation and vehicle use	9.6, 11.2		100%								100%
Education	10								100%		100%
Financial & Other Services	12.4, 12.5, 12.6, 12.7	100%									100%
Delivered Fuels (indirect)	4.5 (part)[2]	11%	6%	48%	9%		13%	13%		1%	100%
Space Heating				100%							100%
Water Heating							50%	50%			100%
Cooking					100%						100%
Electricity (lighting)		100%									100%
Electricity (cold appliances)					100%						100%
Electricity (brown goods)			90%							10%	100%
Electricity (wet appliances)							50%	50%			100%
Electricity (misc)		100%									100%
Personal vehicle use		1%	40%		5%	37%	7%	6%	4%		100%
Personal aviation			100%								100%

[1] Discrepancies in totals are due to rounding errors.
[2] COICOP category 4.5 includes emissions from electricity production, which are excluded from this domestic functional category as they included directly elsewhere.