

**Report to the  
Scottish Environment Protection Agency**

**Workshop on economy-  
environment statistics and potential  
calculation of an ecological and/or  
carbon footprints using input-output  
techniques held at the  
University of Strathclyde  
on 11 March 2008**

**Karen Turner, Fraser of Allander Institute,  
Department of Economics**

## Executive Summary

A workshop on economy environment statistics and potential calculation of an ecological and/or carbon footprint using input-output techniques was held at the University of Strathclyde on 11 March 2008. This workshop was commissioned by the Scottish Environment Protection Agency (SEPA) from Dr Karen Turner at the Fraser of Allander Institute, Department of Economics, University of Strathclyde, as part of the ongoing activity by the Scottish Government's Steering Group on Additional Measures of Progress to identify appropriate indicators of the sustainability of economic development in Scotland. The workshop focused specifically on what are referred to as 'consumption-based' indicators of sustainability and the importance of emissions and/or resource use embodied in local economic transactions and in interregional and international trade. In particular, it aimed to initiate discussion on what would be involved in the accurate and transparent measurement of consumption-based indicators such as ecological or carbon footprints for Scotland, drawing on developments in the academic literature. As explained in Section 1 of this report, the key development in the academic literature has been the application of input-output techniques to accounting for emissions and/or resource use. Therefore, the aim of the workshop was to consider how Scotland's existing strength in terms of input-output accounting for the economy can and should be developed to examine the environmental impacts of economic behaviour, in particular the use of input-output techniques in the attribution of emissions and resource use to producers and users as well as the identification of 'environmental trade balances' in informing climate change mitigation policies.

In terms of the proposal that an economic-environment input-output accounting infrastructure should be developed for Scotland, workshop participants identified three key benefits:

- Environmental input-analysis would facilitate decomposition of overall footprint indicators – i.e. using input-output multiplier analysis to examine the extent to which different activities contribute to the aggregate footprint measurement.
- If an appropriate economic-environmental model can be built around the input-output accounting framework to permit impact analysis of alternative policy options, this will add to the analytical support available to policymakers.
- Uses of an environmental input-output accounting framework are not limited to footprint calculations. Such a framework would facilitate the construction of a wide range of environmental indicators. Therefore, it is likely to represent 'good value for money' to policymakers.

The presentations and discussions at the workshop suggest a consensus that adopting IO techniques to examine a range of measures under different accounting principles would constitute an appropriate, rigorous and transparent approach. However, input-output accounting is resource intensive. Therefore, further consultation is required in order to identify how the greatest value-added can be achieved in terms of current policy concerns and objectives, within the constraints of the availability and resource implications of appropriate input-output data.

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#### A. List of Workshop Participants

#### B. Presentation Slides

Introduction and background – Dr Karen Turner, Fraser of Allander Institute, Department of Economics, University of Strathclyde

Using economic-environmental modeling for Wales: applications and issues – Professor Max Munday, WERU and BRASS, Cardiff Business School

Adopting an input-output approach to estimate Scottish footprints – Dr Karen Turner, Fraser of Allander Institute, Department of Economics, University of Strathclyde.

## **1. Introduction/background: the importance of emissions and/or resource use embodied in local economic transactions and interregional and international trade, and the use of input-output techniques in the identification of 'environmental trade balances' in informing climate change mitigation policies**

In recognition of the problem of climate change an international agreement was reached in 1997 in Kyoto on reducing greenhouse gas emissions, particularly CO<sub>2</sub>. However, ten years later a number of issues hindering the reduction of emissions have yet to be resolved. Major challenges still remain in securing the cooperation of all nations and effective (and efficient) collective action within and between nations. One crucial issue impacting on unilateral attempts to fulfil national emissions reductions targets under the Kyoto Protocol is the impact of international trade on any one country's domestic emissions generation. Under devolution of responsibility for sustainable development, Scotland is faced with the additional problem of contributing to UK national targets on emissions generation while engaging in trade both with other UK regions and with the rest of the world.

The problem for open economies attempting to meet national/regional targets for emissions reductions is that the generation of emissions in producing goods and services to meet export demand is charged to the producing nation or region's emissions account. This mirrors concerns over the impact any one country/region has on emissions elsewhere as a result of its consumption decisions. Munksgaard and Pedersen (2001) highlight this issue, and distinguish between a 'production accounting principle' and a 'consumption accounting principle'. The former focuses on emissions produced within the geographical boundaries of the national/regional economy. This is what is accounted for, and what individual national governments are responsible for reducing, under the Kyoto Protocol. In contrast, the latter focuses on emissions produced globally to meet consumption demand within the national or regional economy. This is what increasingly popular measures such as ecological and carbon footprints attempt to measure, and what many people regard as more appropriate, given that human consumption decisions are commonly considered to lie at the heart of the climate change problem (though, note from the discussion above regarding exports and domestic emissions generation, that concerns under the production and consumption accounting principles are interrelated). In a closed economy, with no trade in goods and services, emissions accounts constructed under the production and consumption accounting principles would, by definition, be equal. However, where there is trade, and pollution is embodied in that trade through emissions generated in one region or nation to meet consumption demand in another, these need not be equal.

In recognition of this point, an extensive discussion on the allocation of greenhouse gas emissions is conducted in the literature (e.g. Wyckoff and Roop, 1994; Kondo et al., 1998; Munksgaard and Pedersen, 2001; Ferng, 2003; Bastianoni et al., 2004; Sánchez-Chóliz and Duarte, 2004; Mongelli et al., 2006; Hoekstra and Janssen, 2006). In parallel to this discussion there is a development of models and accounting techniques that are able to account for pollution embodied in trade, and this has mainly involved the use of input-output analyses. For example, Munksgaard and Pedersen (2001) identify a foreign 'trade balance' in pollution as the difference between total emissions estimated on the basis of the production and consumption accounting principles, or more simply, the difference between the pollution embodied in exports and the pollution embodied in imports. They use input-output techniques to distinguish between emissions under the consumption and production accounting principles and, in turn, to estimate a CO<sub>2</sub> trade balance for Denmark. Particularly in the ecological footprint literature, where focus is on accounting for emissions under the consumption accounting principle, input-output analysis has become increasingly common in the academic literature as a technique to measure and allocate responsibility for emissions generation (see Wiedmann et al., 2007a, for a review). As explained by Turner et al. (2007b) this would seem a natural development, given that the focus of Ecological and Carbon Footprints is to capture the *total* (direct plus indirect) resource use and/or carbon generation embodied in final consumption in an economy. Input-output analysis is based around a set of sectorally disaggregated economic accounts, where inputs to each industrial sector, and the subsequent uses of the output of those sectors, are separately identified. Therefore, by the use of straightforward mathematical routines, the interdependence of different activities can be quantified,

and all direct, indirect and, where appropriate, induced, resource use and/or emissions generation embodied within consumption can be tracked (Leontief, 1970, Miller and Blair, 1985). Turner et al. (2007b) go on to derive a multi-region input-output method that is appropriate for accounting for emissions under the production and consumption accounting principles and determining environmental trade balances.

## **2. Motivation and objectives: issues for the practical application of input-output techniques in accounting for the environmental impacts of the Scottish economy under different accounting principles**

The Scottish Environment Protection Agency (SEPA) commissioned the workshop that is the subject of this report (held at the University of Strathclyde on 11 March 2008) as part of the ongoing activity by the Scottish Government's Steering Group on Additional Measures of Progress to identify appropriate indicators of the sustainability of economic development for Scotland. Since the summer of 2006, this group has engaged in activities first to consider issues associated with composite/aggregate indicators of sustainability (resulting in a discussion paper by Turner et al (2007a) and published by the Office of the Chief Economic Adviser, OCEA); then to consider the types of indicators required for Scotland; to identify what gaps exist in Scotland's current indicator set; to identify potential candidate indicators; and to investigate measurement and data availability issues

This latter point was the focus of the workshop. There is already an intention on the part of the Scottish Government to commission a second ecological footprint for Scotland, and there is increasing interest in Scotland, the UK and internationally in consumption-based measures of the global resource and/or pollution implications of economic activity at the local level. Therefore, the purpose of the workshop was to initiate discussion on what would be involved in the accurate and transparent measurement of consumption-based indicators for Scotland, drawing on developments in the academic literature. As explained above, the key development in the academic literature has been the application of input-output techniques to accounting for emissions and/or resource use under different accounting principles. However, while the multi-region input-output approach to accounting for emissions generation and other environmental impacts within countries, as well as emissions/resource use embodied in trade flows seems to have become accepted in the academic community, it has not yet become common-place in the wider policy and consulting arena. This is most likely in part due to issues of data availability and a lack of policy case studies, but also because developments in the academic literature have only occurred very recently. Therefore, the objectives of this workshop were as follows:

1. To communicate developments in the academic literature in non-technical language to an audience of invited delegates from the policy and wider stakeholder community;
2. To offer practical advice in terms of the application of input-output techniques in the calculation of Ecological and/or Carbon Footprints for Scotland;
3. To initiate a dialogue on meeting the information/data requirements of accounting for implications of Scottish economic activity on the local and global environments.

A list of participants in the workshops is given in Appendix A of this report. Sections 3 and 4 provide an overview of the presentations made and discussion among participants. Section 5 offers some conclusions and recommendations resulting from the workshop.

## **3. Report on Workshop Session 1: Welsh case study**

Professor Max Munday from Cardiff University, and representing the ESRC-funded Centre for Business Relationships, Accountability, Sustainability and Society (BRASS) and Welsh Economic Research Unit (WERU), was invited to give a presentation on the use of economic-environmental accounting and modelling in Wales, where the ecological footprint is already one of the Welsh Assembly Government's headline indicators of sustainable development. Professor Munday's slides are included in Appendix B of this report.

Professor Munday's presentation highlighted the crucial contribution that input-output (IO) accounting can make to economic-environmental analyses in general. The presentation also highlighted Scotland's very strong starting position in this respect. The Scottish Government IO team has access to the same underlying data used by National Statistics to construct the UK IO accounts, and sponsors a boosted sample of the Annual Business Enquiry. In contrast to the UK, however, the analytical IO tables required to conduct the type of 'multiplier' analysis used in footprint measures, are produced annually for Scotland. In the case of Wales, analytical tables are also constructed, but on an independent basis, by the WERU team at Cardiff University, without access to the ONS database. Where Wales does have an advantage over Scotland is the availability of environmental satellite accounts (using regionally derived sectoral emissions data provided by AEA Technology) to augment the economic accounts (see Jones et al, 2006). However, Professor Munday noted that the environmental component of the Welsh accounts is only in pilot form and stressed the need for dedicated and ongoing investment of resources in economic-environmental accounting if responsibilities and objectives exist with respect to sustainable development.

The presentation went on to outline applications of the Welsh environmental IO framework to date, generally focussing on the direct and indirect volumes of given pollutants generated by changes in final demands arising from tourist behaviour, sporting events etc. However, it also noted that there has only been limited interest from policymakers. Moreover, the Welsh IO accounts have not actually been used in ecological footprint calculations to date.

In terms of ecological footprint analysis in particular, Professor Munday commented that it is not clear why this indicator has been selected and developed for Wales, but, now that it has, a commitment is required for estimation at regular intervals. He also pointed to the lack of standardisation of ecological footprint calculations around the world to date and other practical problems that support the case for establishing an accounting infrastructure based around an IO approach. Such an approach will allow (as argued by Turner et al, 2007b) more consistent and transparent measurement. Use of an IO approach would also allow examination of a range of estimates for footprints and acknowledgement of a margin of error (as in GDP accounting) rather than the point estimates reported in current footprint measures.

The discussion following Professor Munday's presentation began with the question as to whether footprint measures purely provide context to the sustainability debate, or whether policy can be used to change the value of footprints and, if so, whether such changes could be tracked and explained (using an appropriate economic-environmental model developed around the IO accounting framework).

A number of interesting points/questions worthy of further consideration were raised:

- How far would politicians be willing to take account of footprint indicators against other policy objectives, and, with so many potential indicators available, under what circumstances would footprints be used for decision-making?
- If the answer is negative - why are ecological footprint measures being commissioned?
- Is it because ecological footprints are unlikely to change much? (In contrast to measures such as the Index of Sustainable Economic Welfare (ISEW) or Genuine Savings Indicator (GSI), which tend to give a worsening picture over time/as economic activity increases?)
- If we distinguish carbon rather than ecological footprints, are we likely to see more changes over time, be able to trace changes back to specific behaviours?

The workshop participants seemed to agree that this discussion raises important issues in terms of:

- What do we want indicators for?
- Do different people get different stories from the same indicator?

- Can we use a modelling framework built around IO to assess alternative policy options to achieve a given objective by modelling the impacts of different options on the footprint and other economic and environmental indicators?
- Can we identify strong, robust indicators that can be used to assist the work of agencies such as SEPA on a daily basis?
- Are footprints actually appropriate indicators on this basis?

In terms of the role of IO, participants noted two key roles:

- To facilitate decomposition of overall footprint indicators – i.e. using IO multiplier analysis to examine the extent to which different activities contribute to the aggregate footprint measurement.
- If an appropriate model can be built around the IO framework to permit impact analysis of alternative policy options, this will add to the analytical support available to policymakers.

#### 4. Report on Workshop Session 2: A way forward for Scotland?

This presentation focussed on explaining how IO analysis can be used in the calculation of different production and consumption based measures of pollution generation and resource use (see Section 1 above). However, there are a number of stages to consider before we get to a full footprint analysis, which is extremely data-intensive, and implies a particular perspective on responsibility for pollution generation and/or resource use. Therefore, the presentation identified developments that may be appropriate for the case of Scotland.

##### *First requirement – Scottish environmental accounts and/or NAMEA framework*

The presentation argued that, in order to carry out any economic-environmental analysis for Scotland, an accounting framework that reports economic and environmental variables in a consistent and compatible format is required. The statistical agency of the European Union, Eurostat, recommends that member states construct a National Accounting Matrix including Environmental Accounts (NAMEA), which consists of sectorally disaggregated economic accounts (in IO format) augmented with physical data on emissions and/or resource use for each production and final consumption sector (see Keuning and Steenge, 1999, and Vaze, 1999, for a UK application).

A Scottish case study of the NAMEA framework has been previously carried out (Turner, 2003), as a contribution to the work of the Scottish Environmental Accounts Working Group (SEAWG). SEAWG was set up by the (then) Scottish Executive, and investigated a number of key issues, such as over-aggregation of some environmentally important sectors (such as electricity production and distribution) in the economic IO accounts, and the need for region-specific data for key activities (see also Turner, 2006), but has not met since 2004. Dr Turner recommended that a crucial step for Scotland is the re-establishment of SEAWG, or some appropriate variant. Moreover this should be a sustainable network development, to ensure regular monitoring of informational needs to provide an appropriate accounting infrastructure and analytical support for policymakers who are responsible for delivering on sustainable development objectives.

##### *Environmental IO multiplier analysis*

The presentation then went on to demonstrate that if the current regular reporting of the Scottish analytical IO framework can be extended with a set of environmental satellite accounts it will be possible to conduct single region environmental IO multiplier analyses. The most straightforward application would be the type of 'attribution to end user' attempted previously for Scotland by McGregor et al (2001).

However, in a single region framework, attribution of local emissions to end user has two important implications/limitations:

1. A share of emissions is allocated to external (export) demand.
2. No account is taken of emissions embodied in imports.

As explained in Section 1 above, point (1) has implications in terms of meeting regional/national targets for domestic emissions reductions, and point (2) in terms of concerns over 'importing sustainability'. Both concerns are reflected in the consideration of environmental trade balances, as the difference between the pollution (or resource use) embodied in exports and that embodied in imports. Again, as explained in Section 1, as with the trade balance in goods and services, the environmental trade balance relationship for any economy can be examined using an appropriately augmented IO framework, where it is possible to distinguish between what Munksgaard and Pedersen (2001) term the production and consumption accounting principles. Dr Turner's presentation demonstrated that, with an appropriate IO accounting framework, it is possible to examine a mix of accounting principles depending on the policy concern under consideration. As an example, the presentation included an overview of results from McGregor et al's (2007) interregional IO analysis of the CO<sub>2</sub> trade balance between Scotland and the rest of the UK, where emissions embodied in intra-UK trade are treated under the consumption accounting principle but the system is closed at the national (UK) level under the production accounting principle in order to reflect policy objectives under the Kyoto Protocol.

The McGregor et al (2007) study is a limited empirical application of the multi-region input-output (MRIO) method of accounting for pollution trade balances proposed by Turner et al. (2007). It uses experimental inter-regional trade data for 1999 supplied by the Scottish Government's input-output (IO) team. It is important to note this particular application embodies a particular theoretical and policy perspective. However, if a more reliable interregional IO framework were developed for the UK, it would be possible to investigate the attribution of carbon emissions systematically under a range of alternative theoretical and policy perspectives and combinations of the consumption and production accounting principles. Whether or not such a framework could be extended to estimate footprint measures that take account of the *global* impact of Scottish consumption behaviour will depend on data availability and what assumptions we are prepared to make with respect to trade with the rest of the world (ROW).

For example, due to a lack of data on actual emissions embodied in external trade flows, Druckman et al (2007) adopts what is known as the 'domestic technology assumption' in accounting for the emissions content of imports. That is, they assume that goods imported from (ROW) are produced using UK technology. While this will not result in an accurate footprint measure (which, as explained in the presentation, would ultimately require a *world* interregional environmental IO account), it does allow consideration of what the impact of UK consumption would be if there were no trade and the UK had to produce all the goods and services required for consumption domestically. This relates directly to concerns over 'importing sustainability'. A similar accounting exercise could be carried out for Scotland in terms of trade with other UK regions as well as external transactors.

The slides for Dr Turner's presentation can be found in Appendix B.

The discussion following Dr Turner's presentation focussed on the potential usefulness of developing the Scottish IO accounting infrastructure to facilitate alternative applications of environmental IO multiplier analysis. Again, a number of interesting points/questions worthy of further consideration were raised:

- It was argued that while the development of the IO framework is resource-intensive, if we have faith in market-based solutions to the problem of climate change, we absolutely need to adopt an IO approach.
- Uses of an environmental IO approach are not limited to footprint calculations. It would facilitate the construction of a wide range of environmental indicators. Therefore, it is likely to represent 'good value for money' to policymakers.
- IO analysis would allow us to develop a better understanding of domestic and direct emissions generation as well as the indirect effects that can be measured through multiplier analysis. Therefore, it would allow us to investigate how Scottish and/or UK direct emissions generation (as accounted for under the type of emissions inventory approach

used in the UK environmental accounts) sit within the wider footprint picture. For example, it would be possible to separate domestic emissions attributable to local and external demands, and to consider the relative importance of emissions that may be attributable to imports under different assumptions regarding technology.

- If, as expected by some participants, the Scottish Climate Change Bill focuses on the consumption accounting principle, it will be necessary to explicitly consider the treatment of emissions embodied in imports and the implications in terms of data requirements.

The discussion closed by noting that, as in the case of Wales, there has not yet been a crossover in terms of using even currently available regional IO data in footprint calculations. For example, the Stockholm Environment Institute (SEI), who were commissioned to estimate the Welsh footprint for 2001, used a Welsh IO table that was mechanically generated from the UK IO table, rather than using the Welsh-specific table produced by WERU. It was also noted that the first Scottish footprint (commissioned from Best Foot Forward) did not make use of the Scottish IO tables.

## 5. Workshop conclusions and recommendations

The presentations and discussions at the workshop suggest a consensus that adopting environmental IO techniques to examine a range of measures under consumption and production accounting principles would constitute an appropriate, rigorous and transparent approach. However, IO accounting is resource intensive. Therefore, further consultation is required in order to identify how the greatest value-added can be achieved in terms of current policy concerns and objectives, within the constraints of the availability and resource implications of appropriate input-output data. It would seem, however, that a minimum requirement for analysis of any economic-environmental issues is to build on the strong foundation that Scotland already has with the current economic IO framework to develop an environmentally augmented analytical IO account (a Scottish NAMEA). The next recommended step will be to consider whether resources should be invested to strengthen the current experimental interregional IO trade data produced by the Scottish Government IO team in order to allow more accurate and disaggregated variants of the environmental trade balance analysis already attempted by McGregor et al (2007). However, the success of such an exercise would be dependent on whether investment were made at the UK level in improving the national IO accounting infrastructure (in particular, the absence of a UK IO table in analytical form since 1995 – see Druckman et al, 2007, and McGregor et al, 2007).

If full carbon and/or ecological footprint measures are required for Scotland, decisions will also have to be made in terms of the treatment of trade with the rest of the world. Assumptions can be made to overcome the lack of an appropriate world interregional IO accounting framework (see Turner et al, 2007b and Druckman et al 2007); however, it is important that these are made in a transparent manner.

Finally, sustainable networks will be required to oversee the development of an accounting and analytical support infrastructure. Capacity already exists in this respect, with the Scottish Government's IO Expert User Group (organised by the Office of the Chief Economic Adviser) and Steering Group on Additional Measures of Progress. However, it is recommended that some variant of the previous Scottish Environmental Accounts Working Group be put in place in order to bring together appropriate experts and stakeholders to consider the specific requirements for an economic-environmental accounting infrastructure. In terms of developing a sustainable carbon accounting programme for Scotland, it is recommended that this report be put forward to the Scottish Carbon Counting Group, which is due to meet for the first time at the Scottish Parliament on 8<sup>th</sup> April 2008. It is also recommended that this report be made available to the Scottish Government Steering Group on Additional Measures of Progress in time for their next meeting; and to the Scottish Government IO Expert User Group at its next meeting on the 10<sup>th</sup> of April 2008.

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## Appendix A

### Workshop on Economy-Environment Statistics and Potential Calculation of an Ecological and/ or Carbon Footprints Using Input-Output Techniques

SPONSORED BY THE SCOTTISH ENVIRONMENTAL PROTECTION  
AGENCY (SEPA)

#### List of Participants

##### Hosts

Energy Modelling Team, Fraser of Allander Institute, Department of Economics, University of Strathclyde	Grant Allan Janine De Fence Michelle Gilmartin Dr Karen Turner Professor Kim Swales
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##### Participants

AEA Technology	Justin Goodwin
Experian	Eric McVittie
Greener Scotland Directorate, The Scottish Government	Tom Davy
OCEA, The Scottish Government	Donna Hosie Jan Young
RERAD, The Scottish Government	Jonathan Dennis Dr Kathy Johnston John Landrock Helen Mansbridge Dr Claire Wainwright Susan Walker
Scottish Environmental Protection Agency, SEPA	Jean Le Roux Eric Mc Rory
Scottish Natural Heritage	Clive Mitchell
Stockholm Environment Institute	Kate Scott
WERU and BRASS, Cardiff Business School	Max Munday

##### Unable to Attend on Day of Workshop

DEFRA	Rocky Harris
University of Surrey	Angela Druckman Tim Jackson
WWF Scotland	Elizabeth Leighton

## Appendix B

Introduction and background – Dr Karen Turner, Fraser of Allander Institute, Department of Economics



**Workshop on economy-environment statistics and potential calculation of an ecological and/or carbon footprints using input-output techniques**

**SPONSORED BY THE SCOTTISH ENVIRONMENT PROTECTION AGENCY (SEPA)**

University of Strathclyde  
Tuesday 11 March 2008



### Background

- Scottish Government Steering Group on Additional Measures of Progress
  - Issues associated with composite/aggregate indicators of sustainability
  - What type of indicators are required for Scotland?
  - What gaps currently exist?
  - Identification of potential candidate indicators
  - Investigation of measurement issues for candidate indicators
- Scottish Environment Protection Agency (SEPA)
  - Small project commissioned from FAI, Department of Economics, University of Strathclyde
  - Focus on latter point for consumption-based measures, e.g. ecological and carbon footprints
  - Outcomes of workshop to be reported to SEPA and to Steering Group on Additional Measures of Progress



### Agenda

- 10.30-10.40am. Introduction and background – Karen Turner, Fraser of Allander Institute, Department of Economics, University of Strathclyde
- 10.40-11.05am. Using economic-environmental modelling for Wales: applications and issues - Max Munday, WERU and BRASS, Cardiff Business School
- 11.05-11.20am. Discussion (1)
  - How far can footprint measures be used to inform policy?
  - Is the footprint a contextual or influencable indicator?
- 11.20am-12pm. Adopting an input-output approach to estimate Scottish footprints – Karen Turner, University of Strathclyde
- 12-12.30pm. Discussion (2)
  - Developing an appropriate economy-environment database for Scotland?
  - Incorporating input-output accounting techniques in Scottish footprint and other indicators?
  - Practical data issues and collection when driving footprints for discrete activities and events?

- Using economic-environmental modeling for Wales: applications and issues – Professor Max Munday, WERU and BRASS, Cardiff Business School

**Using econo-environmental modelling in  
Wales: applications and issues**

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Max Munday



**Plan**

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- Context to ecological & carbon footprint work in Wales**
- Linked and supporting resources; brief review**
- Footprints: applications, outline discussion of merits and issues**
- Future research issues**

**Assessing Progress (Winning Wales?)**

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- A number of indicators but focus on employment and GDP targets
- GVA remains important indicator of Welsh progress (overall underlying target 90% of UK average)
- comparison with UK average
  - ignores activity outside the market process
  - ignore externalities created in production
  - ignores the distribution of income
- but also an SD legal duty
- ...and then alternatives also noted in strategy documents: ISEW/GPI and ecological footprint



## Assessing Progress (Winning Wales?)

- A number of indicators but focus on employment and GDP targets
- GVA remains important indicator of Welsh progress (overall underlying target 90% of UK average)
- comparison with UK average
  - ignores activity outside the market process
  - ignore externalities created in production
  - ignores the distribution of income
- but also an SD legal duty
- ...and then alternatives also noted in strategy documents: ISEW/GPI and ecological footprint



## WAG Headline SD Indicator Set

WAG headline indicator of SD – Issue	Indicator description (latest available data)
Employment	% of people of working age in work (68.1% in 2001)
Education	% of people age 19 with NVQ level 2 or equivalent (72% in 2000)
Crime	Crime rates per 100,000 population: <ul style="list-style-type: none"> <li>• Theft of or from vehicles (1,486 in 2000/01)</li> <li>• Burglary (414 in 2000/01)</li> <li>• Violent crime (1,390 in 2000/01)</li> </ul>
Housing	% of unfit dwellings (8.5% in 1998)
Climate Change	Emissions of greenhouse gases (mt carbon equivalent) (13.6 in 1999)
Air Quality	<ul style="list-style-type: none"> <li>• Days when air pollution is moderate or higher in selected urban (Cardiff, Swansea, Port Talbot) and rural (Aston Hill, Narberth) areas. In 2000 respectively 21, 33, 75, 27 and 21 days.</li> </ul>
River water quality	% of river lengths of good or fair quality: <ul style="list-style-type: none"> <li>• Chemical quality (98.6% in 2000)</li> <li>• Biological quality (98.3% in 2000)</li> </ul>
Wildlife	% of widespread breeding bird species that have increased significantly since 1994 (36% in 2000)
Waste	Household waste and amount recycled or composted (kg/person/year): <ul style="list-style-type: none"> <li>• Total household waste (479 in 1999-00)</li> <li>• Household waste recycled or composted (31 in 1999-00)</li> </ul>
Welsh language	% of people who can speak Welsh: <ul style="list-style-type: none"> <li>• Aged 3 or over (19% in 1991)</li> <li>• Children aged 3-14 (24% in 1991)</li> </ul>
Electricity from renewables	% of electricity produced in Wales generated from renewable sources (3.2% in 2000)
Ecological footprint	Wales's global ecological footprint in area units per person (5.38 in 2000)

## Legal Duty and Headline Indicators of Sustainability

Whilst these monitoring indicators are useful,

- mixed units of account
- what does SD mean in context of each of the indicators (is rapid employment growth a good or a bad)
- fail to deliver any overall picture of sustainability and welfare trends (the ecological footprint measure excepted?)
- difficult to link the indicators to the SD objectives of WAG.



## Issues

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- Overall tools and measures to assess progress towards 'sustainable economic development' objectives appear to be under-developed
- Some progress however....



## Supporting resources to explore econo-environmental linkages and effects?

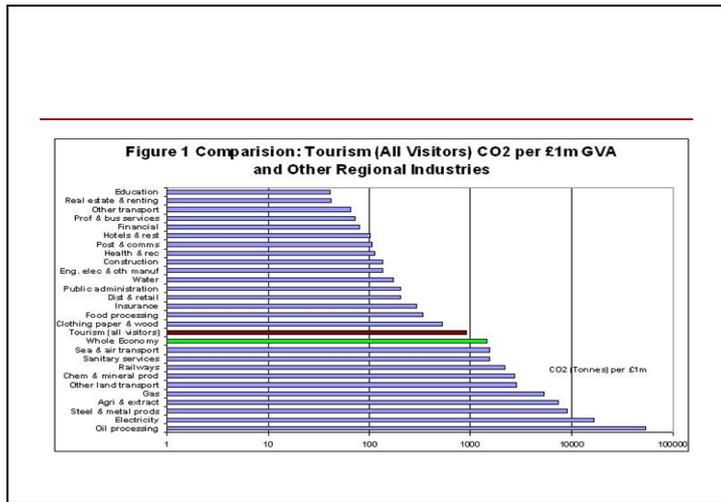
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- Wales Input-Output framework
- Environmental satellite accounts in pilot form
- Ecological footprint studies
- ISEW estimates 1990-2005 but heavily discounted!!

## Welsh input-output framework

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- Survey based, latest 2003, 74 sectors
- Environmental module – regionally derived data greenhouse gases, acid rain etc
- Environmental module used in conjunction with IO framework – direct and indirect volumes of given pollutants generated by changes in final demands
- Applications to date sports events and tourism, limited interest from policymakers



### Environmental Satellite Accounts

- UK Environmental Accounts – demands that economic activity places on the environment
- Natural resources – reserves, land cover etc.
- Physical flows, emissions, waste, water etc.
- Monetary – env. protection spending etc.
- Research by AEA Technology for the Environment Agency and partners has recently provided regional data etc.
- Partial ESA now available for Wales – physical flows/resource productivity
- Unknown whether pilot project to be taken forward

### Coverage of experimental ESA for Wales

•Natural resources                      •Physical flows                      •Monetary accounts

Table in UK ESA	Coverage for Wales
1.1 Oil & gas reserves	Partial
1.2 Oil & gas monetary balance sheet	Not available
1.3 Land cover account	Covered
1.4 Imports and exports of wood products	Covered
1.5 Fish stocks	Covered

Table in UK ESA	Coverage for Wales
2.1 Energy consumption (industries)	Covered
2.2 Atmospheric emissions (over time)	Covered
2.3. Atmospheric emissions (over time)	Covered
2.4 Bridging table: Atmospheric emissions	Not available (but not relevant)
2.5 Material flows	Partial
2.6 Waste arisings	Covered
2.7 Radioactive waste	Covered
2.8 Water consumption by industry sector	Covered

Table in UK ESA	Coverage for Wales
3.1 Government revenue from environmental taxes	Covered
3.2 Environmental taxes breakdown by industry	Partial
3.3 Environmental protection spending by public sector	Covered
3.4 Environmental protection spending by public sector	Covered
3.5 Environmental protection spending in industries	Not available

## Ecological Footprint Analysis

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Footprint derived for each study area by estimating the land areas necessary to support demand in the study area, for example, demands in terms of energy use, travel and freight transport, waster, water consumption etc. Measures environmental pressure. Weak sust. approach.

### Footprint (area units)

- Per capita EF 5.38ha per person in Wales
- Fair share 1.9ha per person

**Adopted by WAG**

## Evolution 1: Ecological footprint work

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- WWF/Best Foot Forward 2000 Pilot**
- SEI (2003) estimated Wales footprint for 2001**
- Sub-regional estimates for Cardiff & Gwynedd (SEI, Bangor and Cardiff University, BIFFA, Environment Agency)**
- 2007: WAG recently commissioned all Wales footprint (SEI) & institutional footprint (BFF)**

## Evolution 2: Ecological footprint work

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- FA Cup 2003-04**
- RBS Six Nations 2006 Wales vs Scotland**
- Hay Festival**
- School meals**
- Stepping up the Pace conference sponsored by ESRC BRASS Centre and WAG with support from GFN**



### Ministerial statement October 2007

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"Wales' ecological footprint is **5.25 global hectares per person** – the lowest of all the UK regions. But we are, as a nation, still using more than our fair share of the earth's resources. If everyone on the earth did the same as us, we would need another 2 planets to provide the resources that this would require. This over-consumption of resources affects environmental sustainability, long-term economic progress, and social justice. ....**The reduction of Wales' ecological footprint to sustainable levels** is therefore urgent and compelling.

As we develop policies to do this, it is important that we have a strong and robust evidence base. Wales' current footprint calculation is based on 2001 data and we have therefore commissioned experts to re-calculate this using the latest available data. This work will in addition explore some of the scenarios needed to reduce Wales' footprint by 10% by 2020".

### Ecological footprint discussion

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- Evolution and interest from Wales policymakers; why has it been adopted over and above other approaches?
- How does it measure up on core criteria that we use to examine alternative indicators of progress

## Criteria?

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- What do the approaches actually measure, and what perspective on sustainability is provided? (Weak/strong)**
- Usefulness of results for informing policy**  
Wales developing sustainably?  
Contextual Vs influencable?
- Transparency and clarity of approaches (a real issue with the footprint!)**
- Developmental costs and practicality of construction**
- Applicability of approaches to a wider regional constituency – firms, communities etc**

## Ecological footprint: Evaluation against criteria

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- One figure, and can be applied down to household level
- Very useful for raising awareness
- A contextual indicator – but does allow an identification of 'big hitters' and behaviours.
- Could assess progress through time/comparisons
- Limited evidence on real policy use to date in Wales or elsewhere, some still find it operationally difficult to relate estimates to what they do on the ground.
- Complex calculation of earth share; conversion of incomparable quantities into land areas.
- Data intensive (particularly for discrete events and activities).

## Future research issues for Wales

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- Support infrastructure**
- Footprint: standardisation of methods and reporting; improving transparency**
- If we are using IO in the estimation process, should we be using point estimates**
- SD duty justifies a set of environmental satellite accounts to support modelling work**

Adopting an input-output approach to estimate Scottish footprints – Dr Karen Turner, Fraser of Allander Institute, Department of Economics, University of Strathclyde.



## Adopting an input-output approach to estimate Scottish footprints

Karen Turner  
Department of Economics and Fraser of Allander Institute  
University of Strathclyde



## Overview

- Why an input-output approach?
- Scottish environmental IO accounts/NAMEA
- Single region IO analysis
- Exports, imports and environmental trade balances
- Production and consumption based accounting principles
- Interregional environmental input-output analysis for the UK
- Accounting for emissions/resource use embodied in trade
- Trade with the rest of the world - options
- Conclusions and recommendations



## Why an input-output approach?

- Key: accounting for total (direct and indirect) resource use/emissions embodied in final consumption
- IO multiplier analysis
- Footprint literature (principally *Ecological Economics*)
  - Increasing use and acceptance of IO techniques as appropriate approach for calculating footprint measures
  - Applications reviewed by Wiedmann et al, 2007
  - Main problem area - data
  - Lack of transparency in assumptions etc
  - Full statement of IO method for footprint calculations in Turner et al 2007
- Production and consumption accounting principles: Munksgaard and Pedersen, 2001
- IO appropriate for both, and range of measures in between

1998 Scottish IO - 3-sector Icd										
	Purchases by Sector Group (at basic prices)				Sales to ID	Final consumption expenditure:			Total Final Demand	Gross output (Total Demand)
	Manufacturing	Non-Mfr Traded	Non-Mfr Sheltered	Sheltered		Local	Capital	External		
Manufacturing	3187.587	3896.852	775.760	7860.199	1545.663	387.604	28069.696	30002.963	37863.162	
Non-Manufacturing Traded	6072.304	18391.215	4726.423	28889.942	16506.298	5383.338	17609.990	39499.626	66389.568	
Non-Manufacturing Sheltered	838.063	4669.769	5302.514	10810.346	20578.096	400.537	292.252	21270.885	33081.231	
<b>Total Intermediate Inputs</b>	<b>10097.955</b>	<b>26657.837</b>	<b>10804.696</b>	<b>47560.488</b>	<b>38630.057</b>	<b>6171.479</b>	<b>45971.938</b>	<b>90773.474</b>	<b>138333.962</b>	
Imports	13797.331	8496.241	3125.215	25418.787	17585.074	5024.481	363.471	22973.027	48391.813	
Net product & production taxes	1314.857	2671.122	754.917	4740.897	3457.135	588.111	1988.153	6033.399	10774.296	
Income from Employment	7076.821	19904.991	11414.186	38395.998	0.000	0.000	0.000	0.000	38395.998	
Other Value Added	5576.205	10659.378	5982.205	22217.789	0.000	0.000	0.000	0.000	22217.789	
<b>Total Primary Inputs</b>	<b>27765.214</b>	<b>41731.733</b>	<b>21276.522</b>	<b>90773.470</b>	<b>21042.210</b>	<b>5612.593</b>	<b>2351.624</b>	<b>29006.426</b>	<b>119779.896</b>	
<b>TOTAL INPUTS</b>	<b>37863.169</b>	<b>66389.570</b>	<b>33081.219</b>	<b>138333.957</b>	<b>59672.267</b>	<b>11784.071</b>	<b>48323.562</b>	<b>119779.900</b>	<b>258113.858</b>	
Total employment (000 FTE)	346.144	1109.426	573.930							
Employment-output coefficients (tVE/m)	0.009	0.016	0.018							

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## Papers cited above:

- Munksgaard, J. and Pedersen, K.A., 2001. CO2 accounts for open economies: producer or consumer responsibility? *Energy Policy*, 29:327-334
- Turner, K., Lenzen, M., Wiedmann, T. and Barrett, J., 2007. Examining the Global Environmental of Regional Consumption Activities – Part 1: A Technical Note on Combining Input-Output and Ecological Footprint Analysis, *Ecological Economics*, 62(1): 37-44.
- Wiedmann, T., Lenzen, M., Barrett, J. and Turner, K., 2007. Examining the Global Environmental Impact of Regional Consumption Activities – Part 2: Review of input-output models for the assessment of environmental impacts embodied in trade, *Ecological Economics*, 61(1): 15-26.

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Total employment (000 FTE)	346.144	1109.426	573.930							
Employment-output coefficients (tVE/m)	0.009	0.016	0.018							

## First requirement – Scottish environmental IO accounts and/or NAMEA framework

### Eurostat – National Accounting Matrix including Environmental Accounts

- Sectoral economic accounts (IO) augmented with physical data on emissions and/or resource use for each production and final consumption sector
- Special issue of *Structural Change and Economic Dynamics* (intro by Keuning and Steenge, 1999, UK application by Vaze, 1999)
- Economic and environmental data reported in a *consistent and compatible format* (Turner, 2003)

### Issues identified in Scottish case study (Turner, 2003) for Scottish Environmental Accounts Working Group (drawing on Salway et al, 2001):

- Importance of region-specific data (also Turner, 2006)
- Bottom-up vs top-down emissions estimates
- Issues of degree of sectoral breakdown in economic accounts

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### Papers cited above:

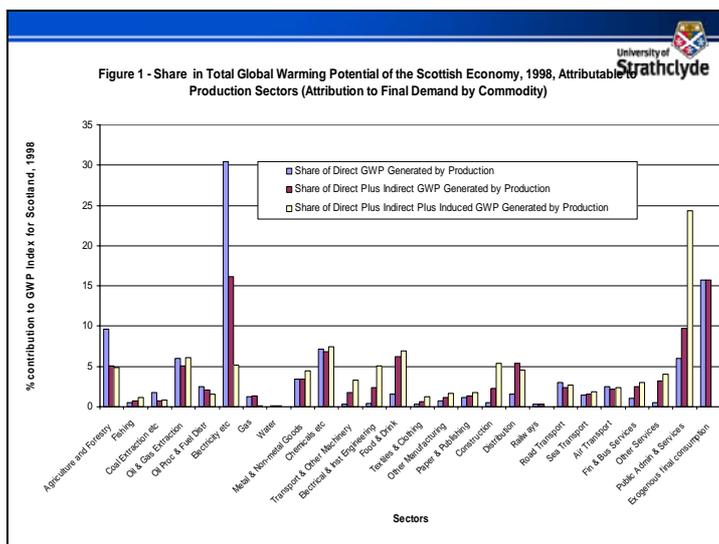
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- Turner, K. (2003) 'A pilot study on constructing a Scottish sectoral CO<sub>2</sub> emissions account', *Quarterly Economic Commentary* (Fraser of Allander Institute, University of Strathclyde), Vol. 28, No.3.
- Salway, A.G., T.P. Murrells, S. Pye, J. Watterson and R. Milne (2001) 'Greenhouse Gas Inventories for England, Scotland, Wales and Northern Ireland: 1990, 1995, 1998 and 1999', report by AEA Technology.
- Turner, K. (2006) 'The Additional Precision Provided by Regional-Specific Data: The Identification of Fuel-Use and Pollution Generation Coefficients in the Jersey Economy', *Regional Studies*, Vol. 40, No. 4, pp347-364.

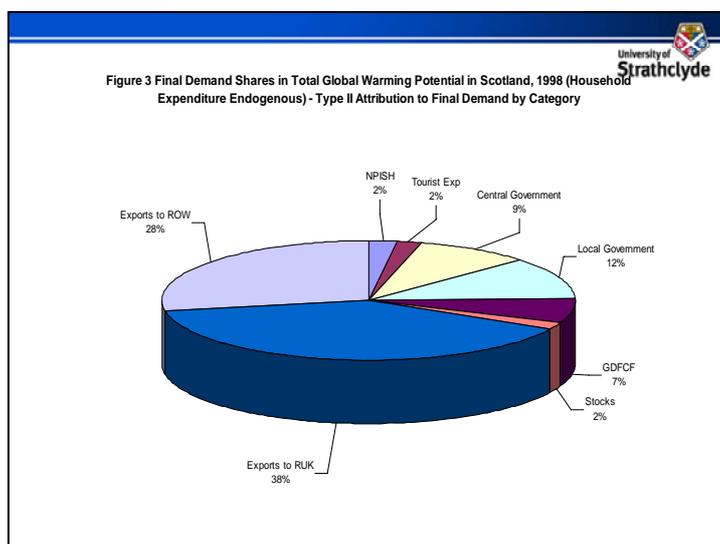
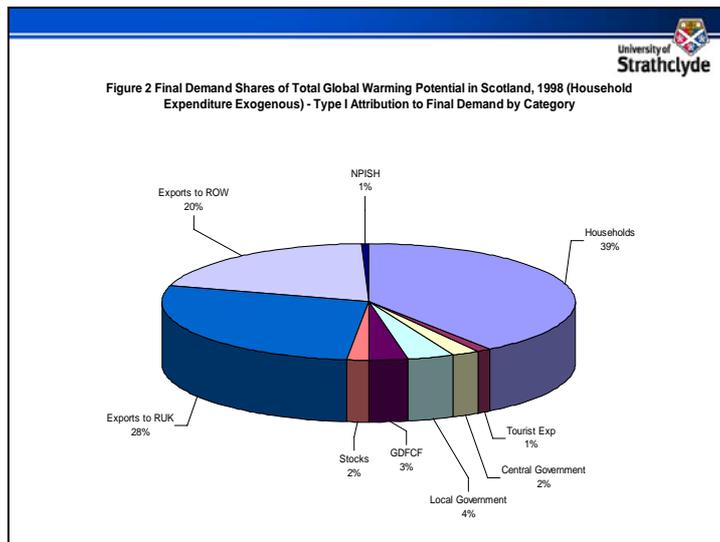
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### Environmental IO multiplier analysis

Additional requirements:

- Analytical environmental IO
  - Symmetric tables (IxI or CxC), basic/producer prices
  - Distinction Analytical and SUT
  - E.g. UK: regular economic-environmental accounts, but no IO in analytical format since 1995, and no analytical envi IO since 1993 (Vaze, 1997).
  - Scotland: regular analytical IO, but no environmental component
- Basic theoretical framework: Leontief (1970)
- With sufficient sectoral disaggregation of economic accounts, and corresponding physical envl/resource data, single region analytical IO applications:
  - Resource implications of cleaning/disposal activities (e.g. Allan et al, 2007)
  - Attribution of local emissions to end user (e.g.McGregor et al, 2001)





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### Papers cited above:

- Vaze, P. (1997) 'Environmental input-output tables for the United Kingdom', *Economic Trends*, No. 527, October 1997.
- Leontief, W. (1970) 'Environmental repercussions and the economic structure: an input-output approach', *Review of Economic Statistics*, Vol.52, pp.262-277.
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- McGregor, P.G., McNicoll, I.H., Swales, J.K. and Turner, K.R. (2001) 'Who pollutes in Scotland? A prelude to an analysis of sustainability policies in a devolved context', *Quarterly Economic Commentary* (Fraser of Allander Institute, University of Strathclyde), Vol.26, No.3.

### Exports, imports and environmental trade balances

- Attribution of local emissions to end user
  - Share of emissions allocated to (external) export demand
  - No account taken of emissions embodied in imports
- Emissions allocated to export demand
  - Implications for meeting regional/national targets for domestic emissions reductions
- Emissions embodied in imports
  - Impacts of local consumption decisions on other countries/global environment
- Environmental trade balances
  - E.g. Equity of Scotland's contribution to UK emissions reductions targets? Important part of devolution settlement? (McGregor et al, 2007)

### Production and consumption based accounting principles

- Production accounting principle
  - Focus on emissions produced within the geographical boundaries of the national economy
  - What is accounted for, and what individual national governments are responsible for reducing, under the Kyoto Protocol.
- Consumption accounting principle
  - Focuses on emissions produced globally to meet consumption demand within the national (or regional) economy.
  - What ecological or carbon footprints attempt to measure
- Environmental or pollution trade balance
  - Difference between total emissions estimated on the basis of the production and consumption accounting principles
  - Or, put more simply, the difference between the pollution embodied in exports and the pollution embodied in imports

### Measurement under production and/or consumption based accounting principles

- Emissions under both accounting principles can be measured using analytical IO framework
- Munksgaard and Pedersen (2001) show equivalence for closed economy
- Can have mix of accounting principles
  - E.g. McGregor et al (2007) application for Scotland and the rest of the UK (RUK)
  - Interregional UK trade accounted for under consumption accounting principle
  - National UK emissions accounted for under production accounting principle (e.g. if policy focus on commitment under Kyoto)
  - 'Trade Engogenised Linear Attribution System' (TELAS)
  - McGregor, P.G., Swales, J.K. and Turner, K.R. (2007) 'Performing a multi-region environmental input-output analysis with limited data: the CO2 trade balance between Scotland and the rest of the UK', *Ecological Economics*, doi:10.1016/j.ecolecon.2007.11.001.

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### Scot-RUK interregional IO analysis – sectoral emissions under production accounting principle (McGregor et al, 2007)

**Table 3. Direct CO2 Emissions Generated in UK, RUK and Scotland in 1999**

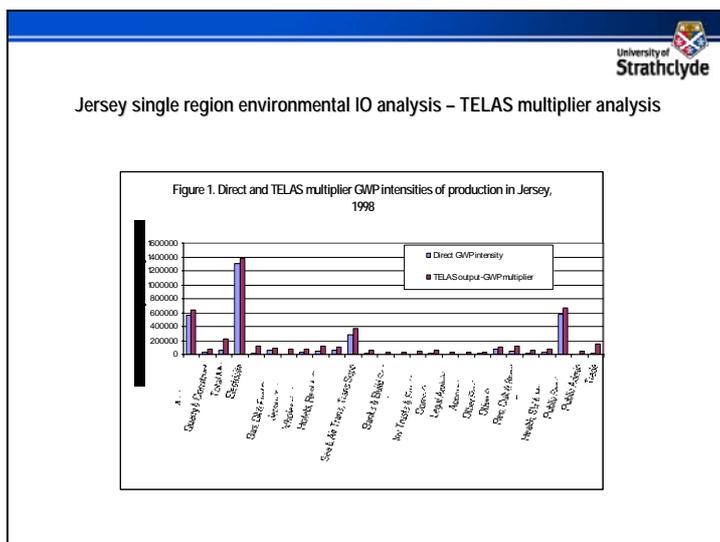
Sector	Region	Tonnes, millions, of direct CO2 emissions		
		UK	RUK	Scotland
PRIMARY		30.9	27.0	3.9
MANUFACTURING		122.5	114.4	8.0
ELEC. GAS & WATER SUPPLY		145.0	128.7	16.3
CONSTRUCTION		4.4	4.0	0.4
WHOLESALE & RETAIL TRADE		14.0	13.1	0.9
TRANSPORT & COMMUNICATION		68.9	63.3	5.6
FINANCIAL INT & BUSINESS		12.8	12.0	0.9
PUBLIC ADMINISTRATION		8.3	7.9	1.0
EDUC. HEALTH & SOCIAL WORK		10.8	10.0	0.8
OTHER SERVICES		2.9	2.7	0.2
HOUSEHOLD FINAL CONSUMPTION		143.0	132.3	10.7
TOTAL		564.3	515.4	48.9
Direct contribution to UK emissions		100%	91.33%	8.67%

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### Scot-RUK interregional IO analysis – Type I IO analysis of CO2 trade balance (McGregor et al, 2007)

**Table 4. The CO2 Trade Balance Between Scotland and RUK (tonnes, millions) - Type I Input-Output**

Pollution generated in:	Pollution supported by:								Total regional emissions of CO2
	Scottish HH	Scottish Govt	Scottish Capital	Scot-ROW	RUK HH	RUK Govt	RUK Capital	RUK-ROW	
Scotland	21.3 (43.6%)	3.6 (7.4%)	1.4 (2.9%)	8.8 (18%)	9.1 (18.6%)	0.9 (1.8%)	1.5 (3.1%)	23 (4.7%)	48.9 (100%)
RUK	7.1 (1.4%)	1.7 (3.3%)	2.3 (4.6%)	3.1 (6.7%)	332.5 (64.5%)	33 (6.4%)	33 (6.4%)	102.7 (19.9%)	515.4 (100%)
Total (UK) emissions supported by	28.4 (5%)	5.3 (1.0%)	3.7 (0.7%)	11.9 (2.1%)	341.6 (60.5%)	33.9 (6%)	34.5 (6.1%)	105 (18.6%)	564.3 (100%)
Environmental trade balance:									
Scot pollution supported by RUK final demand	13.8	(-9.1+0.9+1.5+2.3)							
RUK pollution supported by Scot final demand	14.2	(-7.1+1.7+2.3+3.1)							
Scotland's CO2 trade surplus	-0.4								



  
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**Scot-RUK interregional IO analysis – IO analysis of CO<sub>2</sub> trade balance,  
combined production and consumption accounting principles  
(McGregor et al, 2007)**

**Table 5. The CO<sub>2</sub> Trade Balance Between Scotland and RUK (tonnes, millions) - IO TELAS**

	Pollution supported by:				Total regional emissions of CO <sub>2</sub>
	Scottish HH	Scottish Govt	RUK HH	RUK gov't	
Pollution generated in:					
Scotland	22.7 (46.5%)	3.9 (7.9%)	<b>19.7 (40.2%)</b>	<b>2.7 (5.4%)</b>	48.9 (100%)
RUK	<b>16.9 (3.3%)</b>	<b>3.3 (0.6%)</b>	443.7 (86.1%)	51.4 (10%)	515.4 (100%)
Total (UK) emissions supported by:	39.6 (7%)	7.2 (1.3%)	463.4 (82.1%)	54.1 (9.6%)	564.3 (100%)
Environmental trade balance:					
Scot pollution supported by RUK final demand	<b>22.3</b>	(=19.7+2.7)			
RUK pollution supported by Scottish final demand	<b>20.2</b>	(=16.9+3.3)			
Scotland's CO <sub>2</sub> trade surplus	2.1				

  
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### Accounting for emissions/resource use embodied in trade

- Need imports broken down by commodity
- Need information on pollution content of each imported commodity
- For *actual* footprint, need to know about production technology in each country that we directly *and* indirectly import from
- Effectively, need world interregional analytical IO tables
  - IO table for each direct or indirect trading partner
  - In NAMEA format (augmented with sectoral physical resource use and/or emissions data)
  - Trade matrices disaggregated by producing and consuming sectors in producing and consuming regions
  - See Turner et al (2007) for 2-region derivation (extend to *N*-region)
  - McGregor et al (2007) apply 2-region interregional IO to Scotland-RUK but close system using production accounting principle

  
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### Trade with the rest of the world - options

- For full/actual footprint need world IO as above
- At present, doesn't exist
- Increasing number of applications in literature using Global Trade Analysis Project (GTAP – Purdue University, Indiana) international IO database
- Problem: GTAP database doesn't cover all countries in the world
- Also, international trade matrices
- Variety of assumptions, techniques to fill in gaps (see Wiedmann et al, 2007, for review)
  - SEI study for DEFRA (with ISA, Sydney) on multi-region emissions accounting for UK
- One option – assume ROW 'like' large trading nation(s) (e.g. US, China)
- Or, 'domestic technology assumption' – e.g. Druckman et al (forthcoming)
- Problem of estimating emissions embodied in imports to UK considered in ONS (2002) – domestic technology assumption among options considered

## Perspectives on responsibility for emissions generation

- Implications of domestic technology assumption?
- Not actual footprint and probably less appropriate than assuming ROW 'like' a big trading nation
- Question: are we responsible for technological choices in other countries?
- Issues of legislative domain
- Appropriate to consider what impacts would be if we had to produce commodities for ourselves rather than import?
- *Hypothetical* footprint?
- Footprints hypothetical anyway?
  - E.g. critique by Van den Bergh and Verbruggen (1999) – no account taken of multiple land uses, marginal differences in productivity etc.

## Conclusions and recommendations

- IO approach to calculating footprints appropriate, rigorous and transparent
- Minimum requirement: environmentally augmented analytical IO table for Scotland (Scottish NAMEA)
- Given that Scotland must contribute to UK targets, extend to interregional framework for Scotland-RUK? More accurate and disaggregated version of that used by McGregor et al (2007)
- Decision on what to do about ROW?
- Decision on whether we want accounting under production and/or consumption accounting principles?
- Multiple measures possible and desirable to look at different issues
- Sustainable networks to oversee
  - We have the Scottish Government IO expert user group (OCEA)
  - Resurrect the Scottish Environmental Accounts Working Group?

## Papers cited above:

- Druckman, A., Bradley, P., Paphanasopoulou, E., and Jackson, T. 2007. Measuring progress towards carbon reduction in the UK. Forthcoming in *Ecological Economics*.
- ONS (2002) 'Methodologies for estimating the levels of atmospheric emissions arising from the production of goods imported into the UK'. Report of a project undertaken by the Office of National Statistics, United Kingdom.
- Van den Bergh, J.C.J.M. and H. Verbruggen (1999) 'Spatial Sustainability, Trade and Indicators: An Evaluation of the 'Ecological Footprint'', *Ecological Economics*, Vol. 29, pp.61-72.

