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Who Creates Waste? Different Perspectives on Waste Attribution in a Regional Economy

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Abstract. We use a regional input output (IO) framework and data derived on waste generation by industry to examine regional accountability. In addition to estimating a series of industry waste-output coefficients, the paper considers a series of methods for waste attribution, and practical use for policymakers. The paper first considers perspectives on attribution of domestic waste generation using basic Type I and Type II industry multipliers, and also compares these with multipliers derived from a trade endogenised linear attribution system (TELAS) which permits a greater focus on private and public final consumption as the main exogenous driver of waste generation in the domestic economy. Second, it uses a domestic technology assumption (DTA) to consider what Wales's 'waste footprint' would be if it had to meet all its consumption requirements through domestic production.

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1. Introduction

This paper uses a regional input-output framework together with survey data on waste generation by industry to examine waste attribution in a regional economy. In addition to estimating a series of industry direct waste-output coefficients, the paper considers a series of methods for waste attribution and the usefulness of these different methods for policymakers. Specifically, the paper considers waste attribution from basic Type I and Type II multiplier analysis, and also compares these with multipliers developed through a trade endogenised linear attribution system (TELAS), originally proposed by McGregor *et al* (2008). The TELAS approach permits a greater focus on regional private and public final consumption as the main exogenous driver of domestic waste creation. We argue that the latter system provides a useful tool for the domestic waste attribution problem and an additional perspective for regional policymakers.

However, since interest may lie in assessing the total waste burden implied by local consumption, as well as waste actually produced in the region, another accounting technique is considered in this paper. This technique estimates the waste burden imposed by total use of commodities in the region under what is termed a domestic technology assumption. This gives a hypothetical 'waste footprint', measuring what domestic waste generation would be if the region had to meet all of its consumption demands through domestic production (i.e. in the absence of trade).

As a case study, this paper focuses on Wales. The devolved Welsh Assembly Government (WAG) seeks to actively promote sustainable development. Duties under the Government of Wales Act (1998) act include setting sustainable development objectives and the provision of a series of indicators to support the evaluation of activities and policy (see Munday and Roberts 2006).

A concern with the waste generated in the regional economy has been one focus of regional strategy and resulting policies. For example, adopted headline indicators of sustainability include indicators of household waste and the amounts of waste recycled. Moreover, waste indicators link closely to other headline indicators that focus on air and water quality and climate change. In a series of economic, environmental, and social strategic documents produced in the region, the increasing burden that waste places on environmental assets, and the future services from those same assets has been acknowledged (see Welsh Assembly Government, 2002).

The 2007 World Wildlife Fund (WWF) *One Planet Wales* report revealed measures that could be used to reduced Wales' ecological footprint by 75% in 2050, and the linked consultation in November 2008 for a new Sustainable Development Scheme for Wales was contextualised on a movement towards year on year reductions in carbon emissions and 'zero waste'. The general projection for the region is now understood in terms of decreasing amounts of household waste, increasing amounts of waste recycled and composted, and increasing commercial, industrial, and construction waste recycling. The region also faces the challenge of having just under 8 years of landfill capacity remaining at non-hazardous sites, and with ARUP (2008) reporting that "waste generation from consumption based activities (manifested primarily as household waste) contributes 15% of Wales' ecological footprint". There has been limited progress in the region towards waste reduction. For example, total amounts of household waste per person fell by nearly 4% between 2004 and 2007 along with increases in reported recycling. However, this is not prima facie evidence of any decoupling of growth and waste generation as economic growth faltered in this period. Furthermore, there is evidence of reductions in commercial and industrial waste generation (see Frater and Hines, 2004; Urban Mines, 2008).

Wales is currently moving towards a new waste strategy in 2010 (Welsh Assembly Government, 2009). The processes of reflection and extensive consultation undertaken in the region in 2008-09 represented a time to reflect on the issue of who creates waste in Wales, and how one understands where the ultimate responsibility for this waste generation lies.

The explicit policy concern in Wales appears to be in terms of a production principle (Munksgaard and Pedersen, 2001), which would make sense in terms of the Welsh Assembly Government's direct jurisdiction. This is evidenced in part through the indicator set used to monitor progress towards targets on the Welsh Assembly Government's Environment Strategy. Here the emphasis is in terms of waste generated in Wales with indicators speaking to quantities of municipal, industrial and commercial wastes and proportions recycled and landfilled in the region (see Welsh Assembly Government, 2009a, 2009b). However, the wider sustainable development duty speaks to more global responsibilities with a vision that "Wales demonstrates the contribution a small, developed nation can make to global sustainable development and environmental improvement" (Welsh Assembly Government, 2009b, pp.2-3). This wider duty is connected with uptake of the ecological footprint measure as one headline overarching sustainable development indicator (Munday and Roberts, 2006).

Thus, as well as accounting under production accounting principles (waste generated within the region) there is a need for the region to consider how consumption activity within its borders creates impacts outside the regional boundary. Generally, in the case of any open economy, there is a need to examine the impacts of trade on waste generation (we may also want to consider how external consumption demands impact on domestic waste generation). However, this raises the issue of how such analyses may be carried out, where currently available data and analytical tools may only provide an indication of the region's waste footprint.

More generally, this paper addresses issues raised by Munday and Roberts (2006) who argued that the strategic drive towards implementation of sustainable development objectives in UK regions have in some cases not been matched by the development of approaches to monitor and evaluate progress under the legal sustainable development duty and the need for empirical frameworks that link policies and actions to environmental outcomes, and vice versa. Thus, and in the specific context of devolved regional government in the UK, it would seem that there is real scope for an economic-environmental accounting and modelling framework that can fill this analytical gap (see also McGregor *et al*., 2001, 2008). This is particularly relevant in the case of waste, where at the regional level there are challenges in linking waste creation to different types of industry activity and linking waste generation to local consumption.

The remainder of this paper is structured as follows: Section 2 revisits how industry externalities such as pollution and waste are dealt with in an input-output framework. The section then describes different attribution approaches formally, but also highlights the strengths and weaknesses of each approach from the policy and strategic perspective. In particular, the section demonstrates the dangers of focusing on simplistic industry/waste output coefficients when exploring key sectors in terms of waste generation, and introduces waste attribution measures that permit a focus on private and public final consumption as a driver of waste generation (i.e. approaches featuring TELAS and the domestic technology assumption). Section 3 describes the regional input-output framework constructed for Wales, its current application, and the nature of the waste data used in conjunction with this framework. The focus is on how the waste data was incorporated into the Welsh input-output framework, and the issues of missing data. The fourth section reports the results of the analysis, showing the industry and consumption categories that are highlighted under the selected attribution approaches. Different perspectives offered particularly by the TELAS and DTA attribution technique are illustrated through the examples of four industries (*Wood*

Products, *Dairy Products*, *Electricity Generation*, and *Education*). The final section concludes and discusses how the analysis provides useful information for regional policy development on waste, its abatement, and how data might be improved to develop the research theme.

2. Alternative 'treatments' of waste in input-output frameworks

2.1 'Conventional' approaches

Leontief's (1970) basic demand driven input-output framework is extended for waste generation as follows[1]:

$$\mathbf{W} = \omega^{\mathbf{P}}[\mathbf{I} - \mathbf{A}]^{-1}\mathrm{Y} \tag{1}$$

Where there are i=j=1,…,N industries and commodities (here, N=74) and z=1,...Z final consumption groups (here, in the Type I case, Z=4). $\boldsymbol{\omega}^{\mathbf{P}}$ is a 1xN vector of direct output-waste coefficients with elements $\omega_i=w_i/X_i$, where w_i is the physical amount of waste generated by each production sector i in producing its output, X_i. $\boldsymbol{\omega}^{\mathbf{P}}[\mathbf{I}\text{-}\mathbf{A}]^{-1}$, then, is a 1xN vector of waste output multipliers, which, for each industry output j, gives us the total amount of waste generated in production (across all N production sectors) to meet one unit of final demand for sectoral output j.

Where waste is directly generated by final consumers (e.g. households), one defines $\boldsymbol{\omega}^{\mathbf{C}}$ as a 1xZ vector of direct waste-final expenditure coefficients with elements $\omega_z=w_z/Y_z$, where w_z is the physical amount of waste generated by each final consumption group z in consuming goods and services in the process of its total final expenditure, Y_z (column totals for each final consumption group from the input-output tables). Thus the total amount of waste generated in the region to meet final consumption demand, W^R, is calculated by extending equation (1) as follows:

$$\underset{\substack{(1x1)\\(1x1)}}{W^R} = \underset{\substack{(1xN)\\(1x74)}}{\omega^P}\underset{\substack{(NxN)\\(74x74)}}{[\mathbf{I}-\mathbf{A}]^{-1}}\underset{\substack{(NxZ)\\(74x4)}}{\mathrm{Y}} + \underset{\substack{(1xZ)\\(1x4)}}{\omega^C}\underset{\substack{(Zx1)\\(4x1)}}{\mathrm{Y}} \tag{4}$$

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[1] In this paper the concern is with a single pollutant, physical waste. However, it is straightforward to extend the input-output system for multiple pollutants/types of waste (by extending the 1xN and 1xZ vectors ω^P and ω^C to KxN and KxZ matrices for 1=1,…,K pollutants/types of waste).

For a standard Type I input-output analysis, the dimensions of each of the matrices and vectors are as given in the calculation of W^R in (2). That is, industries and final consumers are defined as in the input-output accounts. This allows an analysis to capture the direct and also indirect output and waste effects of backward supply linkages between local production sectors.

With no *changes* in final demand, the system in (2) provides the same figure for W^R as one would get from an analysis using the direct waste intensities of each activity:

$$(3) \qquad \underset{(1x1)}{W^R} = \underset{(1xN)(Nx1)}{\omega^P X} + \underset{(1xZ)(Zx1)}{\omega^C Y}$$

Consequently, (2) simply attributes waste generated in the regional economy (during a single time period) to demand for regional outputs, rather than the production of those outputs, as in equation (3). The approach in (2) is analogous to the attribution of total regional output, X, to final consumption demand for this output, Y, in the basic demand-driven input-output system. This is an important distinction. The approach in (3) is entirely focussed on what Munksgaard and Pedersen (2001) term the 'production accounting perspective'. However, the approach in (2) takes account of what consumption behaviour is driving waste generation activity in the local economy. In a closed economy (2) would equate to an analysis under the consumption accounting perspective, or a 'waste footprint'. The issue of economic openness and trade is considered below.

It is also common to extend to a 'Type II' input-output analysis, where households are shifted from the final demand matrix, **Y**, into the production matrix, **A**. This is done to examine induced (income and consumption) effects of employing household services as labor inputs to production. Household consumption is endogenised by subtracting household final consumption expenditure from the matrix **Y** (consumption of local outputs) and vector Y (total final consumption) in (2) and adding an additional column and row of input-output coefficients to the **A**-matrix. In the additional row, the new a_{ij} entries record the value of use of household production (additional production sector, i) as inputs to production of sectoral output X_j. In an input-output account, household production is solely composed of the provision of labour services, so the additional row entries are payments to labour services, or 'income from employment', divided by total input/output for each sector. In the case of households, where no labour is directly employed the coefficient collapses to zero. In the additional column, the new a_{ij} entries record use of local inputs from each production sector, i, by the household sector, j (formerly recorded as final consumption) and X_j as the total input/output of households, which is given by total payments to labour/income from employment.[2]

The key features of the standard Type I and Type II environmental input-output approaches (which we have applied to the chase of physical waste generation) are identified in Table 1. The conventional Type I and Type II attribution techniques are useful in considering the structure of pollution/waste problems in the local economy and allow (from a demand/consumption driven perspective) a consideration of the types of activity that drive waste generation. However, there are two main problems with these approaches. First, with an attribution based around Type I or Type II multipliers, responsibility for pollution or waste generation is partly attributed to external sources of final demand (exports). This is especially the case in an open, regional economy, such as Wales. Moreover, in a Type II analysis, local private consumption (i.e. household demand) almost entirely disappears as a driver of local waste generation. The second problem concerns imports, the waste implications of which do not enter into the calculation in equation (2) (or the direct calculation in equation (3)).

[2] Note that, in contrast to the conventional production sectors reported in the input-output accounts, it is rarely the case (if ever) that household input and output balance, as income from employment is unlikely to be the only source of household income that funds consumption expenditure. Strictly speaking, it would be appropriate to retain some household consumption expenditure as exogenously determined within the final consumption matrix **Y**. Only in a social accounting matrix (SAM), where a complete set of income and expenditure flows are reported, do household 'inputs' and 'outputs' balance.

Table 1. Key aspects of different IO approaches for regional environmental/waste analysis

	Factors included in analysis	Issues for environmental analysis
Direct	* Domestic waste generation in target region (Wales)	* Analysis entirely from a production perspective
Type I	* Domestic waste generation in target region (Wales) * Direct and indirect (backward linkage/inter-industry) effects	* Attribution of some waste generation to external (export) demand but no account of impacts of imports * No induced (consumption and income) effects from household provision of labour services
Type II	* Domestic waste generation in target region (Wales) * Direct and indirect (backward linkage/inter-industry) and induced (consumption and income) effects	* Attribution of some waste generation to external (export) demand but no account of impacts of imports * No responsibility attribution to local households for waste generation in the target region (Wales)
TELAS	* Domestic waste generation in target region (Wales) attributed entirely to local (private and public) consumption demands * Treatment of trade issues (also endogenise capital formation) * Direct and indirect (backward linkage/inter-industry) effects	* Focus on local waste generation retained with focus on trade but no account taken of actual/estimated waste content of imports (i.e. external/rest of world waste generation) * No induced (consumption and income) effects from household provision of labour services
Domestic Techology Assumption	* Hypothetical domestic waste generation in target region (Wales), in absence of trade, attributed entirely to Welsh consumption demands (households, government and capital) * Can apply T1 and/or T2 focus (T1 may be preferable in environmental analysis)	* Capacity and capability issues - could the target region (Wales) meet all of its local consumption demand in this way? * Assumes 'in spirit' that imported goods create the same amounts and types of waste as domestic production
Interregional 'footprint' analysis	* Actual (estimated) waste generation within and outwith target region (Wales) to support Welsh consumption demands * Potential full application of Consumption Accounting Principle	* Focus on global rather than local waste generation issues, raising issues of jurisdictional responsibility and authority * Extensive data requirements (depending on focus, may involve world interregional IO tables, with economic and environmental data in IO format for all direct and indirect trade partners, and interregional trade matrices)

2.2 The TELAS approach to addressing trade issues

McGregor *et al.* (2008) propose a method to address trade issues in a single region input-output framework. They call this a Trade Endogenised Linear Attribution System (TELAS). The TELAS approach involves endogenising trade in much the same way as household final consumption is endogenised in the Type II approach outline above. Instead of counting export (including tourist) demands from the rest of the UK (RUK) and rest of the world (ROW) for Welsh output as vectors of final consumption demand within matrix **Y** in (2), the approach creates an additional regional production sector in the **A** matrix, a Trade sector, t, which produces the imports required in the economy as a whole. The row entries for each (consuming) sector j are that sector's total imports from RUK and ROW[3], m_{tj}, as a share of the total input/output of the (consuming) Welsh sector j, X_j:

$$(4) \quad a_{tj} = m_{tj}/X_j$$

The additional column entries are the outputs that must be produced for export to RUK, ROW via the trade sector, t, by each (producing) sector i in Wales, x_{it}, per unit of *total*

[3] Note that it would be possible to treat trade with RUK and ROW separately, though the creation of two trade sectors.

imports required in the Welsh economy as a whole (intermediate and final consumption), M, as the output of the trade sector:

$$(5) \qquad a_{it} = x_{it}/M$$

The direct waste intensity of the output of the new Welsh trade sector, ω_t, is equal to zero, as generally no emissions are directly generated here. Waste directly generated in producing output for export demand is generated in the producing sectors and is, therefore, embodied indirectly in intermediate sales to the new trade sector, just as waste generated in producing output for household consumption is embodied in intermediate sales to the household production sector in a Type II analysis.

Note that when we calculate (2) with trade endogenised, each individual (production or consumption) sector that imports from RUK and/or ROW is attributed the waste embodied in the share of total Welsh domestic export production required to finance these imports, which is measured using ω^P. This is analogous to the Type II case, where each production sector that employs labor is attributed the waste embodied in the share of total household consumption that becomes an 'input' to labor supply in a Type II analysis. Under TELAS, there is no attempt to estimate the waste generated in other regions/countries in producing the commodities that are imported (i.e. the waste embodied in imports). In other words, TELAS does not address the waste generated outside Wales to support Welsh consumption; rather it focuses on waste generated *within* Wales to support Welsh consumption.

Note also that imports and exports are unlikely to be equal in an open economy (there is likely to be a trade surplus or deficit). This is similar to the point made above with regard to endogenising households in a Type II analysis, inputs to and outputs from the Trade sector will also not balance.[4] In order to focus attention on local (private and public) final consumption (i.e. Welsh households and government consumption), under TELAS capital formation/investment is also endogenised as covering depreciation/payments to capital. See McGregor *et al* (2008) for full details. This is done by adding another row and column to the **A** matrix, where the row coefficients are given by payments to other value added divided by

[4] This problem may be overcome with extension to a social accounting matrix (SAM) analysis, where a full balance of payments is accounted such that income and expenditure in the trade sector balance (see the SAM TELAS analyses carried out by McGregor *et al*, 2004, 2008).

total inputs for each sector. The new column coefficients are given by local sectoral outputs produced to meet final consumption in the form of gross regional capital formation, divided by the total output of the (consuming) Welsh capital sector, given by total regional payments to capital or other value-added. Again, as with the trade sector, the direct waste intensity of the output of the Welsh regional capital formation sector is equal to zero.

Formally, under TELAS for Wales, equation (2) is estimated where the **A** matrix becomes a 76x76 (N production sectors as in Type I analysis plus the new trade and capital formation sectors) matrix. The export terms that are included in the **Y** matrix in a standard Type I analysis and capital formation drop out so that the only exogenous demands are Welsh regional private (household) and public (government) final consumption. Thus, **Y** becomes a 76x2 matrix (in contrast to the Type II analysis, where there is no final demand for labor services in the additional row of the adjusted **Y** matrix, there is final (import) demand for the outputs of the trade sector).

McGregor *et al* (2008) explain that the philosophy underlying the TELAS approach is basically to adopt a neo-classical, resource-constrained, view of the operation of the open economy, where exports essentially finance imports (Dixit and Norman, 1980). Thus, the TELAS approach can be used to retain local consumption as the driving force behind environmental attribution (applied here to the case of physical waste generation) while allowing a focus on (in the present study) the waste generation within the spatial jurisdiction of Welsh agencies. Under TELAS, each individual importing sector is attributed the pollution embodied in the share of total domestic export production required to finance those imports. In terms of the Welsh responsibility for sustainability, it is argued that this places the responsibility for waste generation at the appropriate spatial level. It also has the advantage of only requiring data for the Welsh economy and not the detailed economic, trade and waste generation of trading partners. As with Type I and II, Table 1 highlights the key features of and potential issues with the TELAS approach.

2.3 The domestic technology assumption – an alternative approach?

The basic issue that may be considered problematic by some is that under TELAS there is no attempt to account for the *actual* waste involved (directly or indirectly) in producing *all* goods and services consumed in Wales (including imports). It is important to note that adopting a perspective that did account for waste in this way implies a shift in focus away from the waste generated within Wales (over which the Welsh Assembly Government and its agencies have control) to waste generated in other regions and countries (where there is no jurisdiction). However, input-output methods can also be (and increasingly are being) employed to calculate 'footprint' type indicators (see Turner *et al*, 2007, and Wiedmann *et al*, 2007).

Two potential alternative methods are identified in Table 1. Taking the last, and perhaps most obvious, one first, if one is concerned with total waste generated around the world to support Welsh consumption, one ideally requires estimation of a Welsh 'waste footprint'. Turner *et al* (2007) explain how this can be done using an interregional input-output framework (as opposed to the single region framework currently available for Wales). However, they also discuss the considerable data requirements of a full footprint calculation (see Table 1 – basically a world interregional input-output framework, or at least one that incorporates appropriate economic and waste input-output data on all Wales's direct and indirect trade partners, and corresponding interregional trade data in input-output format, would be required). McGregor *et al* (2008) attempt a partial application of the approach explained by Turner *et al* (2007), where they focus on applying the 'consumption accounting principle' (Munksgaard and Pedersen, 2001) in the case of interregional trade between Scotland and the rest of the UK, but close the system at the national (UK) level under the production accounting principle (using the TELAS method).

However, as noted above, there are also issues relating to jurisdiction in using such 'footprint' analyses for policy analysis. Wales does not have any authority over technology used in production in other countries. However, there may be a desire to attempt to take responsibility for the full waste implications of consumption decisions within Wales. Therefore, an alternative approach may be to consider the question of what if Wales had to produce all of the goods and services that it consumes for itself. That is, what would Wales's 'waste footprint' be in the absence of trade? This would seem to be a relevant question, given the commonly argued position that one ought to try and consume locally produced goods and services where possible.

This question can be approached using what is referred to as the 'domestic technology assumption' (see also, Druckman *et al*., 2008, 2009). This involves assessing the waste (or other pollution) content of *total* use of commodities (local and imported) according to the domestic production and polluting technology in Wales (i.e. what regional agencies have some jurisdiction over). That is, the vectors ω^P and ω^C of direct waste-output coefficients (direct waste intensities) identified for Wales in Section 2.1 and a variant of the **A** matrix that records *total* (combined domestic and imported) use of intermediate inputs to production (and thus a revised **[1-A]**$^{-1}$ matrix showing the, hypothetical, global multiplier effects if all production were carried out in Wales).

The Welsh Economy Research Unit at Cardiff Business School provided experimental data in the form of an imports matrix showing imports (summed across RUK and ROW) to each of the N=74 Welsh regional production sectors and Z=4 final consumption groups (returning to the standard Type I classification of activities). This permits an analysis based on domestic technology assumption. The data comprises an NxN (74x74) intermediate imports matrix[5], labelled **M**, which corresponds to the existing **A** matrix, which is re-labelled matrix **R** (to distinguish it as the local regional intermediate use matrix), in that it contains entries m_{ij} showing the use of the output of external sector i used in the production of one unit of output in Welsh sector j, X_j (i.e. corresponding to the domestic a_{ij} coefficients, which we re-label r_{ij} in this section). In terms of final consumption, there is an additional 74x4 final consumption matrix, which is labelled $\mathbf{Y^M}$ to distinguish imports to final consumption from the existing **Y** matrix from Section 2.1, and which is re-labelled $\mathbf{Y^R}$ (to distinguish final consumption of local, or Welsh regional, outputs). However, in order to focus on the impacts of Welsh consumption, the vector of export demands from both these matrices is removed so that $\mathbf{Y^R}$ and $\mathbf{Y^M}$ become 74x3 matrices (where we have Z=3 for Welsh household and government consumption, and capital formation).

In consequence, an analysis of what the total waste implications of Welsh final consumption (labelled W^T below) would be if these had to be met entirely from Welsh production (in the absence of trade) can be undertaken by restating and calculating equation (2) as follows:

$$W^T = \omega^P[\mathbf{I} - (\mathbf{R} + \mathbf{M})]^{-1}(Y^R + \mathbf{Y^M}) + \omega^C Y \tag{6}$$

(1x1)	**(1xN)**	**(NxN)**	**(NxZ)**	**(1xZ)**	**(Zx1)**
(1x1)	**(1x74)**	**(74x74)**	**(74x3)**	**(1x3)**	**(3x1)**

Note that the entries in the (now) 1x3 vector Y used to estimate direct waste generated in final consumption (which, in fact, only applies in the case of households) remains as before: total final consumption expenditure by each type of consumer is unchanged (previously it included aggregate imports; here we have simply disaggregated imports in terms of commodity/type of output in the $\mathbf{Y^M}$ matrix).

[5] Note that, as with the TELAS analysis, it is possible to work with two matrices identifying imports from rest of the UK and rest of the world separately. The same is true for final consumption.

In this paper the focus is on the Type I case (given the issue of alleviating households from responsibility for waste generation in a Type II analysis, which would seem to contradict the philosophy underlying consumption-oriented measures, which is that human consumption decisions are the ultimate drivers of environmental problems). However, the method in (6) is not consistent with TELAS, as there is no consideration of trade issues in this new method – here we ask what would happen if Wales had to meet all of its own consumption needs (i.e. a hypothetical autarkic situation).

The system in (6) incorporates feedback effects so that $\mathbf{[I-(R+M)]^{-1}}$ can be interpreted as a Leontief multiplier matrix for the portion of the global economy that serves Welsh consumption demand *only* under the assumption that the portion of the global economy that serves Wales shares its production structure. Note that working under this assumption does not mean we are taking it to be fact; rather we are using the system to consider what would happen if Wales had to meet its own consumption demands without trade and, crucially, using technologies over which Welsh government and agencies have some control/jurisdictional authority).

It is important to note that the system in (6), unlike the Type I, Type II, or TELAS accounting frameworks above, *will not* replicate the amount of waste generated in Wales as accounted under the direct method, or, more importantly, to our base year survey-based data set. Nor would the standard economic variant of (6) replicate the base year output vector of the Welsh 2003 input-output table, or Welsh employment in 2003, and so on. This is because, while the Type I, Type II and TELAS analyses are basically *accounting* frameworks (which must balance to the actual base year input-output data), the system in (6) is a *modelling* framework: it is being used to arrive at a *hypothetical* waste account for Wales.

This brings us to the main difficulty in working under the domestic technology assumption, and, perhaps more importantly, with the notion of Wales attempting to meet all its consumption demands domestically/without trade. In a hypothetical measure, such as that produced by (6) – rather than actual accounting where one balances to real data as in equation (2) and the Type I, Type II and TELAS analysis – one is not giving any consideration to whether Wales has (a) the capacity or (b) the capability of meeting its own consumption demands. In terms of (a) the domestic technology assumption method in (6) shares the limitations of using the conventional demand driven input-output model for impact analysis: it implicitly assumes infinitely elastic supply (and is silent on any price response to the existence of short or long run supply constraints). However, issue (b), whether Wales has the capability of meeting all of its own consumption demands is perhaps the more basic of the two. For example, the imports in matrix **M** include commodities such as bananas, which cannot be produced in Wales, or at least not by any cost-effective method that is not, e.g. hugely energy-intensive. This is why we need to trade, and why, it would seem, any analysis of *domestic*[6] waste generation requirements in an open regional economy like Wales, requires the use of an accounting framework, such as TELAS, that takes account of both imports and exports, and associated balance of trade issues.

3. Data

We now turn our attention to the data available to allow us to apply the methods outlined in Section 3 to the case of Wales. Wales is one of few regions in the UK which produces survey-based input-output tables which are the bedrock of the analysis undertaken here. The development profile of the Welsh input-output tables is provided in Bryan *et al.* (2004) which also describes the developing survey base of the tables. The analytical tables used here are for 2003 (WERU, 2007).

The latest iteration of the input-output tables for 2003 provides information on the sales and purchases of 74 defined sectors, and describe different components of final demand including a series of tourism final demands. Also available are a symmetrical domestic use matrix and an imports matrix, the latter providing information on the make-up of imports going to these same sectors. The Welsh input-output framework has had limited application for econ-environmental modelling. For example, regionally derived emissions data has been combined with information from the earlier 2000 Welsh input-output tables to generate the direct and indirect volumes of selected pollutants generated by changes in final demands in each industry (see Munday and Roberts, 2006, and Bryan *et al.*, 2004). This type of framework has also been used to assess the environmental consequences of tourism spending in the region, particularly connected to major events (see Jones and Munday, 2007; Collins *et al.*, 2005). However, to date, there has been no detailed analysis of waste or a detailed consideration of waste attribution.

Here, information from detailed industry responses to the *Commercial and Industrial Waste Survey Wales* 2003 gives us an opportunity to undertake a more careful analysis of waste attribution results from. This survey was carried out by the ESRC funded Centre for Business Relationships Accountability Sustainability and Society (BRASS) at Cardiff University (see

[6] It is important to emphasise that our focus here and argument in favour of the use of the TELAS approach over alternatives is based on the assumption that we are interested in the issue of domestic waste generation in the regional economy. As noted earlier, if our interest is in the global waste requirements of Welsh consumption, we require a footprint measure. However, as highlighted in Table 1, the main limitation of footprint measures is their lack of focus on domestic waste generation.

Frater and Hines, 2004). The results from this survey were primarily used to provide waste arisings (i.e. waste occurring at production sites) and disposal data for Welsh policymakers. The dataset compiled information from 2,122 firms comprised of around 11,000 defined individual waste streams and 2,200 mixed waste streams. The dataset also provided 5 digit standard industrial classification (SIC) codes for the reference firm, values for employment, a coding of waste stream according to European waste codes (ewc) and tonnage, substance form, information on initial and final destination, a hazardous waste marker, and summary details of the waste management options being employed in the case of each stream.

The 2003 survey revealed that Welsh businesses produced an estimated 5.3 million tonnes of waste in 2002-3, a 14% decrease from the 6.1 million tonnes produced at the time of the prior survey in 1998-9. It is expected that the shrinkage of the regional manufacturing sector over this period may have contributed to the fall. The survey also estimated that 4.2 million tonnes of waste came from industry, and 1 million tonnes were generated by the commercial sector. Some 28% of commercial and industrial waste went to landfill compared to 40% in 1998-9 and recycling or re-use had increased from 53% in 1998-9 to 62% in 2003. The 2003 survey has recently been superceded by the 2007 *Commercial and Industrial Waste Arisings in Wales* which has revealed further reductions in waste. We use the findings from the 2003 survey as they are more consistent with the data in the 2003 Welsh input-output tables.

For the analysis in this paper we use total waste tonnages rather than focusing on different types of waste and their resulting managerial options. The paper then highlights the multiple perspectives of waste attribution using Welsh data. As discussed in the conclusions in Section 5, future work using more disaggregated waste data would also permit us to examine the generation and flows of different waste types and management options in Wales.

Data on total tonnages of waste is provided at the 3 digit SIC code level. There were some gaps in the coverage. For example, the *Commercial and Industrial Waste Survey* did not collect data from sectors producing waste that was ‘not controlled’. This included waste from agriculture, fishing, and mining and quarrying waste. There were also some details of waste by sector where data was estimated from parallel surveys undertaken in England (i.e. data for pulp and paper, coke and refined petroleum, recycling, wholesale, retail and utilities). Additional data on waste from construction and mining and quarrying sectors was subsequently collected from the *Pilot Environmental Satellite Accounts for Wales* (DTZ & WERU, 2006). Moreover household waste data for the 2003-04 financial year was collected from the *Municipal Waste Management Report for Wales 2007-08*.

This body of data on sectoral waste generation, together with additional information, is then used to gain an estimate of tonnes of waste per full time equivalent (FTE) employee in each 3 digit SIC sector. These data provide the basis for grossing-up to an estimate of tonnes of waste generated by each SIC industry in Wales. These data are then aggregated into the 74 industry sectors within the Welsh input-output tables permitting the initial estimation of waste output coefficients (sectoral direct waste intensities), which are shown in the first column of Appendix 2. These direct waste intensities give us the 1x74 vector ω^P and sole entry ω_z (where z=household consumption) of the ω^C vector introduced in Section 2.1. They are derived by dividing the total tonnage of waste estimated as being generated in each production sector and by households (as outlined above and reported in the first column of Appendix 3) by total sectoral output, X_i, and, in the case of households, total final expenditure, Y_z (these are given by the column totals of the 2003 input-output tables). Note that this gives us the reverse calculation to that shown in equation (3) (Section 2) for a direct allocation of waste under the production accounting principle. Summing down the first column of Appendix 4 gives us W^R, the total waste generated within the Welsh economy in 2003 (also including uncontrolled waste not accounted for in the survey discussed above), which is 18.6m tonnes. Thus, as explained in Section 2, and shown below in Section 4, with no *changes* in final demand, any attribution exercise using equation (2) will return the same numerical result for W^R.

4. Waste attribution for Wales 2003

In this section we report the results of applying the various attribution techniques outlined in Section 2 to the case of Wales in 2003 (the year that our data relate to). Thus, waste, as measured above under the production accounting principle, is attributed to final consumption in four different ways:

(1) Type I Analysis: attributes direct and indirect waste generation to private and public consumption, capital formation, and exports.

(2) Type II Analysis: attributes direct, indirect, and income induced waste generation to public consumption, capital formation, and exports.

(3) TELAS Analysis: attributes direct, indirect, and import-induced waste generation to private and public consumption.

(4) Type I Analysis incorporating consideration of the waste content of imports under the Domestic Technology Assumption. As noted above, this means that exports are removed from the attribution exercise and the attribution is based on equation (6),

where total waste implied by Welsh final consumption demands, W^T, need not equal W^R from equation (3).

In section 4.1 we report the results of attribution methods 1-3, all of which are derived by calculating equation (2) under the different assumptions as explained for each method in Section 2. In order to focus on the importance of the production structure of the economy we focus mainly on the amount of waste attributable to the final demand for the output of each production sector i, by breaking down the estimation of (2) so that we take each element of the (1xN) vector of output-waste multipliers, $\omega_i^P \left[\mathbf{I} - \mathbf{A}\right]^{-1}$ in turn and multiply it by total final demand for that sector's output, Y_i. We also consider the amount of waste attributable to each type of final consumer by estimating (2) for each vector Y_z in the (NxZ) matrix of final consumption, **Y** (direct waste generation given by the second element on the right-hand side of (2) is only relevant for households). This highlights the differences between the three approaches in terms of where responsibility for waste generation is ultimately attributed.

In Section 4.2, we estimate equation (6) for the Type I case with waste embodied in imports given by the domestic technology assumption and focus on the difference in activity levels (production of output and waste generation) implied if Wales had to meet all of its own final consumption demands.

4.1 Type I, Type II and TELAS attribution of waste to total final demand for sectoral outputs

The full results of estimating equation (2) under Type I, Type II, and TELAS assumptions respectively are given in the last three columns of Appendix 3. The vector of output-waste multipliers underlying these results is given for each case in the last three columns of Appendix 2.

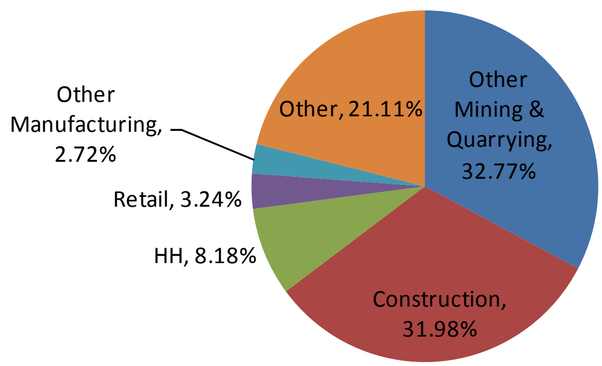
In each type of analysis, we are particularly interested in identifying sectoral outputs (commodities) whose production to meet final consumption demands involves high waste generation in the Welsh economy. Four sectors are then selected for a more detailed analysis that allows us to consider the results of the less conventional TELAS approach more carefully. In Section 4.2, we also determine the contribution of the different types of final consumers in driving activity in these key sectors (as well as total waste generation).

First, we identify the sectors that have relatively high direct waste generation in the production of their output.[7] Table 2 shows the amount of waste generated in Wales in 2003 by the five sectors that directly generate the greatest shares of total waste.[8] Figure 1 shows these figures as shares of total waste generation. Figure 1 shows that these five sectors directly account for almost 70% of total waste generation in Wales in 2003, with the top two sectors alone accounting for almost 64%.

Table 2: Top Five Direct Waste Generation Sectors (tonnes of waste)

Sector Description	Direct Waste Generation
Other Mining & Quarrying	6100000.00
Construction	5952000.00
Households	1522000.00
Retail	602862.45
Other Manufacturing	505989.07

Figure 1: Proportion of Total Direct Waste Generation by Top Five Sectors



However, these results depend not only on waste intensity but also scale of activity. Perhaps a more meaningful measure of direct waste generation is the direct waste intensity of activity, given by the output-waste coefficient (tonnes of waste per million £ of sectoral output). Table 3 shows the top five sectors in terms of output-waste coefficients or direct waste intensity.[9]

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[7] Data on direct waste generation were not available for the following sectors: *Coal Extraction*, *Oil Processing*, and *Gas*, *Water* (see Appendix 2 where zeros appear for these sectors in the first column). However, in the analyses reported here, indirect, income-induced, and import-induced values can still be calculated for these sectors, though the quantitative results for all activities will be impacted by the absence of direct waste coefficients for these sectors in calculating the vectors of output-waste multipliers.
[8] The results in Table 2 are taken from Appendix 3.
[9] The results in Table 3 are taken from Appendix 2.

Table 3: Top Five Waste-Output Coefficients

Sector Description	Waste Output Coefficients
Other Mining & Quarrying	28438.14
Construction	1765.37
Other Manufacturing	983.43
Wood Products	533.29
Furniture	494.51

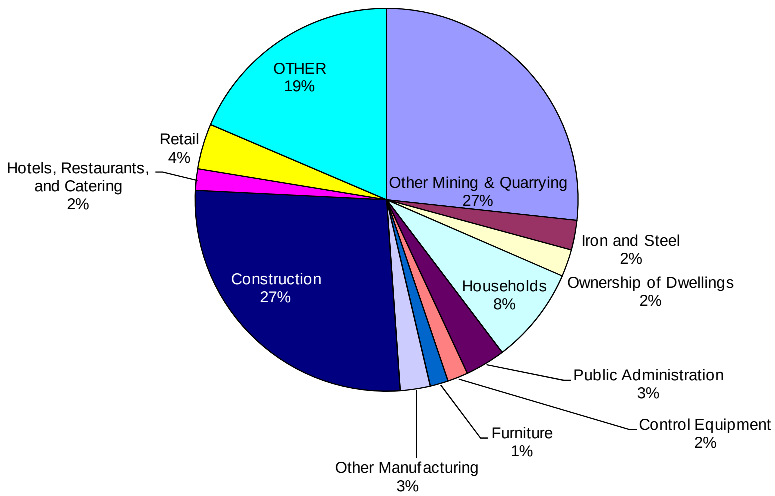
Table 3 shows that three of the largest direct waste generators are also the most waste intensive. However, *Households* (in terms of direct waste generation in final consumption) and *Retail* drop out of the top five, suggesting that scale of activity is also a key issue with these activities (Appendix 2 shows that households produce 68 tonnes of waste per £1m expenditure; Retail is higher at 155.5 tonnes per £1m output).

Type I Attribution Results

However, the results discussed so far only tell us about direct production of waste in different activities. This gives an accounting record under the production accounting principle. However, if we want to understand the structure of the regional waste problem with attention to a more consumption-orientated approach, we can use the input-output framework to consider the implications of interdependencies between different sectors of the economy. To this end, we employ the methods outlined in Section 2 above.

First, within the conventional Type I system, all final demand categories identified in the input-output accounts are treated as being exogenous. Therefore, private (household) consumption, public (government) consumption, capital formation (private investment) and exports (tourist expenditure as well as goods and services) are included in the matrix, **Y**, of final demand in equation (2). That is, these final demands are considered as driving all production activity in the economy. Considering final demand for each sector's output in turn, direct and indirect waste generation can be attributed to the final consumption of each sector's output. Figure 2 highlights the sectoral outputs whose consumption involves the highest waste generation under the Type I analysis.

Figure 2: Type I Final Demand Attribution by Sectoral Output/Commodity



It is clear from Figure 2 that *Construction* and *Other Mining and Quarrying* are by far the most waste intensive industries. However, the share of total waste generation attributed to these two sectors falls slightly relative to Figure 1. This is because a share of output produced in these sectors is to meet intermediate demands by other production sectors; waste generated to meet these intermediate demands is reallocated in the Type I analysis to the sectors whose final demand ultimately drives this activity.

Note also that for many of the sectors in Figure 2, most of the waste attributed under the Type I analysis is generated directly. For example, if we refer to Appendix 2, we can see that *Other Manufacturing* has a direct waste intensity of 983.4 tonnes per £1m output and a Type I waste output multiplier of 1020.0 tonnes per £1m of output produced to meet final demand. However, this is not true for all sectors. *Construction* has a direct waste intensity of 1765.4 tons and a Type I waste output multiplier of 2320.9. This means that while some of *Construction*'s direct waste generation is allocated to other production sectors that use its outputs as intermediate inputs, it also receives a share of the waste generated in other sectors to produce outputs that *it* uses as intermediates. Other sectors that exhibit large differences when indirect effects are incorporated using a Type I analysis include *Forestry*, *Plastics and Ceramics*, *Cement/Plaster*, *Iron and Steel*, and many of the service related industries – see Appendix 2.

Type II Attribution Results

As explained in Section 2 (and summarised in Table 1), while the Type I analysis takes account of indirect effects through backward supply linkages between production sectors, it does not take account of induced consumption and income effects from the payment of income to labour services in the production process. Induced effects are captured (along with direct and indirect effects) in the Type II system, which is closed with respect to households. In other words, households are considered endogenous within the production block (the A matrix and Leontief inverse) and no longer appear as a part of final demand (the **Y** matrix) in the estimation of equation (2). Therefore, the total final demand vector is now comprised of public (government) consumption, capital formation, and exports. This implies that within a Type II analysis households entirely disappear as an exogenous driver of local waste generation. Now, direct, indirect *and* income-induced waste generation can be attributed to the consumption of each sectoral output. Figure 3 highlights the sectoral outputs whose consumption involves the highest waste generation under the Type II analysis (note from the column totals in Appendix 3 that the same total amount of waste is being attributed as in the direct and Type I cases in Figures 1 and 2).

Figure 3: Type II Final Demand Attribution by Sectoral Output/Commodity

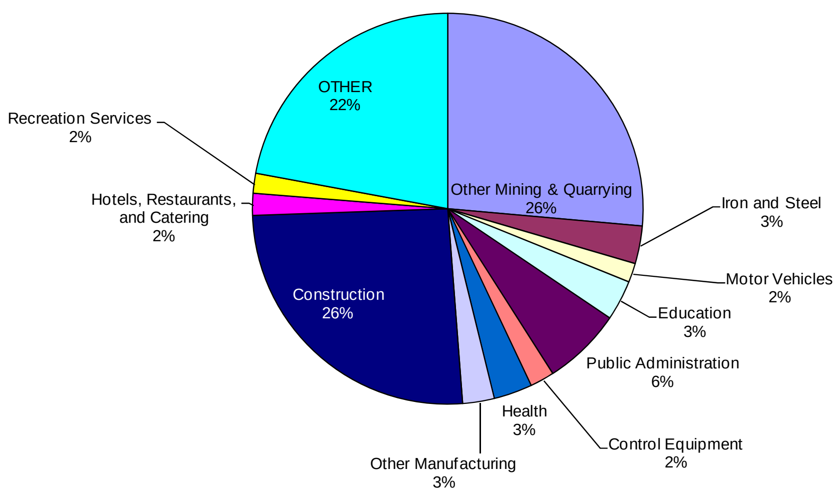


Figure 3 clearly shows that *Construction* and *Other Mining and Quarrying* remain the main contributors to total waste generation under a Type II analysis. Many of the same sectors from Figure 2 appear in Figure 3 implying that income-induced effects do not make a significant difference in the rankings of waste-intensive commodities. For example, *Other Manufacturing* has a Type I waste output multiplier of 1019.99 and a Type II waste output multiplier of 1085.1. However, some sectors that did not appear in Figure 2 now appear in Figure 3 indicating a change in final demand attribution once households are endogenised and income-induced effects are accounted for. For example, note from Appendix 2 that the output-waste multipliers more than double in the *Education*, *Health*, and *Recreation Services* when induced effects are taken into account. This happens in cases where payments to labour services account for a large share of inputs, either because the sector is labour-intensive or wage rates are high. In the case of *Education* where the Type II output-waste multiplier is 199.91 tonnes per £1million final demand for output, compared to only 44.13 in the Type I case, payments to labour services account for 66% of the total input requirement.

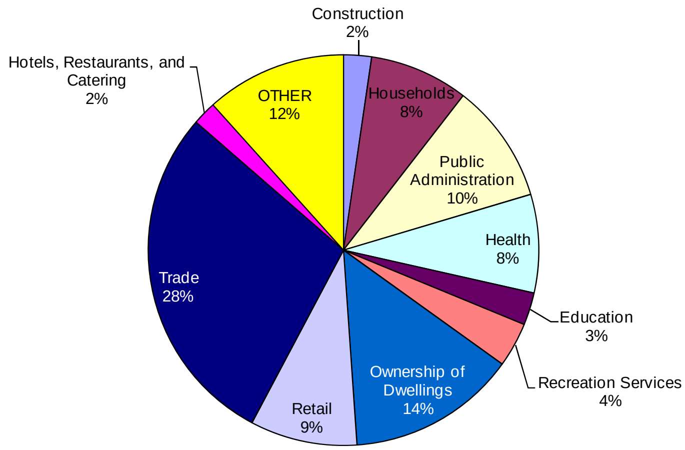
Table 4: Summary of Attribution of Total Waste (tonnes) to Type of Final Consumer			
	Type I	Type II	TELAS
Total local (private and public) consumption demand	26.27%	14.14%	100.00%
Total capital formation	32.08%	33.33%	0.00%
Total exports (g&s)	39.85%	49.71%	0.00%
Total external tourists	1.80%	2.82%	0.00%
Total waste attributable to final consumers	**100.00%**	**100.00%**	**100.00%**

TELAS attribution results

However, if we examine Table 4, where we show the full results of attribution to the matrix of final consumption by each type of consumer, **Y**, a crucial issue is that households are effectively absolved of responsibility for driving waste generation in their consumption activities (this is also reflected in Figure 3 where direct waste generation by households disappears). Such results would seem to run contrary to the commonly held perspective that human consumption decisions lie at the heart of all environmental problems. Moreover, as shown in Table 4, in both the Type I and Type II analysis, exports and external tourists are key consumers of the outputs to which waste is attributed in Figures 2 and 3. For example, the Welsh IO tables for 2003 show that 44% of output in the *Other Mining and Quarrying* sector is produced to meet external demand. In addition, as discussed in Section 2, no account is taken in the Type I and II analyses of the import requirements of intermediate or final consumption. Therefore, we also conduct the TELAS approach outlined in Section 2.2.

The TELAS system can be thought of as closed with respect to trade and capital. As described in section 2.2, trade and capital are considered endogenous within the model. Total final demand is then comprised of only private and public consumption. Within a TELAS analysis, it is local private and public final consumption (household and government expenditures) that drive local waste generation. Therefore, under this third attribution approach, direct, indirect, and *import-induced* waste generation can be attributed to the consumption of each sectoral output. Figure 4 highlights the sectoral outputs whose consumption involves the highest waste generation under the TELAS approach.

Figure 4: TELAS Final Demand Attribution by Sectoral Output/Commodity



Key sector analysis of the TELAS case

Figure 4 shows quite a different picture in terms of responsibility at the sectoral output/product level for waste generation relative to Figures 2-3. As in the Type I case, the 8% attributable to *Households* is the direct waste generation in final consumption rather than waste generation in production. However, with waste generated in production to meet export demand reallocated to the new *Trade* sector, it is now the outputs of sectors where the majority of output is produced to meet local consumption demand that are now attributed with the most responsibility for waste generation. For example, more than 99% of production in the *Ownership of Dwellings* and *Public Administration* sectors is produced to (directly) meet local household and government consumption (with household consumption dominating in the former and government consumption in the latter).

However, the high allocation in Figure 4 to the new *Trade* sector under this attribution of final demand by sectoral output/commodity masks what the TELAS analysis actually tells us about the waste *intensity* of different activities. In order to examine the TELAS results in more detail, we turn our attention to the output-waste multipliers (reported in full in Appendix 2), selecting four sectors that have been chosen based upon different waste and trade attributes, and also their significance in the Welsh economy, for a key sector analysis. Differences in waste intensity by sector provide some insight into the importance of direct effects within waste output multipliers. Industries with relatively high waste intensity should have relatively high direct effects within the TELAS multiplier. Also, differences in import intensity provide us with an idea of the size of the import-induced effects. We expect sectors with relatively high import shares to have relatively high import-induced effects within the TELAS analysis. The following four sectors are examined (see Figure 5):

1. *Wood Products* - relatively high (direct) waste intensity, relatively high (direct) import share
2. *Dairy* - relatively high (direct) waste intensity, relatively low (direct) import share
3. *Electricity* - relatively low (direct) waste intensity, relatively (direct) high import share
4. *Education* - relatively low (direct) waste intensity, relatively low (direct) import share

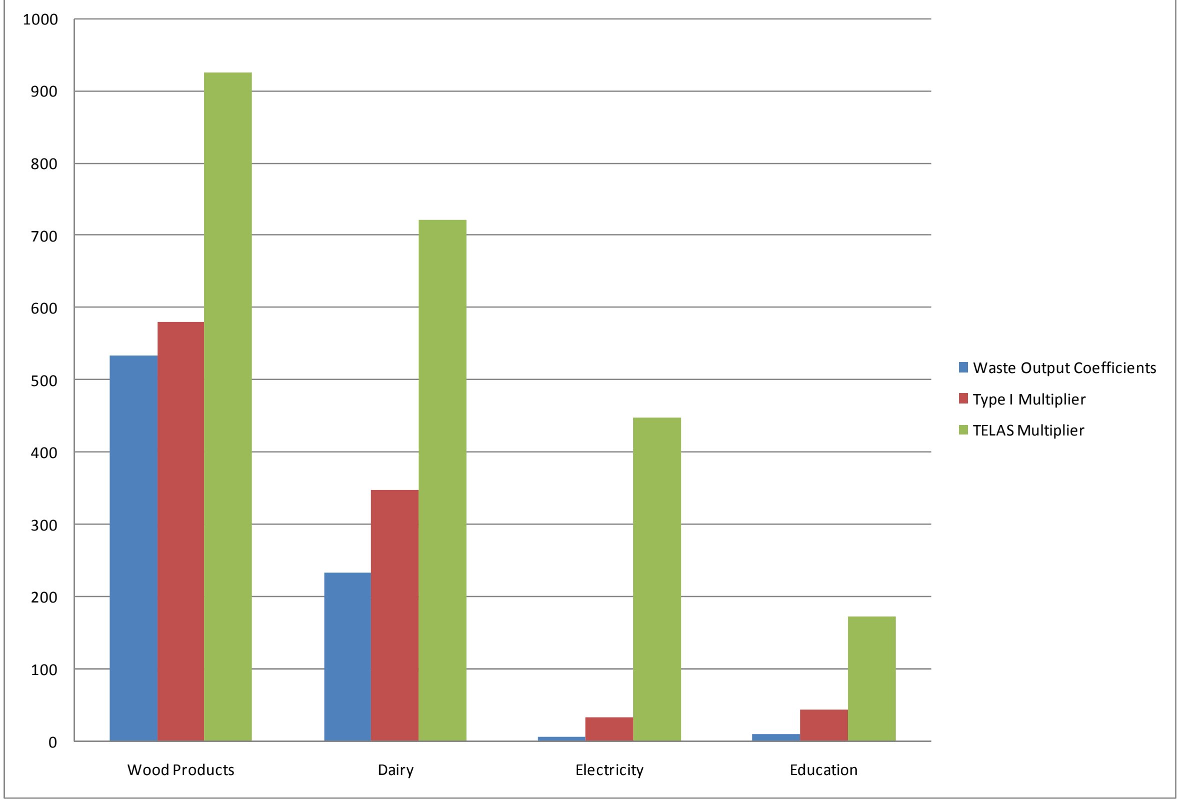
Wood Products

Wood Products is a sector that represents a relatively high waste intensity and also a relatively high import share. While the region produces large amounts of softwood, it is unfit for use for many wood products meaning that the producers of wood products tend to import a large percentage of their inputs through ports in South Wales or from the wider UK. This is also a sector where there has been a great deal of policy interest at the regional level, particularly in terms of increasing local wood product use in local industry supply chains. This industry has also been linked to the waste reduction initiative, biomass energy and is a major recycler of products.

If we examine the apportionment of the output-waste TELAS multiplier for *Wood Products*, we get the following breakdown (see Figure 6):

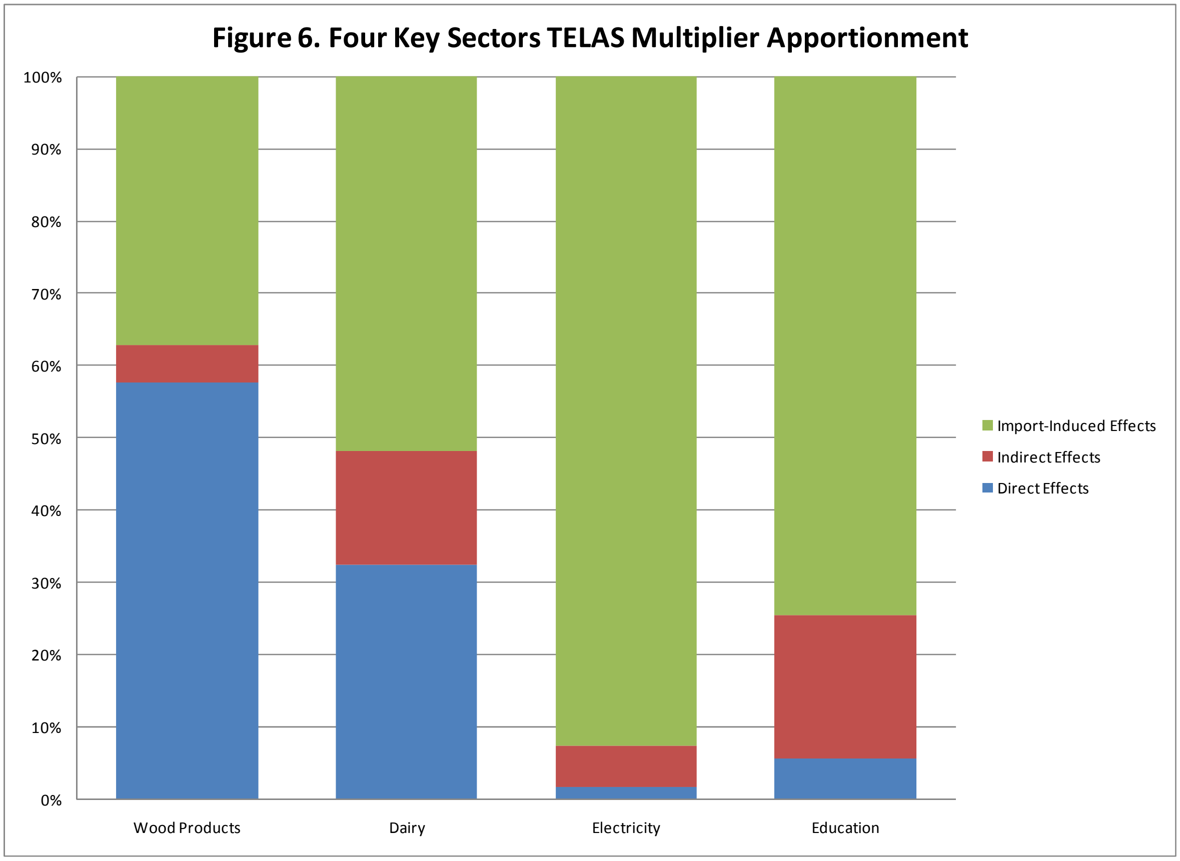
- Direct Effects: 58%
- Indirect Effects: 5%
- Import-Induced Effects: 37%

Figure 5. Four Key Sectors



As suggested above, a relatively high direct waste intensive industry with a relatively high direct import share such as *Wood Products* reveals relatively large direct effects and relatively large import-induced effects within its TELAS multiplier. Note also from Appendix 2, that the TELAS output-waste multiplier for this sector, at 924.6 tonnes per £1million of output produced to meet (local) final demand is almost double the size of the Trade sector multiplier, at 466.26 tonnes. From a purely environmental standpoint, a possible implication of importing *Wood Products* rather than producing them domestically is reduced domestic waste generation (though note that the size of the *Trade* sector multiplier is influenced by the production of *Wood Products* for export, and this will be an upward influence)[10]. Only 11.5% of this sector's output is consumed locally (by households), with the implication that the majority of its output is produced to meet final demand in other sectors or external demands (i.e. to facilitate trade from the TELAS perspective).

[10] This point in brackets reflects the nature of the problem with using fixed multiplier values to consider the impacts of changes in activity – e.g. a change in the export composition of the economy.



Dairy

Dairy is a sector that represents a relatively high waste intensity with a relatively low import share. Much of Welsh agricultural produce is linked to dairy, and the sector features a relatively well integrated supply chain, but with the sector seeing structural changes due to the rationalization and restructuring of large dairies and creameries.

If we examine the apportionment of the TELAS multiplier for *Dairy*, we get the following breakdown (see Figure 6):

- Direct: 32%
- Indirect: 16%
- Import-Induced: 52%

Large direct effects arise because *Dairy* is a relatively waste intensive sector. However, having a low import share generally implies a relatively low import-induced effect whereas that is not the case in this sector. Import-induced effects are not necessarily only related to the sector in question. *Dairy*'s relatively large import-induced effects in its TELAS output-waste multiplier can be explained through backward linkages particularly to *Agriculture* (where 31% of *Dairy*'s input requirement is purchased from, and which itself imports 24% of its own input requirement). Again, with a TELAS output-waste multiplier of 720.78 tonnes per £1m of production to meet local final demand (24% of its output), 255 tonnes more than the *Trade* sector, it could be argued that, from a production accounting perspective at least, it would be better if Wales imported its *Dairy* product requirements.

Electricity

Electricity is a sector that represents a relatively low waste intensity with a relatively high import share. It is an interesting sector in terms of waste attribution as it generates relatively low Type I and Type II multipliers and then produces a much larger TELAS multiplier. The technological base for power generation in Wales is changing as the industry moves towards renewable energy sources and away from conventional coal generation.

If we examine the apportionment of the TELAS multiplier for *Electricity*, we get the following breakdown (see Figure 6):

- Direct: 2%
- Indirect: 6%
- Import-Induced: 92%

These are the results that we would expect for a low waste intensive, high imports intensive sector such as *Electricity*. Due to its low waste intensity, direct and indirect waste generation in this sector account for less than 10% of the TELAS multiplier. *Electricity*'s high import intensity drives the high import-induced effects. Even with this, the TELAS output-waste multiplier, at 447.38 tonnes per £1million of output to meet local final demand is lower than the *Trade* sector output-waste multiplier (466.26 tonnes), suggesting that, in terms of waste concerns, Wales could gain in terms of waste reduction be producing more of its own electricity. Moreover, if the structure of the sector were to change, making it less waste and import intensive, the input-output multiplier analysis suggests that the situation would be more positive.

Education

Education is a sector that represents both a relatively low waste intensity and a relatively low import share. In Wales, this sector has recently seen consistent growth in line with government spending patterns.

If we examine the apportionment of the TELAS multiplier for *Education*, we get the following breakdown (see Figure 6):

- Direct: 6%
- Indirect: 20%
- Import-Induced: 74%

We observe relatively low direct effects due to the low waste intensity of the education sector. However, similar to *Dairy*, we see large import-induced effects in a sector with low import intensity. Once again, effects can be attributed to backward linkages to import intensive industries. In this case, *Education* has strong linkages to *Electricity*, *Computers and Related Services*, *Motor Vehicles*, and *Other Business Services*, all of which all have import shares above 60%. However, *Education* is also one of the simplest sectors to analyse from a TELAS perspective. Almost 78% of its output is produced to meet local consumption demands, which is why, even with a relatively low TELAS output-waste multiplier (172.7 tonnes per £1million output to meet local final demand relative to the *Trade* sector benchmark of 466.26 tonnes), it sees a much higher share of responsibility attributed to its production 2.7% than in the direct (0.2%) and Type I (0.8%) analyses. The discussion above shows that this is due not so much to its own import intensity (though at 25% of its input requirements this could possibly be lowered), but that of the sectors that supply it. It is only through an input-output analysis, where we can carry out a detailed examination of interdependencies between sectors, and of dependence on trade, that such issues can be examined.

4.2 Waste generation under the consumption accounting principle using a domestic technology assumption

Here, we estimate equation (6) from Section 2.3 in a *modelling* exercise to consider the waste implications if Wales were to cease trade and produce all its consumption requirements domestically. That is, as explained in Section 2.3, using (6) we conduct a Type I attribution analysis where imports are incorporated into domestic production and exports are removed from final demand. Detailed results of this analysis are shown in Appendix 5. Here, we examine some key results. We reiterate that the crucial point to bear in mind is the system in (6) is a modelling rather than accounting framework (as in the Type I, Type II and TELAS analyses above) and, as such, produces *hypothetical* simulation results for all economic variables and for the waste account assuming that the region meets all of its own consumption requirements. This means that the total waste generated, W^T, need not be the same as actual waste in the accounting framework, W^R. Indeed, given that in 2003 Wales ran a trade deficit (with imports of goods and services exceeding exports) we would expect that estimation of (6) will give us increased output and waste requirements.

In terms of the change in production output required to satisfy Welsh consumption demands in the absence of trade (that is, what would the output of the Welsh economy have to be were it to become autarkic), we calculate the overall implied increase in output to be 23.6%. Within this, the results in the second column of Appendix 5 show that the required change in output at the sectoral level varies considerably. For example, *Clothing* would need to expand its output by nearly 418% to meet the demands of an autarkic Wales. Similarly *Office Machinery* would require output to increase by 428.69% to meet the Welsh domestic demand in the absence of trade. At the other end of the spectrum, *Cement & Plaster* and *Iron & Steel* would see their output shrink by 56.65% and 28.49% respectively in the absence of trade. This demonstrates the reliance of these industries on non-Welsh demands for their output, i.e. export demand.

Turning to the specific issue of waste generation, the first two columns of Appendix 5 show the impact of the modelled change in the scale and composition of production activity on direct waste generation. The column totals show that the aggregate change in the waste required in support of Welsh production would be an increase of 46%. Given that the proportionate increase in waste (at the aggregate level) is almost double the required increase in aggregate output from production, this implies that, as well as increasing the size of the economy, Wales would have to move towards more waste intensive production if it were to cease trade and meet all of its own consumption demands (i.e. this implies that Wales is currently 'importing sustainability' in terms of waste generation).[11]

However, note that above we are considering the results of the hypothetical analysis under the domestic technology assumption from the perspective of an autarkic situation – i.e. what if Wales were a closed economy meeting all of its own consumption demands. The domestic technology assumption is also commonly employed in full footprint analyses (the fifth option in Table 1 in Section 2) where data are not available on the production and waste generation technology employed in exporting countries. From a footprint perspective, it is worth bearing in mind that if (as seems a reasonable speculation) the waste embodied in the

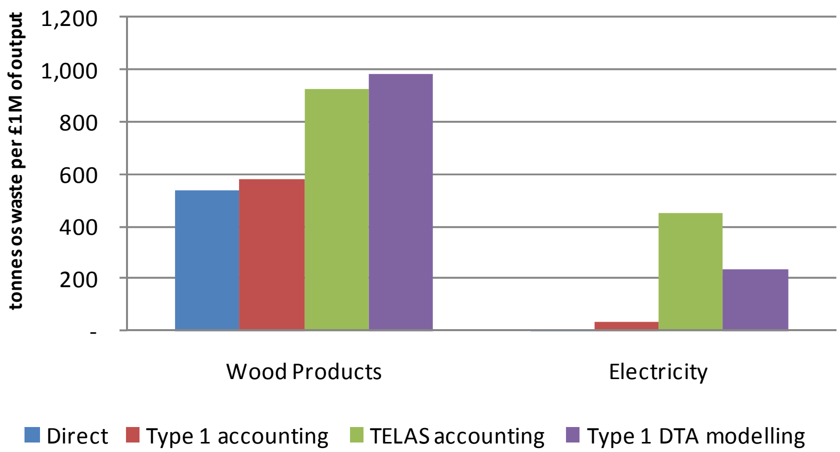
[11] Note that at the sectoral level, the proportionate change in waste and output is the same. This is due to the assumption of fixed proportional Leontief technology in the relationship between the two variables (and all others) at the sectoral level. What gives us the difference at the aggregate level is a change in the composition of activity in the Welsh economy.

production of the output of, for example, *Clothing* from other countries is greater than the waste that would be generated in the Welsh production of *Clothing*, then the actual waste supported by Welsh consumption may be higher still.

The third column of Appendix 5 show the Type I output-waste multipliers that form the $\omega^{P}[\mathbf{I}-(\mathbf{R}+\mathbf{M})]^{-1}$ element in the calculation of equation (6) – i.e. tonnes of waste per £1m final demand for sectoral output and comparable to the results of the standard Type I IO accounting exercise in the second column of Table 2 (though these now incorporate direct and indirect effects associated with imports, which were previously not considered in the Type I analysis). The fourth column of Appendix 5 shows the resulting attribution of waste generation to final demand for sectoral outputs/commodities (comparable to the results in the second column of Appendix 3) and the fifth shows the results of this attribution in percentage terms (comparable to Figures 2, 3 and 4 in Section 4.1).

Using the output-waste multipliers, Figure 7 gives us a useful comparison between the TELAS accounting results and the modelling exercise under the domestic technology assumption (DTA). Here we take the two sectors identified in Figures 5 and 6 in the TELAS analysis in Section 4.1 as having high direct import intensities, and, therefore, relatively high import-induced effects in the TELAS output-waste multipliers. These were *Wood Products* and *Electricity*. Figure 7 shows the TELAS multipliers for these two sectors again (alongside the direct waste intensities and conventional Type I output-waste multipliers from the accounting analysis in Section 4.1) and compares them with the Type I output-waste multipliers from the DTA modelling exercise. The more interesting of the two is *Electricity*. Here we see that the TELAS multiplier, at just over 447 tonnes of waste per £1million output to meet final demand is much larger than the Type I DTA multiplier at just under 233 tonnes. In understanding the result, it is important to remember that the TELAS analysis involves allocating waste generation embodied in export production to the sectors whose imports these exports are financing. In the DTA analysis, we are estimating the actual waste generation involved in producing imports under the domestic technology assumption. Therefore, comparing the DTA Type I multipliers to the TELAS ones (and conventional Type 1 to focus on the additional impact of imports to production) for *Electricity* implies that the exports that are taken to finance imports to the *Electricity* sector in the TELAS analysis are more (directly and indirectly) waste intensive than the actual imports themselves (as estimated here using the DTA).

Figure 7. Key sector waste-output multiplier comparisons (sectors with relatively high direct imports)



In the case of the *Wood Products* sector, on the other hand, the DTA Type I and TELAS output-waste multipliers are very close in magnitude (985 tonnes and 925 tonnes respectively). However, it is important to note that the two approaches are measuring very different things. The results in Figure 7 simply suggest that the exports which finance *Wood Products* imports have a similar level of waste embodied as the imports themselves.

However, in both cases we should bear in mind that in the 2003 account, Wales did not produce sufficient exports to fully finance its imports (i.e. there was a trade deficit) implying that the TELAS multipliers are likely to be understated.

5. Discussion and conclusions

This paper has focused on different methods of waste attribution within a regional input-output accounting framework. UK regions have prioritized the reduction in absolute amounts of wastes and in the case region of Wales examined in this paper a zero waste strategy has been muted in recent planning documents. However, in Wales, as in other UK regions, monitoring activity has centred on waste created within physical boundaries, rather than considering how regional consumption creates a waste footprint further afield. We argue that general sustainable development indicators in the Welsh case suggest that some consideration should be given to the consumption principle rather than just the production principle with respect to waste, and with the relatively open nature of the regional economy meaning that monitoring of sustainable development duties that specifically excludes trade may be problematic. Indeed a broad footprint principle is advocated in environmental strategy documents in the Welsh case. Moreover, similar conclusions have been made with respect to climate change indicators (greenhouse gas indicators) where monitoring under the production principle provides a very partial understanding of regional 'responsibilities'.

While a consumption principle for regional monitoring may be desirable, there are problems in deriving appropriate information. In this paper we have explored a series of approaches to understanding the issue of who creates waste in Wales, considering production and consumption principles using the single-region data that are currently available. It is suggested that the single region input-output framework is a useful starting point for a detailed attribution analysis, and an important adjunct for regional policy makers exploring industries and consumptive behaviors that create waste both directly and indirectly.

The paper presents a menu of options for waste attribution analysis in the regional economy. Importantly, the paper has revealed that the approaches vary in their ability to encompass trade, and vary considerably in terms of underlying assumptions. The analysis for selected industries reveals that each approach has some value. However, we believe that the TELAS and Domestic Technology Assumption methods may provide particularly useful insights for policymakers in that both explicitly deal with issues of trade: the former is a means of linking all domestic waste generation to domestic private and public consumption categories, and with the latter providing an insight into the nature of the regional waste footprint. There are issues involved in the use of these measures. However, provided that the underlying assumptions, and their implications, are understood, these measures are a cost effective and transparent means of gaining waste attribution insights. We accept that in the case of the approach focusing on domestic technology assumptions this is something of a half way house towards a full consumption accounting principle. However, it allows us to consider what the waste implications of Welsh consumption would be in the absence of trade, thereby highlighting the importance of trade to the Welsh economy. Moreover, it is expected that few regions have the resources to produce the extensive data that a complete inter-regional footprint analysis would require. For example, the approaches discussed in this paper only require data on the regional economy and not the large amounts of economic, trade, and waste generation data from regional and national economies that are linked to Wales through trade.

Care is obviously required in drawing too much inference from modelled results from an input-output framework. The general limitations of the input-output approach are well known and are not repeated here (see Miller and Blair, 1985, for a review). Moreover, at the time of writing, not all UK regions have published input-output tables available, but with many having access to tables which have been mechanically derived from the UK input-output framework, the type of analysis undertaken here could be repeated for other UK regions.

Going forward, there is a series of possibilities. The paper has concentrated on total waste generated. However, in terms of policy development and monitoring there is particular interest in different types of waste. We have shown that the approaches explored can be adapted for different waste streams fairly easily (and could be used for examining other externalities, such as generation of greenhouse gases). As shown by Leontief (1970), the input-output approach can also be extended to consider the resource implications of disposing of waste generated in the economy (see Allan *et al*, 2007, for an application to waste generation and disposal in Scotland). Furthermore, there is the possibility within the underlying regional input-output framework of deriving scenarios based on changes in consumer behavior and industry structure. This is of interest at the moment with the structure of the regional economy changing through the recession and with a need for planning purposes to understand what this means for waste generation. The framework also allows policy makers to investigate changing demands for different waste management options, and expected changes in the regulatory pressures placed on regional industries and consumers. However, we would qualify this last point by noting the particular limitations of input-output techniques in analyzing the impacts of *changes* in activity, which centre on the conventional input-output model's silence on prices and assumption of inelastic supply. For this reason, another priority for future research may be to relax these assumptions in a more flexible computable general equilibrium framework (where the waste input-output framework constructed here would serve as the core database).

References

Allan, G., Hanley, N.D., McGregor, P.G., Swales, J.K. and Turner, K.R. (2007) Augmenting the Input-Output Framework for "Common Pool" Resources: Operationalising the Full Leontief Environmental Model, *Economic Systems Research*, 19, pp. 1-22.

ARUP (2009) *Ecological footprint impact of the Welsh Waste Strategy*. Study report for the Welsh Assembly Government, by Ove Arup and Partners Limited, Admiral House, 78 East Street, Leeds.

Bryan, J., Jones, C., Munday, M. and Roberts, A. (2004) *input-output tables for Wales 2000*. Cardiff: Cardiff Business School.

Collins, A., Jones, C. and Munday, M. (2009) Assessing the environmental impacts of mega sporting events: Two options? *Tourism Management*, forthcoming.

Dixit, A.K. and Norman, V., (1980). *Theory of International Trade*. Cambridge University Press, Cambridge.

Druckman, A., Bradley, P., Papathanasopoulou, E. and Jackson, T. (2008) Measuring progress towards carbon reduction in the UK, *Ecological Economics*, 66.4: 594-604

Druckman, A and Jackson, T. (2009) The carbon footprint of UK households 1990–2004: A socio-economically disaggregated, quasi-multi-regional input–output model, *Ecological Economics*, 68.7: 2066-2077.

DTZ and WERU (Welsh Economy Research Unit), (2007). *Experimental Environmental Satellite Accounts for Wales*. Report for Economic Research Advisory Panel. Cardiff: Welsh Assembly Government. See http://wales.gov.uk/firstminister/research/economic/completed/satelliteaccounts/environmentalsatelliteng.pdf?lang=en accessed 13th August 2009.

Environment Agency Wales (2008) *An assessment of waste data for the Waste Strategy Review.* A report for the Welsh Assembly Government by Environment Agency Wales, Cambria House, Newport Road, Cardiff.

Frater L. and Hines, F. (2004) *Commercial and Industrial Waste Survey Wales 2003*. Report for Environment Agency Wales and Biffaward.

Hogg, D. and Elliott, T. (2009) *Future recycling and landfill diversion targets for Wales.* Report for Welsh Assembly Government by Eunomia Research and Consulting, 62 Queen Square, Bristol.

Jones, C and Munday, M. (2007) Exploring the environmental consequences of tourism: A satellite account approach, *Journal of Travel Research*, 46, 2: 164-172.

Leontief, W. (1970) Environmental repercussions and the economic structure: an input-output approach. *Review of Economic Statistics*, 52: 262-277.

McGregor, P., McNicoll, I., Swales, J. Kim., and Turner K (2001) Who Pollutes in Scotland, *FAI Quarterly Economic Commentary*, 26, 23-32.

McGregor, P.G., McLellan, D., Swales, J.K., Turner, K.R. (2004) Attribution of Pollution Generation to Local Private and Public Demands in a Small Open Economy: Results from a SAM-Based Neo-Classical Linear Attribution System. Mimeo, Strathclyde Discussion Papers in Economics, 04–08.

McGregor, P.G., Swales, J.K. and Turner, K. (2008). The CO2 trade balance between Scotland and the rest of the UK: performing a multi-regional environmental input-output analysis with limited data. *Ecological Economics*, 66; 662-673.

Munday, M. and Roberts, A. (2006) Developing approaches to measuring and monitoring sustainable development in Wales: A review, *Regional Studies*, 40: 535-544.

Munksgaard, J. and Pedersen, K.A., (2001). CO2 accounts for open economies: producer or consumer responsibility? *Energy Policy*, 29:327-334

National Statistics (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

Turner, K., Lenzen, M., Wiedmann, T. and Barrett, J., (2007). Examining the Global Environmental Impact of Regional Consumption Activities – Part 1: A Technical Note on Combining Input-Output and Ecological Footprint Analysis, *Ecological Economics*, 62(1): 37-44.

Urban Mines (2009) *Survey of Commercial and Industrial Waste Arisings in Wales*. Report for Environment Agency Wales, Cambria House, Cardiff and see http://www.environment-agency.gov.uk/static/documents/Research/Survey_of_Industrial_and_Commercial_Waste_Arisings_in_Wales_2007.pdf accessed 13th August 2009

Welsh Assembly Government (2008) *One Wales: One Planet* – Consultation on a new Sustainable Development Scheme for Wales

Welsh Assembly Government (2008) *Sustainability Appraisal of the Draft Wales Waste Strategy*: Annex A: Review of Policy Plans and Programmes & Annex B Environmental, Economic and Social Baseline.

Welsh Assembly Government (2009a) *Towards Zero Waste – A Consultation on a New Waste Strategy for Wales*. Waste Strategy Branch, Department for Environment, Sustainability and Housing, Welsh Assembly Government see http://wales.gov.uk/docs/desh/consultation/090429wasteconsultationen.pdf accessed 13th August 2009.

Welsh Assembly Government (2009b) *State of the Environment.* 23rd July 2009. Available for http://www.statswales.wales.gov.uk, accessed 16th September 2009.

WERU (Welsh Economy Research Unit) (2007) *Welsh Input-Output Tables for 2003*, Report for Welsh Assembly Government, and available on request from WERU, Cardiff Business School, Colum Drive, Cardiff, CF10 3EU.

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.

World Wildlife Fund (2007) *One Planet Wales: Transforming Wales for a prosperous future within our fair share of earths resources*.

Appendix 1: Sectoral Aggregation Scheme

Sector #	Sector Description	SIC
1	Agriculture & Fish	1, 5
2	Forestry	2
3	Coal Extraction	10, 11, 12
4	Other Mining & Quarrying	13, 14
5	Meat	15.1, 15.4
6	Dairy	15.5
7	Fish Products, Vegetables, Grain Mill Products	15.2, 15.3, 15.6
8	Bread & Biscuits	15.81, 15.82
9	Misc Foods	15.7, 15.85 to 15.89
10	Confectionery	15.83, 15.84
11	Drinks and Tobacco	15.91 to 15.98, 16
12	Textiles	17.1 to 17.7
13	Clothing	18, 19.1 to 19.3
14	Wood Products	20
15	Paper and Pulps	21.1, 21.2
16	Publishing	22
17	Oil Processing	23
18	Chemicals	24.1 to 24.3, 24.6, 24.7
19	Pharmaceutical	24.4
20	Soaps	24.5
21	Rubber Products	25.1
22	Plastics	25.2
23	Glass and Ceramics	26.1 to 26.3
24	Cement/Plaster	26.4 to 26.8
25	Iron and Steel	27.1 to 27.3
26	Aluminium & Non-Ferrous Metals	27.41, 27.43, 27.45
27	Forging/Pressing	27.5, 28.4, to 28.7.
28	Structural Metals	28.1, 28.2, 28.3
29	Machinery	29.1 to 29.6
30	Domestic Appliances	29.7
31	Office Machinery	30
32	Electrical Motors and Transformers	31.1, 31.2
33	Wires and Cables	31.3
34	Industrial Electrical Equipment	31.4 to 31.6
35	Electronic Components	32.1, 32.2
36	TVs	32.3
37	Control Equipment	33
38	Motor Vehicles	34
39	Other Vehicles	35
40	Furniture	36.1
41	Other Manufacturing	36.2 to 36.6, 37
42	Electricity	40.1
43	Gas	40.2, 40.3
44	Water	41
45	Construction	45
46	Distribution and Repairs	50
47	Wholesale	51
48	Retail	52
49	Hotels, Restaurants, and Catering	55
50	Railways	60.1
51	Road Transport	60.2, 60.3
52	Sea and Air Transport	61, 62
53	Transport Services and Travel	63
54	Postal Services	64.1
55	Telecomms	64.2
56	Banking and Finance	65.1
57	Insurance	66, 67
58	Other Financial Services	65.2
59	Real Estate	70.1, 70.3
60	Ownership of Dwellings	70.2
61	Renting of Moveables	71
62	Legal Services	74.11
63	Accountancy Services	74.12
64	Computer and Related Activities	72
65	R&D	73
66	Market Research & Advertising	74.13 - 74.15, 74.4
67	Other Business Services	74.5 - 74.8
68	Other Professional Services	74.2, 74.3
69	Public Administration	75
70	Education	80
71	Health	85.1, 85.2
72	Recreation Services	85.3, 91, 92
73	Sanitary Services	90
74	Other Services	93, 95

Appendix 2: Direct Waste Output Coefficients and Output-Waste Multipliers (tonnes per £1million activity)

Sector #	Sector Description	Waste Output Coefficients	Type 1 Waste Output Multipliers	Type 2 Waste Output Multipliers	TELAS Output Waste Multipliers
1	Agriculture & Fish	159.90	223.58	278.49	631.22
2	Forestry	27.52	96.39	203.16	405.40
3	Coal Extraction	-	54.33	137.32	347.20
4	Other Mining & Quarrying	28,438.14	29,314.88	29,383.62	29,645.75
5	Meat	208.44	295.95	362.82	643.36
6	Dairy	234.13	347.93	410.75	720.78
7	Fish Products, Vegetables, Grain Mill Products	128.62	196.95	264.24	555.62
8	Bread & Biscuits	78.33	118.12	205.48	397.15
9	Misc Foods	78.34	135.42	208.50	463.39
10	Confectionery	78.11	127.01	206.14	445.50
11	Drinks and Tobacco	20.25	56.14	109.74	446.88
12	Textiles	40.46	67.29	154.22	345.96
13	Clothing	19.54	56.83	139.39	353.95
14	Wood Products	533.29	580.88	648.60	924.60
15	Paper and Pulps	79.49	135.36	191.13	490.03
16	Publishing	138.54	163.23	252.25	456.12
17	Oil Processing	-	26.03	55.01	433.43
18	Chemicals	26.43	72.80	131.27	418.43
19	Pharmaceutical	23.02	49.75	131.68	362.33
20	Soaps	80.62	124.45	199.97	426.76
21	Rubber Products	100.70	142.93	240.33	402.09
22	Plastics	96.50	133.10	220.52	410.82
23	Glass and Ceramics	116.60	242.91	330.05	531.63
24	Cement/Plaster	105.90	418.99	493.97	761.19
25	Iron and Steel	147.15	281.82	353.08	581.20
26	Aluminium & Non-Ferrous Metals	1.11	96.33	143.88	469.71
27	Forging/Pressing	113.47	154.76	253.96	406.77
28	Structural Metals	106.92	166.50	260.42	423.48
29	Machinery	54.21	85.58	166.00	385.08
30	Domestic Appliances	44.12	72.62	146.67	393.73
31	Office Machinery	18.41	55.94	112.45	398.11
32	Electrical Motors and Transformers	38.67	72.48	150.57	388.61
33	Wires and Cables	214.67	245.77	318.77	564.01
34	Industrial Electrical Equipment	82.14	113.55	197.30	410.67
35	Electronic Components	26.37	65.46	129.43	407.79
36	TVs	6.27	41.40	103.97	375.61
37	Control Equipment	425.57	464.54	552.24	742.20
38	Motor Vehicles	39.49	110.34	174.40	430.95
39	Other Vehicles	21.86	56.25	129.13	374.84
40	Furniture	494.51	566.94	640.06	893.76
41	Other Manufacturing	983.43	1,019.99	1,085.10	1,369.69
42	Electricity	7.47	33.62	63.33	447.38
43	Gas	-	35.43	73.11	444.01
44	Water	-	71.93	127.92	482.37
45	Construction	1,765.37	2,320.94	2,392.90	2,656.29
46	Distribution and Repairs	290.15	319.80	414.08	589.22
47	Wholesale	37.43	90.43	179.46	370.87
48	Retail	155.53	192.09	270.28	510.49
49	Hotels, Restaurants, and Catering	107.77	150.21	231.68	468.21
50	Railways	4.10	64.16	149.65	346.51
51	Road Transport	32.85	59.48	159.11	291.61
52	Sea and Air Transport	23.28	43.38	109.73	358.53
53	Transport Services and Travel	17.44	76.34	163.71	365.13
54	Postal Services	97.44	121.38	246.68	326.06
55	Telecomms	1.68	49.48	120.67	405.27
56	Banking and Finance	1.24	46.69	121.97	369.18
57	Insurance	15.96	79.63	149.57	395.75
58	Other Financial Services	2.79	29.43	121.36	304.53
59	Real Estate	3.60	119.20	167.62	592.56
60	Ownership of Dwellings	1.10	121.01	133.87	742.11
61	Renting of Moveables	82.80	112.95	201.28	423.83
62	Legal Services	5.98	24.07	112.55	360.15
63	Accountancy Services	5.99	23.79	122.93	334.05
64	Computer and Related Activities	10.85	26.76	125.43	302.02
65	R&D	81.70	100.85	205.06	367.31
66	Market Research & Advertising	5.55	29.24	111.06	346.02
67	Other Business Services	71.45	98.45	197.97	361.60
68	Other Professional Services	42.39	69.85	188.61	304.02
69	Public Administration	10.26	117.08	230.67	339.33
70	Education	9.86	44.13	199.91	172.69
71	Health	11.02	38.87	133.71	319.46
72	Recreation Services	39.50	74.51	188.82	315.18
73	Sanitary Services	51.74	107.94	201.29	391.22
74	Other Services	67.96	85.54	187.91	371.07
	HH	56.18		212.67	
	Trade				466.26
	Capital				683.04

Appendix 3: Direct Waste Distribution and Attribution (tonnes) to Final Demand for Sectoral Output

Sector #	Sector Description	Direct Waste Distribution	Type I Attribution to Final Demand	Type II Attribution to Final Demand	TELAS Attribution to Final Demand
1	Agriculture & Fish	175,042	141,161	145,303	69,196
2	Forestry	2,209	5,100	10,604	288
3	Coal Extraction	-	554	938	1,170
4	Other Mining & Quarrying	6,100,000	4,973,510	4,914,742	71,059
5	Meat	178,264	199,349	166,461	138,196
6	Dairy	89,001	115,003	97,932	66,392
7	Fish Products, Vegetables, Grain Mill Products	39,305	42,628	40,712	34,653
8	Bread & Biscuits	31,895	36,343	41,298	42,373
9	Misc Foods	18,266	15,769	11,632	28,106
10	Confectionery	5,642	6,857	7,625	7,571
11	Drinks and Tobacco	9,994	25,685	15,864	139,860
12	Textiles	15,664	24,861	55,769	2,706
13	Clothing	3,369	8,008	16,720	7,422
14	Wood Products	210,801	177,779	168,896	42,212
15	Paper and Pulps	65,772	89,393	121,512	12,063
16	Publishing	92,128	50,278	70,191	13,574
17	Oil Processing	-	6,581	10,571	26,322
18	Chemicals	56,057	142,270	252,935	11,500
19	Pharmaceutical	5,682	8,770	22,445	2,112
20	Soaps	29,519	37,693	41,814	40,027
21	Rubber Products	8,684	9,165	14,398	1,696
22	Plastics	101,165	83,899	133,037	11,108
23	Glass and Ceramics	36,628	57,919	75,871	4,549
24	Cement/Plaster	40,358	97,160	109,216	8,215
25	Iron and Steel	304,175	466,537	582,759	2,871
26	Aluminium & Non-Ferrous Metals	990	76,675	113,361	3,767
27	Forging/Pressing	119,953	109,029	170,207	13,952
28	Structural Metals	47,190	54,745	83,530	3,409
29	Machinery	51,822	59,658	111,232	10,420
30	Domestic Appliances	13,907	21,897	42,059	5,810
31	Office Machinery	1,802	4,143	8,017	1,101
32	Electrical Motors and Transformers	13,508	22,627	45,618	3,580
33	Wires and Cables	30,378	31,074	39,986	559
34	Industrial Electrical Equipment	39,734	47,331	80,778	3,041
35	Electronic Components	12,264	26,783	51,455	4,731
36	TVs	4,049	23,279	57,507	3,475
37	Control Equipment	332,807	321,397	375,607	8,693
38	Motor Vehicles	75,113	189,308	294,443	11,745
39	Other Vehicles	32,003	71,037	158,835	12,330
40	Furniture	325,266	285,217	275,959	64,297
41	Other Manufacturing	505,989	471,440	489,559	15,118
42	Electricity	19,868	57,346	91,588	116,168
43	Gas	-	1,737	1,596	12,079
44	Water	-	16,658	14,975	55,249
45	Construction	5,952,000	5,010,632	4,778,600	430,030
46	Distribution and Repairs	280,838	183,695	45,921	273,108
47	Wholesale	66,511	77,571	118,176	73,916
48	Retail	602,862	713,357	129,496	1,651,188
49	Hotels, Restaurants, and Catering	267,115	335,874	313,639	414,998
50	Railways	1,932	20,242	30,767	38,091
51	Road Transport	38,871	32,403	59,241	50,296
52	Sea and Air Transport	5,148	7,385	11,295	24,128
53	Transport Services and Travel	20,681	46,275	88,420	24,132
54	Postal Services	42,492	12,822	17,893	10,793
55	Telecomms	1,769	33,287	50,237	103,936
56	Banking and Finance	2,913	53,111	114,786	72,484
57	Insurance	8,128	12,735	16,486	19,667
58	Other Financial Services	1,550	10,498	37,819	13,723
59	Real Estate	1,787	33,283	46,804	-
60	Ownership of Dwellings	3,883	426,362	3,025	2,598,038
61	Renting of Moveables	26,016	12,829	10,783	25,433
62	Legal Services	3,681	7,530	33,580	5,225
63	Accountancy Services	2,190	1,524	7,558	863
64	Computer and Related Activities	5,656	3,263	15,013	686
65	R&D	7,685	2,706	5,498	9
66	Market Research & Advertising	4,008	11,946	45,371	21
67	Other Business Services	89,404	58,069	113,534	5,902
68	Other Professional Services	26,992	18,891	49,320	2,731
69	Public Administration	55,527	628,845	1,221,464	1,835,032
70	Education	36,667	147,752	623,654	499,001
71	Health	73,245	183,560	596,015	1,506,059
72	Recreation Services	138,463	191,718	305,576	689,832
73	Sanitary Services	42,559	62,572	98,857	113,773
74	Other Services	33,791	36,240	(11,757)	180,428
	HH	1,522,000	1,522,000		1,522,000
	Trade				5,292,336
	Capital				-
	TOTAL	**18,612,628**	**18,612,628**	**18,612,628**	**18,612,628**

Appendix 4: Summary of Attribution of Total Waste (tonnes) to Type of Final Consumer			
	Type I	**Type II**	**TELAS**
Local households	3,860,721	-	14,452,431
Local government and non-profit institutions serving households	1,028,998	2,631,475	4,160,197
Total local (private and public) consumption demand	**4,889,719**	**2,631,475**	**18,612,628**
Capital Formation	3,763,842	3,948,650	-
Stocks	2,207,451	2,254,861	-
Total capital formation	**5,971,294**	**6,203,511**	**-**
RUK exports (g&s)	5,457,260	6,743,425	-
ROW exports (g&s)	1,959,078	2,508,818	-
Total exports (g&s)	**7,416,338**	**9,252,244**	**-**
Total external tourists	**335,278**	**525,399**	**-**
Total waste attributable to final consumers	**18,612,628**	**18,612,628**	**18,612,628**

Appendix 5: Results of Consumption Analysis under the Domestic Technology Assumption

	Sector	Hypothetical direct waste distribution (tonnes).	Hypothetical % change in direct waste generation (and output) relative to actual 2003.	Type I hypothetical output-waste multipliers (tonnes per £1m output/exp).	Type I attribution to final demand for commodities.
1	Agriculture & Fish	256,871.93	46.75%	451.69	250,786
2	Forestry	1,670.45	-24.36%	227.83	1,807
3	Coal Extraction	-	0.00%	358.86	1,798
4	Other Mining & Quarrying	12,219,833.47	100.33%	33,039.92	2,561,380
5	Meat	246,713.01	38.40%	610.33	335,787
6	Dairy	109,921.50	23.51%	648.79	195,334
7	Fish Products, Vegetables, Grain Mill Produc	87,006.61	121.36%	466.30	160,088
8	Bread & Biscuits	43,322.28	35.83%	355.92	115,419
9	Misc Foods	37,850.34	107.22%	398.63	81,331
10	Confectionery	24,206.46	329.06%	353.45	53,985
11	Drinks and Tobacco	21,307.86	113.20%	316.05	291,075
12	Textiles	40,239.75	156.89%	296.50	108,587
13	Clothing	17,449.73	417.99%	242.02	164,166
14	Wood Products	320,517.09	52.05%	985.22	212,419
15	Paper and Pulps	107,890.91	64.04%	610.42	96,117
16	Publishing	188,800.58	104.93%	370.91	157,168
17	Oil Processing	-	0.00%	359.36	68,304
18	Chemicals	56,276.52	0.39%	834.18	139,947
19	Pharmaceutical	13,772.54	142.38%	238.99	14,758
20	Soaps	33,866.03	14.73%	406.20	106,203
21	Rubber Products	22,633.48	160.63%	466.27	22,740
22	Plastics	100,419.56	-0.74%	496.20	53,388
23	Glass and Ceramics	31,731.77	-13.37%	2,054.45	61,201
24	Cement/Plaster	28,860.72	-28.49%	2,850.23	62,986
25	Iron and Steel	131,864.28	-56.65%	2,841.39	60,747
26	Aluminium & Non-Ferrous Metals	990.26	0.00%	3,734.43	63,070
27	Forging/Pressing	162,879.78	35.79%	1,001.32	280,035
28	Structural Metals	47,380.35	0.40%	956.92	156,517
29	Machinery	86,288.75	66.51%	648.50	309,144
30	Domestic Appliances	10,840.35	-22.05%	590.06	111,081
31	Office Machinery	9,528.40	428.69%	480.41	36,233
32	Electrical Motors and Transformers	13,603.82	0.71%	435.18	63,413
33	Wires and Cables	29,112.61	-4.17%	1,139.65	62,692
34	Industrial Electrical Equipment	46,541.83	17.13%	498.97	42,146
35	Electronic Components	25,460.77	107.60%	425.82	88,509
36	TVs	6,644.56	64.11%	349.59	185,923
37	Control Equipment	419,834.16	26.15%	777.13	291,088
38	Motor Vehicles	104,308.76	38.87%	858.88	1,539,967
39	Other Vehicles	30,851.55	-3.60%	434.34	258,426
40	Furniture	428,807.41	31.83%	980.76	417,654
41	Other Manufacturing	870,647.11	72.07%	1,613.62	1,013,313
42	Electricity	14,559.29	-26.72%	232.94	85,617
43	Gas	-	0.00%	307.58	36,346
44	Water	-	0.00%	233.20	28,834
45	Construction	7,056,848.33	18.56%	3,779.21	7,256,664
46	Distribution and Repairs	346,884.97	23.52%	501.15	255,876
47	Wholesale	55,189.60	-17.02%	299.05	84,504
48	Retail	564,300.88	-6.40%	349.81	1,159,488
49	Hotels, Restaurants, and Catering	242,548.36	-9.20%	308.04	557,676
50	Railways	2,174.73	12.57%	301.98	85,466
51	Road Transport	51,143.16	31.57%	190.43	49,781
52	Sea and Air Transport	18,968.33	268.47%	188.98	81,369
53	Transport Services and Travel	25,534.48	23.47%	308.49	28,932
54	Postal Services	47,856.78	12.63%	217.18	9,641
55	Telecomms	2,482.42	40.30%	236.46	125,112
56	Banking and Finance	2,740.28	-5.92%	187.74	68,702
57	Insurance	30,866.53	279.75%	270.51	305,962
58	Other Financial Services	1,113.55	-28.18%	133.38	8,999
59	Real Estate	3,071.33	71.85%	328.02	77,952
60	Ownership of Dwellings	3,904.30	0.56%	296.66	1,051,090
61	Renting of Moveables	45,044.46	73.14%	225.07	23,168
62	Legal Services	3,820.26	3.77%	87.22	7,960
63	Accountancy Services	2,926.62	33.66%	83.83	185
64	Computer and Related Activities	14,991.85	165.04%	119.29	6,955
65	R&D	25,967.39	237.89%	189.83	89
66	Market Research & Advertising	8,766.74	118.73%	139.62	41,246
67	Other Business Services	195,584.79	118.77%	211.31	19,738
68	Other Professional Services	38,978.60	44.41%	155.06	11,442
69	Public Administration	56,204.98	1.22%	371.21	2,012,273
70	Education	34,949.23	-4.68%	140.35	412,936
71	Health	89,236.25	21.83%	170.49	791,201
72	Recreation Services	164,800.00	19.02%	180.43	503,884
73	Sanitary Services	32,325.02	-24.05%	309.55	99,357
74	Other Services	36,505.17	8.03%	166.18	71,864
	HH	1,522,000.00	0.00%	-	1,522,000
	Total	**27,179,035.99**	**46.02%**	**-**	**27,179,036**