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RESPONSIBILITY FOR REGIONAL WASTE GENERATION: A SINGLE REGION EXTENDED INPUT-OUTPUT ANALYSIS WITH UNI-DIRECTIONAL TRADE FLOWS

BY

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Responsibility for regional waste generation: A single region extended input-output analysis with uni-directional trade flows

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Abstract. The paper uses a regional input-output (IO) framework and data derived on waste generation by industry to examine regional accountability for waste generation. In addition to estimating a series of industry output-waste coefficients, the paper considers two methods for waste attribution but focuses first on one (trade endogenised linear attribution system (TELAS)) that permits a greater focus on private and public final consumption as the main exogenous driver of waste generation. Second, the paper uses a domestic technology assumption (DTA) to consider a regional 'waste footprint' where local consumption requirements are assumed to be met through domestic production.

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Key words: waste attribution; regional economy; input-output analysis; Wales
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Introduction

This paper uses a regional input-output framework together with survey data on waste generation by industry to examine regional waste attribution. In addition to estimating a series of industry direct output-waste coefficients, the paper considers two methods for waste attribution and the usefulness of these different methods for policymakers. First, the paper considers waste attribution through a trade endogenised linear attribution system (TELAS see 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. This provides a useful tool for understanding 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, another accounting technique is considered estimating the waste burden imposed by total use of commodities in the region under a domestic technology assumption. This gives a hypothetical 'waste footprint', measuring what domestic waste generation would be were the region to meet all of its consumption demands through domestic production (i.e. in the absence of trade).

As a case study, the paper focuses on Wales, where concern with the waste generated in the 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 (MUNDAY and ROBERTS, 2006). Moreover, waste indicators link closely to other headline indicators that focus on air and water quality and climate change. The increasing burden that waste places on environmental assets, and the future services from those same assets has been acknowledged in the region (see WELSH ASSEMBLY GOVERNMENT, 2009a). Waste strategic objectives for the region are 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. Indeed, SEI (2008) reported that waste generation from consumption based activities (manifested primarily as household waste) contributed around 15% of Wales' ecological footprint (see also ARUP, 2008).

Wales is currently moving towards a new waste strategy in 2010 (WELSH ASSEMBLY GOVERNMENT, 2009a). 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), tying to the Welsh Assembly Government's direct jurisdiction. This is evidenced in part through the indicator set used to monitor progress towards waste targets where the emphasis is in terms of waste generated in Wales and with indicators speaking to quantities of municipal, industrial and commercial wastes and proportions recycled and land filled in the region (see WELSH ASSEMBLY GOVERNMENT, 2009a, 2009b). However, the stated 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).

Consequently, 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 region i.e. trade impacts on 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 not always been matched by the development of approaches to monitor and evaluate progress. Thus, and in the specific context of devolved regional government, it would seem that there is real scope for an economic-environmental accounting and modeling 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: The second section revisits how industry externalities such as pollution and waste are dealt with in an input-output framework, and describes different attribution approaches formally. In particular, the section demonstrates the dangers of focusing on simplistic industry output-waste coefficients when exploring waste attribution, and introduces measures that permit a focus on private and public final consumption as a driver of waste generation. The third section describes the case regional input-output framework constructed and the nature of the waste data used in conjunction with this framework. The fourth section reports the results of the analysis, showing the industry and consumption categories that are highlighted under the selected attribution approaches. 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.

Alternative 'treatments' of waste in input-output frameworks

'Conventional' approaches

LEONTIEF's (1970) basic demand driven input-output framework, where the vector of output produced in each production sector of the economy, **x**, is determined as the product of the Leontief inverse (multiplier) matrix, $[\mathbf{I} - \mathbf{A}]^{-1}$ and the vector of final demands for sectoral outputs, **y**, is extended for waste generation as follows (bold font upper case denotes matrices; bold font lower case vectors, and non-bold lower case scalars):

$$(1) \qquad \mathbf{w} = \mathbf{\Omega}^{\mathbf{P}}[\mathbf{I} - \mathbf{A}]^{-1}\mathbf{y}$$

Where there are i=j=1,…,N industries and commodities (in this paper, N=74) and $\mathbf{\Omega}^{\mathbf{P}}$ is a KxN matrix of direct output-waste coefficients with elements $\omega_{k,i}=w_{ki}/X_i$, where w_{ki} is the physical amount of waste type k generated by each production sector i in producing its output, x_i. Here, there is one type of waste (K=1) so the (1xN) vector $\boldsymbol{\omega}^{\mathbf{P}}$ replaces $\mathbf{\Omega}^{\mathbf{P}}$ in (1) and the vector $\boldsymbol{\omega}^{\mathbf{P}}[\mathbf{I}-\mathbf{A}]^{-1}$ is a 1xN vector of output-waste multipliers, which, for each industry output j, gives the total amount of waste generated in production (across all N production sectors) to meet one unit of final demand for sectoral output j.

There are z=1,...Z final consumption groups (here, in the Type I case, Z=4). Where waste is directly generated by final consumers (e.g. households), with a single waste output, 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. The Zx1 vector of total final expenditures for each type of final consumption group (column totals from the input-output tables) is distinguished from the Nx1 vector, **y**, as **y*** (reported as a column vector). 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:

$$(2) \qquad w^R = \boldsymbol{\omega}^{\mathbf{P}}[\mathbf{I} - \mathbf{A}]^{-1}\mathbf{y} + \boldsymbol{\omega}^{\mathbf{C}}\mathbf{y}^*$$

For a standard Type I input-output analysis, the N industries and Z 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) $$w^R = \boldsymbol{\omega}^{\mathbf{P}}\mathbf{x} + \boldsymbol{\omega}^{\mathbf{C}}\mathbf{y}^*$$

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 principle, 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 NxZ final demand matrix, **Y**, underlying **y** (row totals of **Y** give **y**) into the inter-industry transactions matrix, **A**. This is done to examine induced (income and consumption) effects of employing household services as labour inputs to production. It involves adding a column to the **A** matrix showing household expenditure (which become inputs to household production) per unit of income from employment (the value of household output), and a row showing payments to labour as a share of total input in each production sector. See JENSEN et al. (2009) or MILLER AND BLAIR (1985) for fuller details of the Type II method.

The key features of the standard Type I and Type II environmental input-output approaches (which in this paper are applied to the case 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 an explicit 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)).

Table 1 about here

The TELAS approach to addressing trade issues

McGREGOR et al. (2008) propose a method to address trade issues in a national or regional 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 conventional Type II approach. 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 the vector $\mathbf{y}$ in (2), the approach creates an additional regional production sector in the $\mathbf{A}$ 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 (or these could be separated into two *Trade* sectors), m_{tj}, as a share of the total input/output of the (consuming) Welsh sector j, x_j:

(4) $a_{tj} = m_{tj}/x_j$

The additional column entries are the outputs that are produced for export via the trade sector, t, by each (producing) sector i, x_{it}, per unit of *total* imports used in (intermediate and final consumption), m, as the output of the *Trade* sector:

(5) $a_{it} = x_{it}/m$

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 thus 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 (2) is calculated 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. This is analogous to the Type II case, where each production sector that employs labour is attributed the waste embodied in the share of total household consumption that becomes an 'input' to labour 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) so that inputs to and outputs from the *Trade* sector will not balance. This is similar to the problem with endogenising households in a Type II analysis, where income from employment is unlikely to equal total household expenditure. 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).

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. 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 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. See McGREGOR et al. (2008) for full details.

Formally, under TELAS for Wales, equation (2) is estimated where the **A** matrix becomes, in what follows in the paper, 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** vector 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, the underlying **Y** matrix is a 76x2 matrix (summed across the row for each sector to give the vector, **y**, of total final demand for each sector's output).

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. TELAS 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.

The domestic technology assumption (DTA) – 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 some control) to waste generated in other regions and countries (where they have 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 (essentially a world interregional IO - see Table 1 above). 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 $\boldsymbol{\omega}^{\mathbf{P}}$ and $\boldsymbol{\omega}^{\mathbf{C}}$ of direct output-waste coefficients (direct waste intensities) are applied to a variant of the **A** matrix that records *total* (combined domestic and imported) use of intermediate inputs to production. Thus, there is a revised **[I-**

$\mathbf{A}]^{-1}$ matrix showing the, hypothetical, global multiplier effects if all production to local demands 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 the domestic technology assumption. The data comprise an NxN (74x74) intermediate imports matrix, 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 are re-labelled r_{ij} in this section). In terms of final consumption, there is an additional NxZ (74x4) final consumption matrix, which is labelled $\mathbf{Y^M}$ to distinguish imports to final consumption from the existing **Y** matrix from, 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 Z=3 for Welsh household and government consumption, and capital formation). Again, for the calculation of total supported waste (a scalar), the $\mathbf{Y^R}$ and $\mathbf{Y^M}$ matrices are summed across their rows to give NxI vectors $\mathbf{y^R}$ and $\mathbf{y^M}$ of total final consumption demand for sectoral output/commodities.

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:

$$(6) \qquad w^T = \boldsymbol{\omega}^{\mathbf{P}}[\mathbf{I} - (\mathbf{R} + \mathbf{M})]^{-1}(\mathbf{y}^{\mathbf{R}} + \mathbf{y}^{\mathbf{M}}) + \boldsymbol{\omega}^{\mathbf{C}}\mathbf{y}^*$$

Note that the entries in the (now) 3x1 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 imports are simply disaggregated in terms of commodity/type of output in the $\mathbf{y}^{\mathbf{M}}$ vector).

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 DTA method in (6) is not consistent with TELAS, as there is no consideration of trade issues in this new method – here the issue is 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 $\mathbf{[I\text{-}(R+M)]^{-1}}$ 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 taking it to be fact; rather it is 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 DTA system in (6), unlike the TELAS (or Type I and Type II) accounting frameworks in (2), *will not* replicate the amount of waste generated in Wales as accounted under the direct method in (3) (which corresponds to the 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* techniques (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 one 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– 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 trade is needed, and why, it would seem, any analysis of *domestic* 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.

It is important to emphasise that the focus here and argument in favour of the use of the TELAS approach over alternatives is based on the assumption that one is interested in the issue of domestic waste generation in the regional economy. As noted earlier, if the interest is in the global waste requirements of Welsh consumption, one requires a footprint measure. However, as highlighted in Table 1, a key limitation of footprint measures is their lack of focus on domestic waste (or pollution) generation.

Data

This section considers the data available for the analysis of waste attribution. The Wales analytical input-output tables are the bedrock of the analysis undertaken here (see BRYAN et al., 2004 and WERU, 2007). The latest iteration of the input-output tables for 2003 provides information on the sales and purchases of 74 defined sectors. 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 some limited application for econo-environmental modeling (see MUNDAY and ROBERTS, 2006; BRYAN et al., 2004). It has 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.

Waste data for this analysis came from the *Commercial and Industrial Waste Survey Wales 2003* carried out by the Centre for Business Relationships Accountability Sustainability and Society (BRASS) at Cardiff University (see 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. 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.

For the analysis in this paper total waste tonnages are used 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 later in the conclusions, future work using more disaggregated waste data would also permit an examination of the generation and flows of different waste types and management options in Wales.

Data on total tonnages of waste was 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', i.e. unregulated. There were also some details of waste by sector where data was estimated from parallel surveys undertaken in England. 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 was 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. These data are then aggregated into the 74 industry sectors within the Welsh input-output tables (see Appendix 1) permitting the initial estimation of output-waste coefficients (sectoral direct waste intensities), which are shown in the first column of Appendix 2. These direct waste intensities give the 1x74 vector $\boldsymbol{\omega}^{\mathbf{P}}$ and sole entry ω_z (where z=household consumption) of the $\boldsymbol{\omega}^{\mathbf{C}}$ vector introduced in the second section of the paper. 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 for each production sector, 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) 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 the second section of the paper, and shown below, with no *changes* in final demand, any attribution exercise using equation (2) will return the same numerical result for w^R.

Waste attribution for Wales 2003

This section reports the results of applying the TELAS and DTA attribution techniques outlined in the second section to the case of Wales in 2003 (the year that the data relate to). For comparative purposes, these are reported alongside results for the more conventional Type I and Type II attribution analyses. Thus, waste is attributed to exogenous final consumption demands 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 (export demand becomes endogenous through the creation of a *Trade* sector).

Under (1)-(3) the analysis is allocating total waste generated under the production accounting principle, w^R from equation (3) using equation (2) under different assumptions regarding what activities are endogenous or exogenous. This is not the case under the fourth attribution approach:

(4) DTA Analysis: 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).

Below the results of the TELAS analysis are shown first, alongside Type 1 and II (all of which are derived using equation (2)), and those for a direct analysis, using equation (3) In order to examine the importance of the production structure of the economy the focus is 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 each element of the (1xN) vector of output-waste multipliers, $\boldsymbol{\omega}_i^P\left[\mathbf{I}-\mathbf{A}\right]^{-1}$ is taken in turn and multiplied by total final demand for that sector's output, y_i (row totals of the **Y** matrix). Also considered is the amount of waste attributable to each type of final consumer by estimating (2) for each Nx1 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). The latter highlights the differences between the three approaches in terms of where responsibility for waste generation is ultimately attributed (see Table 2 below).

Following this, the section moves to estimating equation (6) for the Type I case with waste embodied in imports given by the domestic technology assumption with a 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. The results of the TELAS and DTA analysis are compared, focusing in particular on two examples of relatively import-intensive sectors.

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

The full results of the direct, Type I, Type II, and TELAS attribution to final demand for sectoral outputs are given in Appendix 3. These are summarised in Figures 1-4 below. The vectors of direct output-waste coefficients and output-waste multipliers underlying these results are given in Appendix 2. The results of the attribution to final demand by type of consumer are given in Table 2. JENSEN et al. (2009) also provide a broader discussion of the results presented here.

Figures 1-4 about here

In each type of analysis, there is interest in identifying sectoral outputs (commodities) whose production to meet final consumption demands involves high waste generation in the Welsh economy.

Table 2 about here

The key result from the direct waste generation analysis, and the Type I and II results is that *Construction* and *Other Mining and Quarrying* are the main contributors to Welsh waste generation by these conventional IO measures, whether one focuses on direct waste generation or final demand for sectoral outputs. This is because (a) in production, these are the two most directly waste intensive sectors in the economy, and (b) the scale and nature of exogenous final demands for these sectors' output. In the case of *Construction,* the Welsh input-output tables for 2003 show that the main source of final demand is capital formation (44.5% of output), while for *Other Mining and Quarrying*, RUK and ROW export demand directly account for 43.4% of sectoral output.

However, examining Table 2, where the full results of attribution to the matrix of final consumption by each type of consumer, **Y**, are shown, 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, as noted above, 43.4% of output in the *Other Mining and Quarrying* sector is produced to meet external demand. In addition, as discussed in the second section, no account is taken in the Type I and II analyses of the import requirements of intermediate or final consumption. Therefore, there is also a need to conduct the TELAS approach outlined in the second section.

The TELAS system can be thought of as closed with respect to trade and capital. As described in the second section, trade and capital are considered endogenous within the model. 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 local consumption of each sectoral output.

Figure 4 highlights the sectoral outputs whose consumption involves the highest waste generation under the TELAS approach. Here there is 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 (28%) 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, attention now turns to the output-waste multipliers (reported in full in Appendix 2). Two sectors are selected for a more detailed analysis based upon their waste and import intensities, as well as their significance in the Welsh economy. Differences in waste intensity by sector provide some insight into the importance of direct effects within output-waste 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. Sectors with relatively high import shares are expected to have relatively high import-induced effects within the TELAS analysis. The following two sectors are examined (see Figure 5):

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

Multipliers from the DTA analysis are also presented in Figure 5. These are returned to later, but first the focus is on the TELAS results.

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 waste reduction initiatives, biomass energy and is a major recycler of products.

The breakdown of effects in the output-waste TELAS multiplier for *Wood Products* is as follows:

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

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 £1m 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 - this point 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). 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).

Figure 5 about here

Electricity is another sector with a relatively high import intensity, but this time with a relatively low (direct) waste intensity. As Figure 5 shows, 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.

The breakdown of effects in the output-waste TELAS multiplier for *Electricity* is as follows:

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

These are the results that are expected 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 (and low indirect effects from backward local supply linkages). Even with this, the TELAS output-waste multiplier, at 447.38 tonnes per £1m 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.

What the TELAS analysis reveals, therefore, is how analysis of the import requirements (under the assumption that these are financed through exports) may help us understand the structure of the waste generation problem in a small open regional economy such as Wales. However, it is important to bear in mind that this analysis does not attempt to consider the waste generated outside Wales that may be embodied in Welsh imports and therefore supported by Welsh consumption. To begin addressing this question, waste generation under the domestic technology assumption (DTA) method is now considered.

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

In this section equation (6) from the second section of the paper is estimated in a *modelling* exercise to consider the waste implications if Wales were to cease trade and produce all its consumption requirements domestically. That is, using (6) a Type I attribution analysis is conducted 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, some key results are examined. The crucial point to bear in mind here is that the system in (6) is a modelling rather than an accounting framework 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) it is expected that estimation of (6) will provide 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), it is calculated that the overall implied increase in output is 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 428.7%. At the other end of the spectrum, *Cement & Plaster* and *Iron & Steel* would see their output shrink by 56.7% and 28.5% 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 modeled 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 (this implies that Wales is currently 'importing sustainability' in terms of waste generation). 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.

However, note that above the results of the hypothetical analysis under the domestic technology assumption are considered 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 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 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 shows the Type I output-waste multipliers that form the $\mathbf{\omega^P[I-(R+M)]^{-1}}$ 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 input-output accounting exercise in the second column of Appendix 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 Appendix 3) and the fifth shows the results of this attribution in percentage terms (comparable to information in Figures 2, 3 and 4).

Using the output-waste multipliers, Figure 5 provides a useful comparison between the TELAS accounting results and the modelling exercise under the domestic technology assumption (DTA). Here two sectors were identified for examples 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*.

The more interesting of the two is *Electricity*. Here the TELAS multiplier, at just over 447 tonnes of waste per £1m 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, the actual waste generation involved in producing imports under the domestic technology assumption is estimated. 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).

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 5 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 one 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.

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. However, in Wales, as in other UK regions, monitoring activity has centred on waste created within political boundaries, rather than considering how regional consumption creates a waste footprint further afield. The paper shows how different methods can be developed to provide insights on waste from a consumption accounting principle as well as the production principle. It is shown that, with respect to waste, and with the relatively open nature of the regional economy, then monitoring that specifically excludes trade provides only a partial perspective. Similar conclusions have been made with respect to climate change indicators (greenhouse gas indicators) where monitoring under the production principle provides just one perspective on the understanding of regional 'responsibilities' (TURNER et al., 2007).

While a consumption principle for regional monitoring may be desirable, there are problems in deriving appropriate information. In this paper it has been 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.

Specifically the paper reveals that the TELAS and Domestic Technology Assumption methods may provide additional insights for policymakers: 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. Clearly in the case of the domestic technology assumption approach this is something of a half way house towards a full consumption accounting principle. However, it allows a consideration of the waste implications of Welsh consumption in the absence of trade, thereby highlighting the importance of trade to the Welsh economy. TELAS, on the other hand, focuses more on the existing structure of trade and the local resource and waste implications of local private and public consumption demands. Both approaches also have the benefits in terms of information requirements as 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 modeled 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, few UK regions have published input-output tables available. Nonetheless 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 are 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. The paper shows 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 also ALLAN et al., 2007). 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, 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 must not be ignored. For this reason, another priority for future research may be to relax these assumptions in a more flexible computable general equilibrium framework, and with this type of analysis already undertaken, for example, in Scotland with respect to energy (e.g. ANSON and TURNER, 2009). If this approach was adopted the waste input-output framework constructed here would serve as the core database.

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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 Technology Assumption	* Hypothetical domestic waste generation in target region (Wales), in absence of trade, attributed entirely to Welsh consumption demands (households, government and capital)	* Capacity and capability issues - could the target region (Wales) meet all of its local consumption demand in this way?
Inter-regional footprint analysis	* Actual (estimated) waste generation within and outwith target region (Wales) to support Welsh consumption demands) * Potential full application on consumption accounting principle	* Focus on global rather then local waste generation issues, raising issues of jurisdictional responsibility and authority * Extensive date requirements (depending on focus, may involve world inter-regional IO tables, with economic and environmental data in IO format for all direct and indirect trade partners, and inter-regional trade matrices)

Table 2: 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%

Figure 1: Direct Attribution by Sectoral Commodity/Output

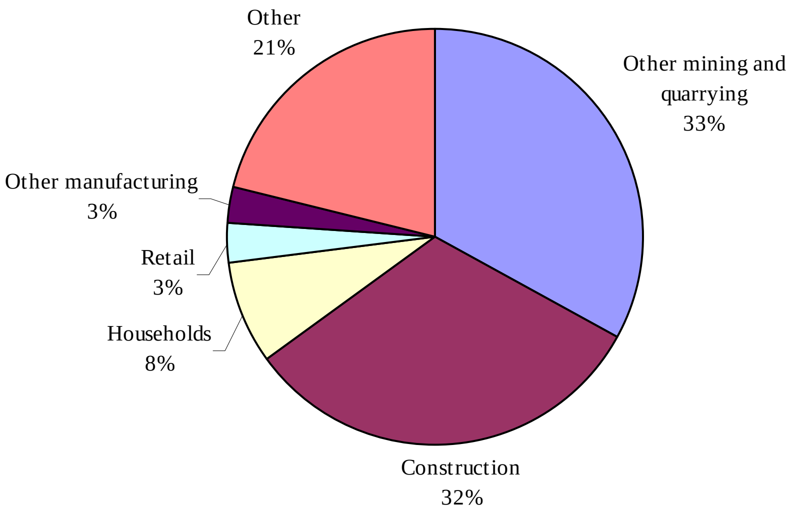


Figure 2: Type I Final Demand Attribution by Sectoral Output/Commodity

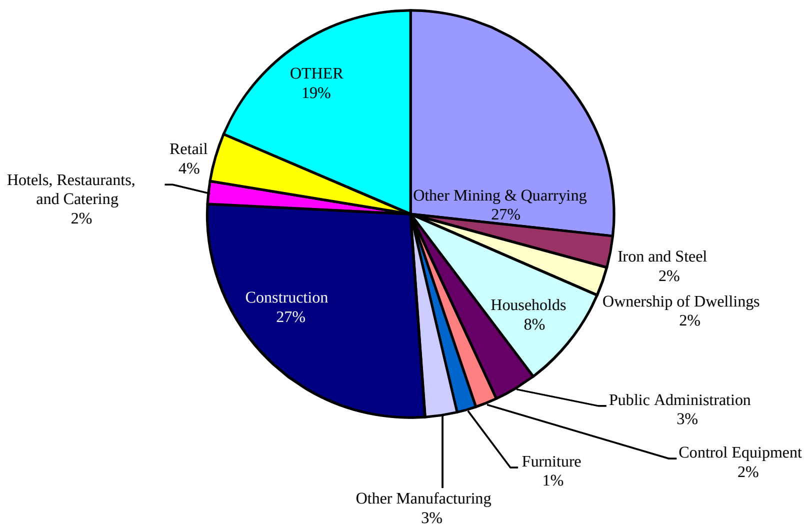


Figure 3: Type II Final Demand Attribution by Sectoral Output/Commodity

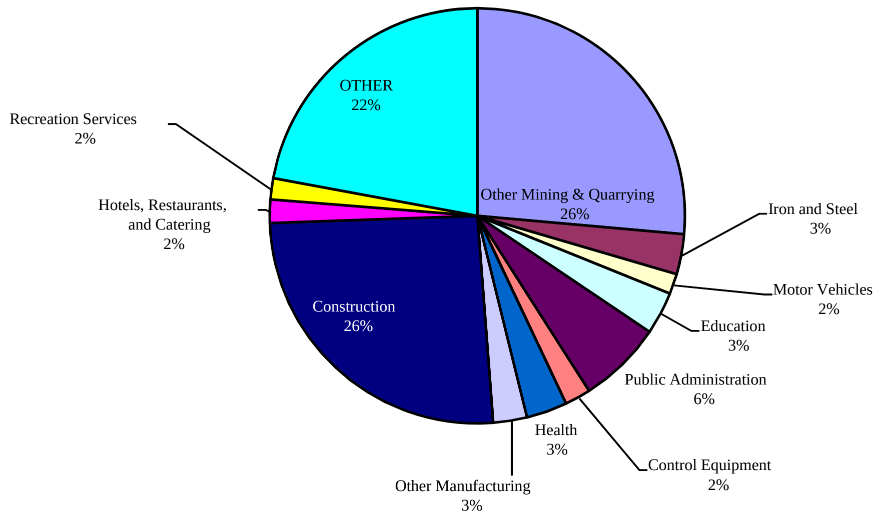


Figure 4: TELAS Final Demand Attribution by Sectoral Output/Commodity

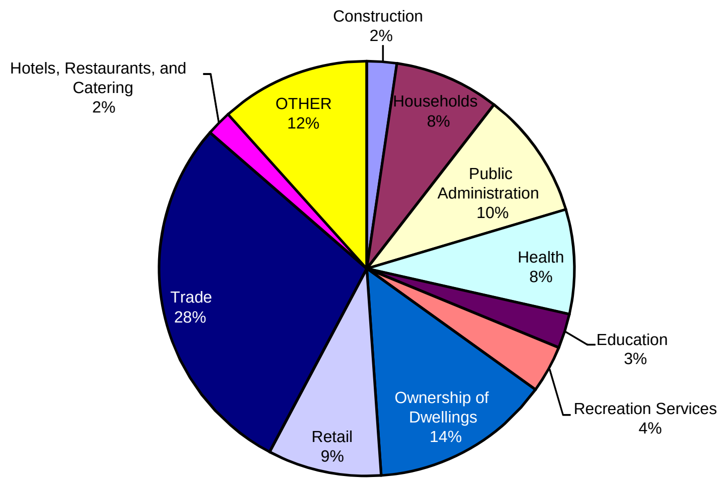
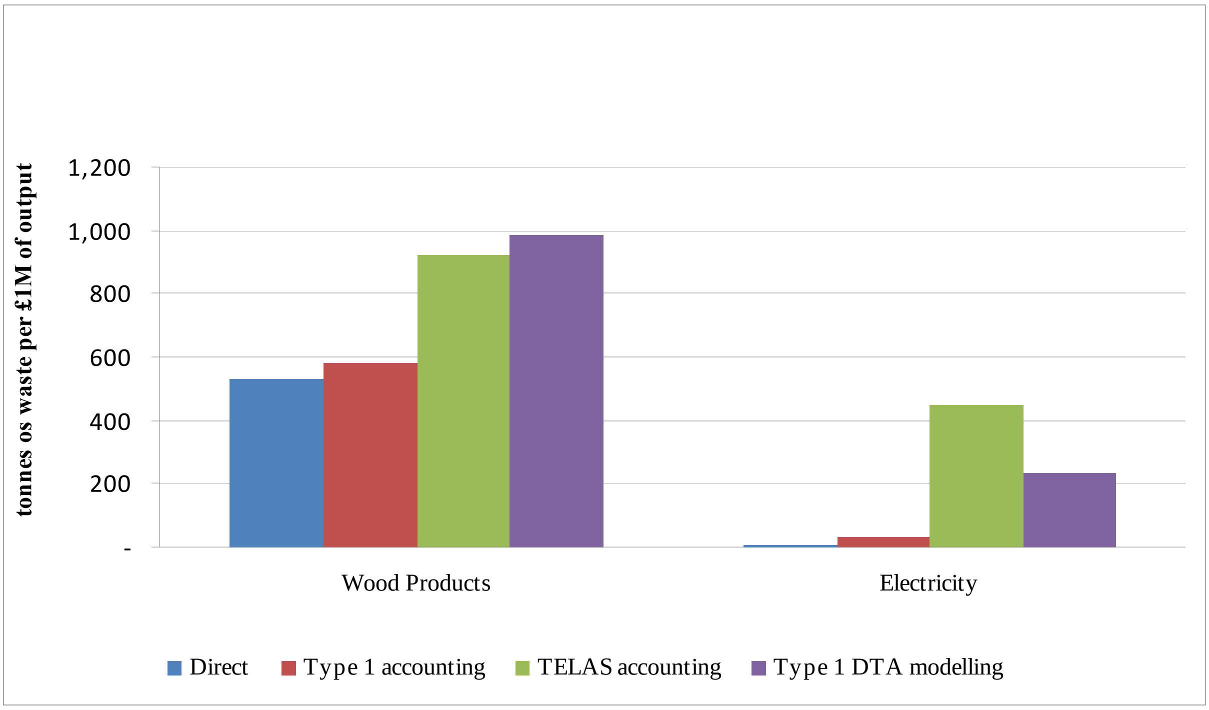


Figure 5. Output-waste multiplier comparisons (sectors with relatively high direct imports)



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 Output Waste Multipliers	Type 2 Output Waste 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

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 Product	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**