Reconsidering the economy-wide implications of incorporating the resource costs of waste management in Scottish input-output accounts

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Abstract

In this paper, we build on a previous and incomplete Scottish study by Allan et al. (2007) that made a key methodological contribution in operationalising the Leontief (1970) environmental input-output model to consider the need to determine social and/or resource costs of supplying common resources such as a 'clean environment' at a local or regional level. At the same time, Allan et al. (2007) acknowledged that poor data hindered complete testing of Leontief (1970) environmental input-output model. For this reason, this paper revisits and expands on the development made by Allan et al. (2007) using improved data and applies the model to incorporate the resource implications of negative externalities from waste generation into the economic process. This is with the aim to answer some key policy issues including identifying whether the polluter pays for waste management and who ultimately bears the resource costs for waste disposal and management within the economy. We argue that this approach may be useful for policy if, for example, a 'polluter pays' scenerio is considered relative to one where government retains some commitment to pay for waste management.

Keywords: Full Leontief environmental model; Input-Output; Multipliers; Scotland; Waste

1. Introduction

Waste generated by production and consumption activities pose a crucial economic problem. This is the need to determine the social and resource costs of supplying common resources, such as a ‘clean environment’, in the form of either waste cleaning, management or disposal. A key question that arises then is who should and who does pay or bear the resource costs for that waste management and the provision of a clean environment. For example, are the industries that directly generate the largest tonnes of waste paying the full resource costs to dispose/manage the waste they generate or, if they are not, what would be the economy-wide implication and the knock on impact to the end users if they were?

Allan et al. (2007) build on Leontief (1970) environmental input-output model and attempt to begin addressing a similar set of issues using a Scottish input-output table and UK average direct waste intensities of production and final consumption activities applied to Scotland for the accounting year of 1999. However, the authors highlight conceptual and practical issues with developing a full environmental IO model for Scotland that impact the extent and reliability of conclusions that could be drawn. First, there was the uncertainly that the original Leontief (1970) environmental input-output model is the appropriate method for considering the resource cost implications of waste cleaning and disposal. Secondly, Allan et al. (2007) acknowledge that poor data (compatible industry-environment data for Scotland, forcing the use of UK average waste intensities) hindered complete testing of the usefulness of Leontief (1970) environmental input-output model in providing better understanding of pollution cleaning and/or disposal as a key environment service activity and, thus, to potentially support policy.

In this paper, with improved region-specific data on waste generated by industries and household in Scotland, we revisit the Allan et al. (2007) study to re-examine, re-evaluate and further develop the Leontief (1970) environmental input-output model to address three main issues. First, we investigate what economic activities seem to pay or not (fully) pay the resource costs of waste management services implied by their waste generation. Second, we attempt to identify the types of final consumers and final consumption that may ultimately bear the full resource costs of waste management in Scotland. Third, we use output and price multipliers derived from what we refer to as the unadjusted (standard published data including actual payments to the waste management sector) and adjusted (to incorporate resource costs actually implied by physical waste generation) input-output accounts- to consider how capturing and attributing the full resource implications of waste management to ‘Polluters’ impacts both up and down-stream regional supply chains.

The remainder of paper is structured as follows. In Section 2, we discuss the issues for policy in addressing the resource costs of economic-environmental interactions as well as the literature around the application of the environmental input-output model to ‘internalise externalities’ through consideration of the cost implications of environmental cleaning and protection. In Section 3, we discuss two main problems of introducing pollution cleaning in the input-output framework as the reason for limited empirical applications of the Leontief (1970) model. In addition, Section 3 also gives some examples of studies that attempt to offer solutions or in other cases a reformulation of the Leontief model (Allan et al., 2007; Arrous, 1994; Flick, 1974; Luptacik & Böhm, 1999b; Qayum, 1991; Steenge, 1978). In Section 4, we describe the Leontief (1970) methodological development of extending conventional input-output tables to environmental input-output tables and the methodological framework of Allan et al. (2007). We also discuss how this paper would build on both developments and contributions. The data employed in this study is described and discussed in Section 5. All empirical results are presented and discussed in Section 6. Lastly, Section 7 and 8 gives some conclusions and policy recommendations based on the results and findings.

2. Issues for policy

The traditional economic approach to address environmental issues is to consider them as problems of externalities and to develop alternative mechanism that allows the economy to correct, partly or fully, for the damage caused by externalities (Bithas, 2011; Gillingham and Sweeney, 2010). For example, governments will use economic measures of the price mechanism (such as taxes, permits, and subsidies) to internalise externalities and ensure environmental protection. In early economic literature, Pigou (1920) proposes a tax (Pigouvain tax) imposed to capture the total value of damage caused by an extra unit of pollution, which should equal the tax levied per unit of pollution generated. Such taxes are used to signal the true social cost of pollution to the emitter, who then has the financial incentive to reduce emissions to the point where the financial implication of one unit of reduction to the emitter is equal to the social damage incurred (Pigou, 1920).

Another price mechanism is marketable permits. It is allocated by the governments or regulatory authority at an ‘output’ level that it is equal to the aggregate quantity of environmental impact. This allocation can be made through negotiations based on clear delineation of environment property rights (Coase, 1960). A contemporary example of price mechanism is the landfill tax used across various countries (e.g. UK and EU) for waste management. It is an environmental tax paid on top of normal landfill rates by any industry, local authority, or other organisation that dispose of waste via landfill (Davies & Doble, 2004; Martin & Scott, 2003). The main global example of a marketable permit system is the EU Emissions Trading Scheme (ETS), although this system has struggled to achieve an output-price equilibrium that reflects the social cost of carbon (Greenstone et al., 2013; Pindyck, 2016).

The various forms of price mechanisms and marketable permits are policy measures that are often primarily designed to redirect behaviour from activities that are detrimental to the economy and environment. However, they also perform the role of raising revenue to support environment protection objectives, but do so by making the polluter pay and bear the costs of the environmental damage (Whitten et al., 2003). This latter point is important as it implies that a clean or unpolluted environment is priced and treated as if it were similar to other costs (such labour or capital). This is in-line with environmental principles, such as the ‘polluter pays’ principle, which requires that the cost of pollution inflicted on the environment, be borne by one who causes it (De Guzman, 2016; Regebro, 2010). The development of the principle is driven by the fact that the environment is a common pool resource and economic activities have a negative impact on the natural environment (Lindhout & den Broek, 2014).

Most economies do not operate a “polluter pays” scenario when it comes to waste management. Typically, the polluter exclude the costs of waste generation and rely on public subsidies and guarantees (Delahaye et al. 2011, Zaman 2014, Schreck and Wagner 2017). More generally, waste management and the provision of a clean environment (waste and pollution free) has generally remained directly or indirectly subsidized by local governments. In the UK, overall collection, transport, and some treatment of physical waste is mainly operated by public companies, whereas waste incinerators and landfills are commonly run by private companies. For instance, in Scotland, across the 32 different local councils, a given number of bins and associated tonnage of waste are collected on a weekly or less frequent basis (increasingly involving households to separate landfill waste from food waste and other materials that can be recycled).

Several studies argue that an issue that is contributing to government covering most of the payment for waste is illegal disposal (e.g. fly-tipping and littering), which worsens the environmental impact, making even the most ambitious waste policies less effective (Broome et al., 2000; Carlsson Reich, 2005; Pires et al., 2011). For example, a Scottish Government (2013) report[1] shows that a huge £53 million of public money is spent tackling litter and fly-tipping annually and that at least £46 million of public money is spent removing litter from the environment each year. Moreover, the wider negative impacts of litter impose at least a further £25 million in costs on the society and economy.

What if we were to consider alternative responsibility for waste management, where the polluter is actually forced to pay and is solely responsible for payment of the resource cost for their waste generation? In addition, if government subsidises only a small amount for waste management and the polluter pays the remaining, what are the potential economy-wide implications? These are some of issues, we attempt to consider in this paper using the 'full' Leontief environmental input-output that allows us to develop adjusted input-output accounts that incorporate the resource cost of waste management across the different sectors in the economy. This type of information may be important for policy and may change feed into government objective of making both private and public sectors contribute to the reduction of waste and sustaining a waste free or clean environment.

3. The problem of introducing pollution cleaning in input-output

Leontief (1970) extends the standard input-output accounting and modelling framework in two ways. First, to incorporate pollution as an additional commodity ('bads') that accompanies production and consumption activities. Second, to separately identify sectors that clean up or prevent these unwanted outputs. The first of these in particular has led, Leontief environmental input-output analysis to be regarded as an important and insightful tool with widespread applications to study various environmental impacts such as

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[1] Scottish Government (2014) Towards a litter free Scotland: A strategic approach to higher quality local environments is available at http://www.zerowastescotland.org.uk/sites/default/files/Scotland%27s%20Litter%20Problem%20-%20Full%20Final%20Report.pdf

calculating and analysing; greenhouse gas emissions, carbon and water footprints, pollution and embedded energy (Barrett et al., 2013; Brizga et al., 2017; Chen et al., 2016; Jones, 2013; Peters et al., 2011; White et al., 2015). However, most of the empirical work using the environmentally extended input-output framework does not consider the resource implications of how the externality might be internalised, or more generally, how the initial impact of the economy on the environment might feedback in the form of economic activity generated in environmental cleaning.

A number of problems have limited the application of the full Leontief (1970) model. In this paper we dwell on and discuss two key issues. The first is a practical one, with attempts to apply the framework hampered by the fact that spend on cleaning may be difficult to identify and, indeed, may already be included in the input-output account. That is, the entire new sector in the Leontief approach may not be necessary. In the design of the model, Leontief proceeded as though the cleaning sector were newly created; this is, as though a cleaning sector were introduced into a system that previously generated untreated pollution. However, cleaning activity will already occur in the economy, whether these cleaning industries are separately identified as input-output industries or not (Allan et al., 2007). A related problem then arises in that, where expenditure in cleaning is already recorded within the input-output accounts, it may not be straightforward to separate out the inputs used in the cleaning from other inputs used in production in different industries. For example, in the case of air pollution, a number of different industries may spend on several inputs to allow them to engage in 'end of pipe' or other cleaning processes.

The second issue has more of an analytical basis. Leontief (1970) focused on physical input-output relationships and the subsequent literature – with key contributions by Arrous (1994); Flick, (1974); Luptacik and Böhm (1999); Qayum (1991); Steenge (1978); and Allan et al., (2007) – focusing on considering the system in value terms. For example, Flick (1974) points out that there are unnoticed and too often disregarded, undesirable by-products (as well as valuable, but unpaid-for natural inputs) that is linked directly to the network of physical relationships that govern the day-to-day operations an economic system. On this basis, Flick (1974) argues that it's imperative to put corresponding monetary values rather than physical quantities on all the physical transaction within the economy. In addressing the need for monetary/value system in the input-output relationship, Steenge (1978) focuses on the aspect of price behaviour and policy implications and proposes that to determine the price for pollution cleaning, a set of rules (e.g. polluter pays system and full waste cleaning) need to be implemented that allocate and determine the cost of environmental protection. Other studies show that the problems associated with the applications of the Leontief's model we discuss above can be dealt with in a straightforward manner by introducing a sector of clean air instead of a delivering sector of air pollution with negative entries and a receiving sector of anti- pollution (for example see Qayum (1991); Arrous (1994); Luptacik and Böhm (1999).

Leontief and Ford (1972) provides the only early attempt to operationalise the Leontief (1970) model. The practical issue outlined above has been an important one and, to our knowledge, prior to Allan et al. (2007), Schäfer and Stahmer (1989) is the only input-output study where a distinct 'sector' that carries out pollution cleaning services is separately identified. However, their analysis focuses entirely on successful completion of this stage, to identify total spending on environmental protection activities within each industry (and where their input-output framework then informed Nestor and Pasurka (1995), computable general equilibrium, CGE, model). However, they do not proceed to an application of the full Leontief (1970) model with consideration of how, and the extent to which, spending on 'cleaning' relates to physical pollution or waste generation. Allan et al. (2007), begins in a similar position to Staffer and Stahmer (1989), with the identification of a single type of pollution generation and cleaning, focusing on physical waste generation and disposal and/or management, but extend to consider issues around whether the direct generator pays for cleaning in-line with their generation.

Allan et al. (2007) start by focusing on waste, where this is a distinct, SIC classified activity, already monetised and valued in input-output accounts. To be specific, existing data for waste generation means that the practical issue of identifying sectoral expenditure on cleaning services is less problematic. However, Allan et al. (2007) did still face issues in that, in the Scottish input-output accounts used, (a) waste disposal was reported within a wider sector that also incorporated sewage and sanitation; (b) region-specific data on physical waste generation by sector were not available so the UK average waste intensities which were only reported at a relatively high level of sectorial aggregation had to be used. As a result, Allan et al. (2007) report difficulties in applying the Leontief (1970) and qualifying conclusions drawn.

In this paper, with improved data on waste generated by industries and households in Scotland (SEPA, 2011), we revisit and build on Allan et al. (2007) study. Specifically, we investigate what economic activity seem to pay or do not pay the resource costs for the waste management services implied by their waste generation. From the latter, we use output and price multipliers derived from what we refer to as the unadjusted (standard) and adjusted (to incorporate resource costs implied by waste generation) input-output accounts to consider how capturing the full resource implications of waste management impacts both up and down-stream regional supply chains. We argue that applying the environmental input-output model in this way may be very useful to policy if, for example, a 'polluter pays' scenerio is considered relative to one where government retains some commitment to pay for waste management.

4. Extending from conventional economic input-output accounts to consider demand for waste management impacts in the adjusted input-output accounts

In this section, we give details of the process of augmenting the conventional input-output framework. Essentially, this section describes how we move from the unadjusted (standard) to adjusted (to incorporate resource costs implied by waste generation) input-output accounts for the case of waste management. The basic Leontief input-output framework is set up so that for an economy with N sectors, the (N x 1) output vector, **x**, can be represented with conventional notations as (Miller and Blair, 2009):

$$\mathbf{x} = [\mathbf{I} - \mathbf{A}]^{-1}\mathbf{y} \qquad (1a)$$

In equation 1a, **A** is the (N x N) matrix of technical coefficients, a_{ij}'s, where a_{ij} is the input sector *i* needs to generate one unit of output in sector *j*, and **y** is the (N x 1) final demand vector. The $[\mathbf{I} - \mathbf{A}]^{-1}$matrix is the Leontief inverse, where each element, b_{ij}, gives the output in sector i directly or indirectly required to produce one unit of final demand in sector j. The general solution of equation 1a determines how much output each sector of the economy must produce in order to satisfy a given level of final demand for its own output and the output of all other sectors. However, what if we wanted to know how the demand for waste management would be impacted by a given level of final demand? If the 'Waste Management' sector is separately identified in the SIC, this can be done by first calculating the conventional Type I or II (household exogenous) input-output multiplier impact of a given vector of changes in the final demand of other sectors (Miller & Blair, 2009). If we consider the waste sector as the j^{th} sector in the input-output accounts, the impact on the 'Waste Management' sector of unit value increase in the final demand of other sectors is given by the entries on the j^{th} row of the Leontief inverse. Specifically, the multiplier would give the change in the value of the output of the 'Waste Management' sector for a unit increase in the value of final demand in, say, the 'Construction' sector. This is a standard approach adopted to account for present waste generation and to identify the impact of changes in final demand for future waste management.

However, a question that arises is whether the demand reflected by the multiplier calculation can be mapped to the resource cost implied by waste generation of each sector. We know that this is not the case, because externalities via pollutants such as waste cannot be fully dealt with through the market mechanism. If the production sector i, for example, generated pollutants that would require X resources of the waste management sector to treat or clean, it does not necessarily mean that the treatment and cleaning takes place and that the cost is borne by the sector i. That is, unless, we make some adjustments to the standard input-output accounts such that, actual physical waste generation by each sector valued per average cost of the demand for waste management services are captured in the multiplier in equation 1a.

The average price of waste, P_g, is found by summing the total expenditure on the output of the waste sector across all intermediate and household final demand, and dividing by the total waste generation in only these uses. Note that other final demand sectors (e.g. government etc.) ideally should be consider in the estimation of price for waste. However, since we only have physical waste data for household, then:

$$p_g = \frac{\sum_{i=1..n,h} q_{g,i}}{\sum_{i=1..n,h} x_{g,i}} = \frac{q_{g,T}}{x_{g,T}} \qquad (1b)$$

Where the h and T subscripts stand for household and total respectively.

Equation 1b is developed in (Allan et al., 2007) to consider the treatment of Scottish waste in an input-output context. In Allan et al. (2007) production sectors appear to only partially and unsystematically pay for the waste treatment, such that some sectors seem to be charged more for waste disposal services than others are. Allan et al. (2007) points out that it is essential to determine the average cost of disposing of a physical unit of waste to identify the demand for waste disposal services implied by the physical waste generated by a sector. Thus, if the resulting value of implied demand differs from the actual demand reflected in published input-output entries for the output row of the waste management industry, this implies distributional issues in deviating from a 'polluter pays' principle. Hence, we need to adjust the coefficients of the **A** matrix in the initial input-output accounts along the waste management input row using equation 1b. Here the 'Waste Management' sector is already identified as the j^{th} row of the **A** matrix, thus we replace that j^{th} row with an implied waste row vector derived from multiplying the physical waste generation per unit of value output divided by the average price of waste (determined in equation 1b). As a result, there will be impacts distributed throughout the multiplier matrices, which we can captured by restating equation 1a as:

$$\mathbf{x} = [\mathbf{I} - \mathbf{A}^{*}]^{-1}\mathbf{y} \qquad (1c)$$

In equation 1c, the notation remains the same as in equation 1a. However, with $\mathbf{A}^{*}$ as the (N x N) matrix (that incorporate resource costs implied by waste generation) of technical coefficients $a_{i,j}$, where $a_{i,j}$ is the input of sector i needed to generate one unit of output in sector j, and **y** is the (N x 1) final demand vector.

Once we have adjusted the input-output system to capture the actual resource costs for waste management in-line with waste generation, then we can consider alternative responsibilities for waste management in terms of 'polluter pays' scenarios or impacts of various levels of waste cleaned. Following Allan et al. (2007) and Leontief (1970), we consider in this paper illustrative scenarios of the adjusted input-output accounts with 100% or 90% waste cleaned.

Thus if we assume that $\beta = 0.1\ (100\%\ )\text{and}\ \alpha = 0.9\ (90\%)$ represents different levels of waste cleaned and/or managed with the waste sector as the j^{th} row, then the adjusted input-output account (equation 1b) with 100% and 90% waste cleaned is represented or calculated as:

$$\beta = \left[a_{ij} = \frac{X_{ij}}{X_j}\right] - 0.1 \tag{1d}$$

$$\alpha = \left[a_{ij} = \frac{X_{ij}}{X_j}\right] - 0.9 \tag{1e}$$

In this paper, we employ the adjusted input-output accounts with 100% and 90% as determined in equation (1d) and (1e) to simulate impacts on outputs and prices under various assumptions of waste management.

It is also useful to consider the price input-output equation that can be used in estimating price effects in the input-output framework. The system of price equations can be extended to capture the cost implication of pollution elimination (Leontief, 1970). This is on the assumption that each industry and pollution elimination activities bears the full cost of eliminating all pollution generated by the industry (Leontief, 1970). This may help in addressing the price impacts of producing sectors when each one of them pays fully or partially the cost to reduce or eliminate pollution. In the conventional input-output system, prices are calibrated to take unit values and have the following form:

$$\boldsymbol{i} = [\mathbf{I} - \mathbf{A}^{\mathbf{T}}]^{-\mathbf{1}}\,\mathbf{v} \tag{2}$$

Hence, if each industry and each waste management sector were to pay and include in the price of its output the costs of eliminating waste generation then the environmental input-output price model can be described in matrix form as:

$$\boldsymbol{p_i} = [\mathbf{I} - \mathbf{A}^{*\mathbf{T}}]^{-\mathbf{1}}\,\mathbf{v} \tag{3}$$

In equation 3, **v** is an N x 1 column vector representing final cost per unit of output/valued added. Through the price model, price multipliers are determined which give the overall price to final demand for any sector *j's* output per £1 spent on primary input. Adopting the price model allows us to estimate changes in relative prices across sectors that demand waste management services as inputs for production. These changes can be calculated as the vector of percentage price changes given as:

$$\Delta p_i = [p_i - i] \times 100 \qquad (4)$$

5. Data and derivation of adjusted input-output row for waste cleaning and disposal

In what follows in adjusting the input-output accounts for use in operationalising the Leontief (1970) model, we use the example of physical waste in Scotland. The dataset forms a basis and lens through which to examine the connections between economic activity and local pollution and the full resource costs of waste management. A series of input-output tables have been produced for Scotland annually from 1998-2014. We use 2011 tables here, which describe the purchasing and sales patterns of 97 separately defined industrial sectors, including a 'Waste Management' sector. The 97 sectors are aggregated to map directly onto the 29 industry groups for which direct waste generation data are available (along with households). This is more appropriate given the focus on whether sectors actually pay for the waste they generate). Table A1 in the Appendix section shows the industrial aggregation used in this paper and how the 97 sectors in the Scottish input-output framework are mapped onto the 29 industries for which waste generation data are available. Crucially, the dataset we use in this paper are Scottish-specific data and have sectoral breakdown that is consistent with the SIC used in developing the economic accounts. As found by Allan et al. (2007), the lack of region-specificity in the data does have implications for the results and conclusions drawn.

A common problem for environmental input-output analysis is that, there is an absence of regional data that report either environmental 'goods' and 'bads' at the sectoral level and relate them to demand patterns implied by the input-output accounts. This is a specific case of the more general problem that has hindered widespread application of the Leontief (1970) environmental model to address economic-environmental issues (Allan et al., 2007). For analytical precision in identifying the relationship between economic activity and the environment, data need to be collected and reported in a manner consistent with the economic accounts and ideally for the studied region, without need for proxies (Turner, 2006).

6. Applications and discussions

In this section, we present and discuss the results of adjusting the environmental input-output to incorporate the resource costs of waste management from waste of industry and household. In what follows, we use the Scottish data outlined in Section 5 to calculate identify what sectors seems to pay or do not pay the resource costs for their waste management services given by equations (1b), (1c) and (1d) in Section 4. We also use the equations (2), (3) and (4) to measure the price impacts from imposing a uniform pricing for Scottish waste .

6.1 Does the 'Polluter' pay the resource cost for waste cleaning and disposal services?

Table 1 is a reduced form of the unadjusted (standard) and adjusted (to incorporate resource costs implied by waste generation) input-output accounts. By reduced form, we mean the Table only has some of the main information in both accounts. Mainly, the results are in an aggregated form and it does not show the whole input-output table. However, if we examine Table 1 in detail, we see that it is a systematic approach showing the difference between the unadjusted and adjusted input-output accounts and how we move from one account to the other.

In Table 1, the 'Non-Waste' sector in row 1 is the value of intermediate sales of non-waste sectors. For example, the intermediate demand sales of the 'Construction' sector to all other non-waste (i.e. 1-14, 16-29, see Table A1 in the Appendix for sectoral breakdown) or the intermediate demand by all non-waste sectors for the 'Construction' sector output is valued at £8208 million in the unadjusted account. The demand for 'Construction' sector output is the highest intermediate demand across the non-waste sectors. This is followed by intermediate demand for 'Wholesale & Retail', 'Finance', 'Health', 'Electricity' sectors respectively.

The figures in row 2, ‘Waste’ sector show total payment to the ‘Waste Management’ sector for supplying its services to other sectors including its own sector demand (i.e. payment made by the ‘Waste Management’ to itself). Examining row 2, we see that there are a number of differences across the individual sectors.

In row 3, ‘Waste Generation’ (value) is the implied demand row. These figures are the new entries based on the actual physical amount/quantity that each sector demands from the ‘Waste Management’ sector valued at the average cost of waste generation (using equation 1b). Examining row 2 & 3 in greater detail, we see that the total demand column of ‘Waste’ sector (row 2) and ‘Waste Generation’ (value) (row 3) are similar. However, there are a number of noticeable differences across the industry and household sectors. On the other hand, note that for non-household final demands, the figures are the same between row 2 and row 3, a result that we will explain in the discussion of row 4.

In terms of the production sectors, the noticeable differences are more evident in ‘Construction’, ‘Waste Management’, ‘Public Administration’, ‘Health’, ‘Electricity’ and ‘Food & Drink’ respectively. Let us consider the value of the ‘Construction’ sector in both rows in more detail. Interestingly, in row 2, the ‘Construction’ sector’s payment to the ‘Waste Management’ sector is valued at £12.3 million in the unadjusted accounts, but the adjusted account reveals a higher payment of £194 million. While, ‘Waste Management’ own sector payment is valued at £166 million in the unadjusted accounts, the adjusted account shows that the payment is £0.3 million. Row 4 shows clearer differences between row 3 and 2.

In row 4, ‘Waste Payment Adjustment’ reports the additional payment entry, which is the difference between row 2 and 3 (i.e. the unadjusted and adjusted accounts). Note that the row total of the ‘Waste Payment Adjustment’ is zero, which shows that overpayments balance out the underpayments. Within the individual sectors in row 4, the negative entries mean that for example, the ‘Construction’ sector (-182.4) is not directly paying the full amount for the environmental resources that it is using. This implies that the ‘Construction’ sector underpays for waste management services.

Table 1 The condensed conventional and full Leontief environmental Scottish input-output table 2011

	Agriculture Forestry & Fishing	Mining & Quarry	Food & Drink	Textile	Manufacturing of Wood	Paper &Printing	Coke, petroleum	Chemical Manufacture	Non Metallic Mineral	Metals	Machinery & Equipment	Misc Manufacture	Electricity	Water Industry
1. Non-waste sectors	1452.3	2548.5	2927.6	390.2	396.7	483.1	813.4	856.0	295.0	936.8	2671.5	620.4	4455.2	193.4
2. Waste sector	1.4	1.8	6.2	4.2	0.7	2.1	1.4	1.4	1.0	5.7	2.7	1.0	1.2	15.8
3. Waste generation (value)	8.4	10.1	17.7	4.0	3.2	1.3	1.5	0.0	0.9	4.3	3.0	1.0	18.8	5.3
4. Waste payment adjustment	-6.9	-8.4	-11.5	0.2	-2.5	0.8	-0.1	1.4	0.1	1.3	-0.3	-0.1	-17.7	10.5
5. Other primary inputs	2344.7	5144.1	5746.8	782.3	522.3	793.2	6368.0	2458.8	442.6	2129.2	5250.4	1592.1	5243.4	1027.6
6. Total inputs	3798.5	7694.4	8680.5	1176.7	919.7	1278.4	7182.9	3316.2	738.6	3071.6	7924.6	2213.4	9699.8	1236.8
7. Physical waste (tonnes)	261050.6	314786.3	548921.8	125542.9	99482.7	41574.1	47586.8	38.0	27070.0	134147.3	91839.5	32260.4	585436.1	165646.4

Table 1 Continued

	Waste, Management	Construction	Wholesale & Retail	Transport	Hotels & Restaurants	Communication	Finance	Real Estate	Professional & Scientific	Administration Support	Public Administration	Education	Health & Social Work	Art & Recreation	Other Services Activities
1. Non-Waste sectors	303.1	8208.4	5552.9	3617.5	1521.0	1474.1	5285.6	2377.6	3154.7	1483.7	3482.0	1114.4	4886.5	623.1	409.4
2. Waste sector	166.2	12.3	15.1	7.0	7.0	4.0	5.7	1.8	7.8	7.4	92.4	5.0	41.7	1.9	3.0
3. Waste Generation (value)	0.3	194.7	24.2	3.6	8.5	1.3	0.8	2.5	2.5	5.8	2.8	3.8	5.4	3.6	1.4
4. Waste Payment Adjustment	165.9	-182.4	-9.1	3.4	-1.5	2.7	4.8	-0.7	5.3	1.7	89.6	1.2	36.3	-1.7	1.6
5. Other primary inputs	1113.8	10729.5	14291.3	7199.3	4527.1	4534.1	10926.8	12247.8	8379.2	5437.9	10456.8	7289.3	13296.7	2479.1	1431.3
6. Total inputs	1583.1	18950.1	19859.3	10823.9	6055.1	6012.3	16218.1	14627.2	11541.8	6929.1	14031.2	8408.6	18224.9	3104.1	1843.8
7. Physical waste tonnes)	8586.4	6051440.0	753162.0	111929.0	264820.0	40413.0	26146.0	76677.0	77653.0	179549.0	87776.0	119030.0	16849.0	111992.0	43110.0

Table 1 Continued

	Total Intermediate Demand	Household	Government	Gross fixed Capital Formation	Stocks	Non-resident households	Rest of UK exports	Rest of world exports	Total Final Demand	Total Demand Products
1. Non-Waste sectors	62534.1	51306.8	30587.6	14331.2	282.6	2182.3	34282.7	20054.6	153028.0	215562.1
2. Waste sector	424.8	23.1	543.8	4.4	0.0	0.4	288.6	297.9	1158.2	1583.1
3. Waste Generation (value)	340.9	83.9	543.8	4.4	0.0	0.4	288.6	297.9	1219.0	1583.1
Waste Payment Adjustment	83.9	-60.7	0.0	0.0	0.0	0.0	0.0	0.0	-60.7	0.0
5. Other primary inputs	154185.8	25828.1	0.0	6977.8	351.8	1367.9	6952.6	3174.0	44652.3	198838.1
6. Total inputs	217144.7	77158.1	31131.4	21313.4	634.5	3550.6	41524.0	23526.5	198838.1	415983.2
7. Physical waste (tonnes)	10596160.1	2606759.0	0.0	0.0	0.0	0.0	0.0	0.0	2606759.0	13202919.1

If the entries are positive like in the ‘Waste Management’ sector (165.9), then the sector is purchasing more waste management resources than are needed to treat and clean the waste it generates. This sector is government-owned. Thus, some implicit subsidy for waste management by the government seems to be what is coming through in the results and causing for instance, the ‘Waste Management’ sector to purchase more waste management services than it directly requires. However, more generally, in the ‘Waste Payment Adjustment’, there are 12 sectors that are underpaying for their waste management services and 17 that are overpaying. If underpayment represents an implicit subsidy, overpayment would seem to imply an implicit tax.

In the final demand part of Table 1, the ‘Waste Payment Adjustment’, is zero for all non-household final demand sectors. This result occurs because physical waste data for these final demand types are not reported. This led to the inclusion of zero values being applied in these cases such that the unadjusted and adjusted accounts coincide. As a result, a ‘polluter pays’ scenario is imposed overall. However, we acknowledge that in reality we do not expect waste to be fully dealt with through the market mechanism. Essentially, we impose this assumption in order to show how the full Leontief environmental approach may be operationalised and to illustrate the type of insight that may be gained. Overall, we find that the production side of the economy is subsidised in terms of direct payment for waste management services by mostly ‘Waste Management’, ‘Public Administration’, and ‘Health’ sectors in particular. Again, these may reflect heavy government subsidies of waste management.

6.2 Output multiplier impacts with the unadjusted and adjusted input-output accounts

The approach discussed above in reference to the results in Table 1 allows us to move beyond considering issues of direct waste generation and payments. The next stage is to consider the nature and magnitude of impacts on the component of each sector’s output multiplier located in the waste management sector, that is to examine how much the demand for waste management services increase and/or decrease as the demand for sectors output changes when we move from the unadjusted to the adjusted case. What is of interest here is to show the magnitude of effects on the waste management sector that are hidden or unidentifiable in the conventional IO account. That is, we use the adjusted system, to identify those sectors that put most pressure of the waste management sectors in order to meet increased demand for their output. We consider the Type I and Type II case to see how the effect changes when household is endogenised.

Output multipliers account for output generated by all sector in the economy per £million of final demand for sector *j's* output. We saw in Table 1 that, in the unadjusted accounts, the output multiplier is understated in terms of the impacts on 'Waste Management' sector output/services in sectors that underpay for their waste management. Table 2 gives the output multiplier in terms of the demand of waste management services per £million of final demand for sectoral output in Type I and II case. Essentially, as an illustrative case on the applicability of the full Leontief environmental input-output model, we are comparing the unadjusted output multiplier against the adjusted output multipliers with 100% and 90% alternative polluter pay scenarios. In the 100% case, we are considering the full impact of the output waste multiplier for the demand of all waste cleaned. While, 90% waste cleaned, we consider the resulting partial impact of the multiplier if government were to change waste management commitment such that not all waste is cleaned. This may come to be if for instance government impose a cap on waste management such that proportions of all waste stream might potentially be use to recover useful energy or in a circular economy context where waste is considered as a resource input rather than a material/pollutant to be cleaned or treated.

From the Type I effects in column 1, 2, and 3 of the results in Table 2, we see that the output multiplier impacts in 'Waste Management' per monetary unit of final demand change markedly in moving from the unadjusted to the adjusted system for a number of sectors. In 15 sectors the output multiplier effect in the 'Waste Management' sector is greater with the adjusted system relative to the unadjusted input-output accounts. In particular, for 'Construction', 'Manufacturing of Wood', 'Electricity', and 'Agriculture'. Note that these are the sectors that directly pay less (see Table 1) for waste disposal and cleaning than their implied demand, hence their multipliers increase when the full implied demand is taken into account (and vice versa). For example, consider the 'Construction' sector, in the unadjusted accounts it generated very low direct and indirect demand for waste management services such that a £million increase in final demand in this sector produced only £1,337 million increase in demand for waste management services. With the adjusted accounts, the impacts increased to £13,642 and £12,946 with 100% and 90% waste cleaned respectively. This reflects that the amount of direct waste generated in the sector as shown in Table 2 is not captured in input-output entries in the unadjusted accounts. This is important, given that around 57% of all waste management in Scotland in the base year (2011) is directly generated in ‘Construction’ sector activities. However, this compares to less than 2% of payment of waste disposal coming from the ‘Construction’ sector as with the adjusted table in Table 1.

On the other hand, there are 14 sector, where the output multiplier impacts on ‘Waste Management’ are larger in the unadjusted account relative to the adjusted one. The largest differences are in ‘Waste Management’, ‘Water Industry’, ‘Textile’ ‘Public Administration’ and ‘Health’, where the Type I output multiplier effects are reduced in moving to the ‘adjusted’ system. The unadjusted account shows that these sectors are the production sector paying most for waste management services, but with lower levels of physical waste generation. Thus, when the actual resource cost implied by waste generation are captured in the adjusted account their multiplier impact on ‘Waste Management’ decreases. For example, ‘Public administration’ sector’s implied direct and indirect demand from waste disposal service is £4,753 less than the amount produced using the conventional calculation.

Turning our attention to the Type II results, we now compare the Type II output multipliers derived using the adjusted input-output accounts relative to the unadjusted calculation by comparing the results in columns 4, 5 and 6 with the results in columns 1, 2 and 3. Note that Type II involves looking at the impacts of increase in employment and employment income which funds consumption expenditure. We find that in the Type II case, there are 23 sectors where the output multipliers are greater in the adjusted accounts relative to the unadjusted accounts. The bigger differences are in ‘Construction’, ‘Textile’, ‘Manufacturing of Wood’, ‘Food and Drink’ and ‘Agriculture’. For the remaining 6 sectors, their output multiplier is larger in the unadjusted accounts relative to the adjusted model. In particular, the bigger differences are in ‘Waste Management’, ‘Water Industry’, ‘Public Administration’, and ‘Health’ with the unadjusted accounts compared to the adjusted input-output accounts with 100% or 90% waste cleaned. This result may be because in Table 1, the household payments for waste disposal services in the unadjusted input-output table are very low relative to the implied demand used in the adjusted system. The implication is that Scottish household contribution to waste generation is understated by the unadjusted accounts. In other words, any induced increase in waste management services resulting from additional consumption expenditure funded by increased income from employment is not captured in the unadjusted accounts.

Table 2 Output multiplier effects in the waste management sector of a £million final demand for sector output

		Type II effects (household exogenous)			Type II effects (household endogenous)		
			Adjusted			Adjusted	
Sector number	Sector/Activity	Unadjusted	100 % waste cleaned	90% Waste Cleaned	Unadjusted	100 % waste cleaned	90% Waste Cleaned
1	Agriculture Forestry & Fishing	897	3099	2940	1431	4034	3828
2	Mining& Quarrying	652	2600	2467	1230	3611	3427
3	Food & Drink	1226	2842	2697	1961	4126	3915
4	Textiles	4968	4410	4185	5864	5975	5670
5	Manufacturing of Wood	1331	4853	4606	2170	6323	6000
6	Paper and Printing	2456	1930	1832	3285	3377	3205
7	Coke & Petroleum	366	395	374	509	645	612
8	Chemical Manufacture	808	373	354	1674	1886	1789
9	Non Metallic Minerals	1875	2073	1967	2806	3698	3509
10	Metals	2594	2010	1908	3516	3618	3433
11	Machinery & Equipment	830	926	879	1709	2461	2335
12	Misc Manufacture	872	981	931	1843	2677	2541
13	Electricity	449	3482	3305	808	4114	3904
14	Water Industry	15427	5056	4798	16022	6080	5769
15	Waste Management	1117865	1000684	1000649	1118730	1002036	1001932
16	Construction	1337	13642	12946	2313	15363	14578
17	Wholesale & Retail	1193	1873	1778	2156	3555	3374
18	Transport	1191	764	725	2162	2458	2333
19	Hotel & Restaurant	1619	2004	1902	2517	3573	3390
20	Communication	1063	685	650	2103	2500	2373
21	Finance	781	496	471	1548	1834	1741
22	Real Estate	465	1258	1194	701	1672	1587
23	Professional & Scientific	1514	532	505	2666	2543	2413
24	Admin Support	1510	1136	1078	2548	2948	2797
25	Public Administration	7701	789	749	8773	2653	2518
26	Education	833	652	619	2489	3544	3363
27	Health & Social Work	3156	600	569	4426	2814	2670
28	Art & Recreation	1003	1539	1461	1867	3049	2893
29	Other Services Activities	2200	1114	1057	3204	2866	2720

6.3 Implications for the resource costs for provision of a clean environment (waste free) on output prices

Another important question and issues is; what would be the impact on output prices if the polluter is forced to pay the actual resource cost for waste management services implied by their waste generation? and how does this compare with the unadjusted price multiplier estimations? The price multiplier determines the overall price to final demand for sector *j* output per £1 spent on primary input i.e. the direct and/or knock on impacts on the price of output (using equation 2 with unadjusted accounts). However, in this paper, we focus on the percentage changes in the vector of output prices generated with the adjusted price input-output system when we replace the unadjusted price inverse with the inverses derived from the full Leontief environmental input-output account as calculated in equation 3.

Table 3, reports the percentage change in the impact on prices of sectoral output in the adjusted account with 100% and 90% waste managed or cleaned relative to the unadjusted account. In Table 3, the first column of the results 'Adjusted' (100% cleaned), gives the percentage change in output prices with the adjusted account. Again, as illustrative scenarios, the figures in column 1 assumes all waste is managed or cleaned and that the polluter pays. The second column 'Adjusted' (90% cleaned), assumes that the polluter partial pays, where there is alternative responsibility for management and government changes its commitment, such that not all waste is cleaned or managed as a result the price of sectoral output is expected to fall relative to the 100% scenario as shown in Table 3. Column 1 and 2 together are the percentage change in output prices with the adjusted accounts based on Type I analysis, while column 3 and 4 of the results in Table 3 present the corresponding Type II multipliers. Let us begin our examination of Table 3, from the 100% waste cleaned column in the Type I case. Looking at column 1 of the results in more details, there are 15 sectors where the percentage change in output price is lower than in the unadjusted accounts, if the polluter is forced to pay the actual resource cost for waste management implied by their waste generation. The negative share price multiplier impacts are highest in 'Waste Management' 'Water Industry', 'Public Administration'. The impact of changes in percentage of the output prices of these sector is 10.4%, 0.9%, 0.6%, and 0.2% respectively lower than with the unadjusted accounts estimations.

In the remaining 14 sectors, the impacts of a percentage change in output prices in the adjusted accounts are higher than for the unadjusted accounts. The bigger differences are in 'Construction', 'Manufacture of wood', 'Electricity' 'Agriculture', 'Mining' and Food & Drink'. These sector percentages change in output prices are 1.10%, 0.31%, 0.27%, 0.20%, 0.17%, and 0.14% higher than in the unadjusted model. The pattern of results in terms of positive and negative price effects are the same in the 90% waste cleaned. The only difference with the 100% waste cleaned, is that in the 90% case, the size of the negative price in the 15 sectors grows and the positive price effects in the other 14 sectors become smaller.

Table 3 Percentage change in output prices with the adjusted account relative to the unadjusted input-output account

Sector number	Sector/Activity	Type I effects (household exogenous)		Type II effects (household endogenous)	
		Adjusted		Adjusted	
		100% waste cleaned	90% waste cleaned	100% waste cleaned	90% waste cleaned
1	Agriculture Forestry & Fishing	0.197%	0.183%	0.225%	0.211%
2	Mining & Quarrying	0.174%	0.162%	0.205%	0.193%
3	Food & Drink	0.145%	0.132%	0.184%	0.171%
4	Textiles	-0.050%	-0.070%	-0.002%	-0.022%
5	Manufacturing of Wood	0.315%	0.293%	0.360%	0.338%
6	Paper & Printing	-0.047%	-0.056%	-0.003%	-0.012%
7	Coke & Petroleum	0.003%	0.001%	0.010%	0.008%
8	Chemical Manufacture	-0.039%	-0.041%	0.007%	0.006%
9	Non Metallic Minerals	0.018%	0.008%	0.067%	0.058%
10	Metals	-0.052%	-0.061%	-0.003%	-0.012%
11	Machinery & Equipment	0.009%	0.004%	0.055%	0.051%
12	Misc Manufacture	0.010%	0.005%	0.061%	0.057%
13	Electricity	0.271%	0.255%	0.291%	0.275%
14	Water Industry	-0.928%	-0.951%	-0.897%	-0.920%
15	Waste Management	-10.483%	-10.486%	-10.441%	-10.444%
16	Construction	1.101%	1.039%	1.153%	1.091%
17	Wholesale & Retail	0.061%	0.052%	0.112%	0.104%
18	Transport	-0.038%	-0.042%	0.013%	0.010%
19	Hotel & Restaurant	0.034%	0.025%	0.082%	0.073%
20	Communication	-0.034%	-0.037%	0.022%	0.019%
21	Finance	-0.026%	-0.028%	0.015%	0.013%
22	Real Estate	0.071%	0.065%	0.084%	0.078%
23	Professional & Scientific	-0.088%	-0.090%	-0.027%	-0.029%
24	Admin Support	-0.033%	-0.039%	0.022%	0.017%
25	Public Administration	-0.618%	-0.622%	-0.561%	-0.565%
26	Education	-0.016%	-0.019%	0.072%	0.069%
27	Health & Social Work	-0.229%	-0.231%	-0.161%	-0.164%
28	Art & Recreation	0.048%	0.041%	0.094%	0.087%
29	Other Services Activities	-0.097%	-0.102%	-0.044%	-0.049%

In the Type II case, we then go through the process of recalculating the price multiplier matrix with the adjusted account to conduct a Type II price multiplier analysis. There are a number of differences in the Type II impact of output price changes results relative to Type I. First, because in the Type II case, induced (income and consumption) effects have spread throughout the system. Moreover, recall from Table 1, that the household implied demand for waste management service do not assign with their payments. Therefore, in the adjusted accounts the Type II price multiplier columns as shown in Table 3, are lower than Type I. Note that the negative price effects are smaller and the positive price effects are larger in column 3 than in column 1. The results and discussion in this section provide us with insights on how the environmental IO framework can be operationalised to capture the full resource implications of waste management impacts through both up and down-stream regional supply chains. This may be very useful to policy if, for example, a ‘polluter pays’ scenerio is considered relative to one where government retains some commitment to pay for waste management. Moreover, this information may help us to identify sources of cost pressures and sector that put upward pressure on the system.

7. Conclusion

In this paper, we revisit and further develop a previous Scottish study conducted by Allan et al. (2007) which made a key methodological contribution by operationalizing the Leontief (1970) environmental input-output model to consider the need to determine social and/or resource costs of supplying common resources such as a ‘clean environment’, at a local or regional level. Thus, from applying environmental input-output model to 2011 accounting year data, important findings arise. First, we find that with the unadjusted system the resource cost of waste management implied by each sector’s waste generation is hidden or identifiable in the unadjusted accounts. Once we adjust the accounts, we find that the production side and household final demand of the economy is subsidised in terms of direct payment for waste management services by mostly ‘Waste Management’, ‘Public Administration’ and ‘Health’ sectors in particular. These may reflect heavy government subsidies of waste management, given that the above-mentioned sectors are government-owned and these sectors are purchasing more resources for waste management than they generate. However, more generally, in the ‘Waste payment adjustment’ there are 12 sectors that are underpaying for waste management service and 17 that are overpaying. Overall, if underpayment represents an implicit subsidy, overpayment would seem to imply an implicit tax.

Secondly, we find that with the unadjusted accounts, the output multipliers are understated in terms of the impacts on ‘Waste Management’ sector output in sectors that underpay for their waste management. Specifically, the demand reflected by the unadjusted multiplier calculation cannot be mapped to the resource costs implied by waste generation of each sector. As a result, sectors that directly pay less for waste disposal and cleaning than their implied demand, have their multipliers increase when the full implied demand is taken into account. Whereas, sectors that directly overpay have their multiplier decrease with the adjusted accounts

Thirdly, with the unadjusted accounts the average cost of waste management/disposal vary across different types of waste and also maybe across different types of public and private waste disposal organisations. However, once we impose of force each polluter to pay the actual cost for waste management implied by their waste generation, there are then positive and negative effects on the price of sectoral output with the unadjusted and adjusted input-output accounts.

Fourth, there are a number contributions this paper add to our knowledge from applying an adjusted Leontief environmental input-output model to consider/incorporated the resource cost of waste manage into the economic system in relation to the previous and/or incomplete study by Allan et al. (2007). In terms of the who pays the resource cost for waste management services implied by their waste generation, we find in this paper that 12 sectors are underpaying and 16 sectors are overpaying for waste management services. Whilst, Allan et al. (2007) found 11 sectors underpaying and 9 sectors to be underpaying. The difference in findings may be attributable to inadequate data and differences in level of aggregation applied [2]. It is also very likely that these Additional payments anomalies reflect problems of inadequate data. The improved data of industrial waste generated we employ in this paper help to better identify sectors within the Scottish economy that pay below the resource cost for waste management. A second point for consideration is based on the implied direct and indirect demand for waste disposal services per £1 million of final demand expenditure across sectors. Allan et al. (2007) identified only 8 sectors, whereas we identified 15 sectors where the multiplier is greater with unadjusted input-output accounts. Moreover, with the full Leontief accounts, they have 12 sector relative to 14 sector here, where the impacts on the demand for waste management or disposal is greater with the adjusted accounts relative to the conventional system. Thirdly, Allan et al. (2007) do not go as far we do to consider the type of final cosnumer that bear the burden and ultimately pays the full resource cost for waste disposal and cleaning are. Therefore, we provide additional information the usefulness of the full Leontief model and arrive at new

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[2] Allan et al. (2007) use Scottish input-output table (20x20) input-output table with 7 final demand sectors for the accounting year 1999 compared to (29x29) input-output table with 7 final demand sectors for the base year 2011 in the current study

conclusions, with final demand consumers in ‘Waste management’,‘Public Administration’ and ‘Health’ sectors with is mainly the Government, and the external cost is pushed to local tax payers bearing the burden of the resource cost for waste disposal and cleaning.

8. Future research initiatives: proposal for modelling CO_2 utilisation using the Leontief (1970) environmental input-output approach

For future research, we propose that similar or even the same method applied in this paper, may play a potential role in thinking of and considering CO_2 utilization in the UK. What if we think of CO_2 utilization and carbon capture and storage (CCS) in a similar or almost replica case to waste as we have done in this paper? We believe that the idea put forward by Leontief (1970) about establishing new economic activities that ‘deal’ with pollution problems provides the basis for introducing recycling processes more generally, and CO_2 utilisation in the context of a circular economy input-output framework. Therefore, we may begin to consider this by potentially combining the ideas discussed in previous sections and in particular Section 3 in a number of stages or a progress way. For instance, carbon capture processes would form the first stage of either a disposal or recycling/utilisation process so that they would share characteristics of Leontief’s ‘cleaning’ (or disposal) sector. Where transport and storage are also required before, during or after utilization (e.g. enhanced oil recovery using CO_2 in the North Sea would require pipeline transport before utilisation and storage after) these will become part of or form additional ‘cleaning’ sector(s).

Thus, what may be considered as the key and primary issue is how the input costs of the capture (and/or transport and/or storage) activity (activities) are met by the total revenue received for the output (provision of capture ‘services’) either through the polluter (carbon producer) paying, or some kind of subsidy. Crucially, it is only when some kind of value can be placed on the treatment of CO_2, and a break-down of the domestic supply chain requirements to facilitate the capture/transport/storage activities can be established, that additional economic multiplier effects of having such activity present in the economy can be assessed. We believe that there is much to gain by developing and testing a new analytical approach for assessing and anticipating the economy-wide implications of introducing CCS systems and networks, and, in doing so, to achieve a transformation in the way that CCS is viewed and considered by policy and other stakeholders.

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Table A1

Sectoral aggregation scheme production sector activities identified in the Scottish input-output Table 2011

	Sectors	Scottish input-output Categories	SIC(2007) Codes
1	Agriculture, Forestry & Fishing	1--5	1-3.2
2	Mining & Quarrying	6--8	5--9
3	Food & Drink Manufacture	9--18	10.1-12
4	Textiles	20--22	13-15
5	Manufacturing of Wood Products	23	16
6	Paper & Printing	24--25	17-18
7	Coke & Petroleum	26	19
8	Chemical Manufacture	26--32	20-22
9	Non Metallic Minerals	33-34	23
10	Metals	35--37	24-25
11	Machinery & Equipment	38--42	26-30
12	Misc Manufacture	43--45	31-33
13	Electricity	46--47	35
14	Water Industry	48	36-37
15	Waste Management	49	38-39
16	Construction	50	41-43
17	Wholesale & Retail	51--53	45-47
18	Transport	54--59	49.1-53
19	Hotels & Restaurants	60--61	55-56
20	Communication	62--66	58-63
21	Finance	67--69	64-66
22	Real Estate	70--72	68.1-68.3
23	Professional & Scientific	73--80	69.1-75
24	Admin & Support	81--86	77-82
25	Public Admin	87	84
26	Education	88	85
27	Health & Social Work	89--90	86-88
28	Arts & Recreation	91--94	90-93
29	Other Service Activities	95--98	94-96