Examining the nature and structure of a local pollutant: An illustrative case of physical waste generation in Scotland using environmental input-output accounting methods

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JEL Codes: C68, R11, Q53

Abstract

This paper explores how the environmental input-output model can be applied to consider the fundamental aspects of physical waste problems in Scotland. In particular, we consider how IO multiplier methods may be used to develop an understanding of demand drivers of a local pollutant (taking physical waste as an example). This is with the aim to demonstrate how environmental IO Type I multipliers (incorporating direct and indirect, or inter-industry, effects) may be used to describe and communicate key elements of local pollution impacts. As a first step, we calculate the amount of waste directly generated in different production activities in Scotland under what is commonly referred to as a 'production based principle'. We also attribute total waste generated in production to the different types of final consumers, whose demand for particular output directly or indirectly may be attributed as driving this waste generation. More generally, we consider how this approach may be used as a basis for the home region dimension of a footprint analysis based on a partial 'consumption accounting principle'. We argue that employing IO methods in this way can provide information that may prove useful if regional policy makers attempt to consider waste reduction through consumption-focussed polices as well as production-based ones.

Keywords: Attribution Analysis; National Accounting: Input-Output; Multipliers; Scotland; Waste

1. Introduction

Economic actions and activity by the ‘Users’ or ‘Polluters’ exert some negative impacts on the environment and cause the generation of environmental ‘bads’ (e.g. air pollution, carbon emissions, waste, resource depletion etc.). Thus, two natural questions arise: (1) who are the ‘Users’ or ‘Polluters’; (2) how can we examine the nature and structure (direct and indirect) of economic-environmental interactions and connections? One way the environment input-output method can be used is to assess and examine the nature of externalities via pollutants in the economic system. Specifically, it can be used for accounting purposes to attribute various environmental ‘bads’ to production and consumption activities at any given point in time (the accounting year the input-output data are reported for). This is a traditional approach that has been used extensively in the literature to examine pollution generation, resource use and other environmental problems (Llop, 2008; Minx et al., 2009; Tukker et al., 2009; Feng et al., 2012; Munday et al., 2013; R. Chen et al., 2016).

In this paper, we focus on investigating which production sectors are directly responsible for waste generation in a single region and determining the final consumption demands that ultimately drive production and its related waste pressures in Scotland. In particular, we demonstrate how environmental input-output Type I multipliers (incorporating direct and indirect, or inter-industry, effects) may be used to describe and communicate key elements of local pollution impacts. For instance, we calculate the amount of waste directly generated in various production activities in Scotland under what is commonly referred to as a ‘production based principle’.Additionally, we also attribute total waste generated in production to various types of final consumers, whose demand for particular output directly or indirectly may be driving this waste generation. More generally, we consider how this approach may be used as a basis for the home region dimension of a footprint analysis based on a partial ‘consumption based principle’, that allows industrial waste generation to be consistently attributed to the respective final demand categories. This approach is considered partial ‘consumption based principle’, or attribution analysis, to distinguish it from full consumption accounting[1]; i.e., a full waste footprint analysis. The intention of this type of attribution analysis is not to assign responsibility to the final consumer but to highlight an alternative (or possibly complementary) approach to the waste production accounting methods at the local/regional level.

The above-mentioned national accounting principles we believe have an important role to play in policy analysis. This is because, this type of environmental accounting provides information that will prove useful if local policy makers attempt to control waste generation through consumption-based policies as well as production-based policies. This may be particularly useful in providing insights/information that may assist policy makers in the process of monitoring the progress of waste generation and prevention within a devolved UK region linked that can inform the thinking and understanding of policy analysts in the Scottish Government and Zero Waste Scotland (ZWS).

The remainder of the chapter is as follows. In Section 2, we begin by discussing some issues for policy in the context of measuring and examining the environmental impacts caused by different economic activities. This is followed by a review of studies that have applied environmental input-output model to consider various environmental impact attribution scenarios, including studies that consider various dimension of the waste problem (e.g. Jensen et al., 2011; Liao et al., 2015; Nakamura and Kondo, 2002; Salemdeeb et al., 2016) (Section 3). In Section 4, we describe the method employed in this chapter that is focused on enumerating the extension of conventional economic input-output model to demand driven environmental input-output model and applying it to account for waste associated with economic activity. The data used for communicating key element of the waste generation in Scotland is described in Section and in Section 2.6, the empirical results are presented and discussed. Finally, we discuss the conclusions of the paper in Section 2.7.

[1] Full consumption based accounts consider environmental bads (e.g. emissions) produced globally to meet consumption demand within a national economy (Wiedmann, 2009; Wiedmann et al., 2006)

2. Issues for policy

Waste creates both direct and indirect environment and health impacts. As a result, governments worldwide introduce various strategies and plans to reduce waste caused by different types of economic activity. In recent years, a mix of policy measures (e.g. zero waste strategies, waste hierarchy, and integrated waste management) has been applied, in order to improve sustainability in waste management (Beylot et al., 2016; Osmani, 2012; Rocco et al., 2016; Song et al., 2014; Zaman, 2014). This is discussed and considered with the overarching objective of how to use natural material resources more efficiently, avoiding waste and where possible using unavoidable waste as a resource (Cobo et al., 2017; Huysman et al., 2015; Schreck and Wagner, 2017).

In the UK and in particular Scotland, there has been continuous improvement of waste management to reduce the proportion of waste generation by economic activity. For instance, the Scottish Government with support of Zero Waste Scotland have introduced several waste management programmes to minimise the adverse effect of physical waste on the environment, public health and to create a waste free society (Zero Waste Scotland, 2016)[2]. Among other are the Zero Waste plan, Safeguarding Scotland Resources, and the Circular economy programmes or strategies (Zero Waste Scotland, 2015)[3]. Together, these types of waste management strategies and policies aims to 'push' waste up the waste hierarchy towards prevention and new initiatives to create a more resource efficient and circular economy (Zero Waste Scotland, 2015). In particular, the circular economy concept is targeted at replacing the traditional linear approach (make-use-dispose) of waste management with a (reduce-reuse-recycle) society of resource efficiency (Zero Waste Scotland, 2015).

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[2] Zero Waste Scotland's Programme Plan (2016-2017). Available at http://www.zerowastescotland.org.uk/sites/default/files/Zero%20Waste%20Scotland%20Programme%20Plan%202016-17.pdf

[3] The most recent report by ZWS on 'the Carbon Impacts of the Circular Economy' was published in 2015 and can be downloaded at http://www.zerowastescotland.org.uk/sites/default/files/CIoCE%20Technical%20Report%20-%20FINAL%20-%2015.06.15.pdf.

However, the majority of waste strategies, targets, objective, and policies to date across the UK has been strongly influenced by EU legislation and Directives. A prominent example is the EU Waste Framework Directive WFD (2008)[4], which is a legal framework obligating EU member states to set waste management policies in order to reduce the negative effects of waste generation. The Directive includes key elements of waste management plans including the introduction of the Waste hierarchy as mentioned above. Scotland 's Zero Waste Plan is conceptualised around the EU Directive in particular the waste hierarchy[5], which places waste prevention, reuse, recycling, recovery, and disposal in this other as the best environmental performance pathways to achieving a zero waste economy. However, most economies (including the UK) typically operate in reverse, putting disposal (e.g. landfill and incineration) at the top of the preference scale.

More generally, although the waste hierarchy is useful in its own right, it can be argued that it does not account for waste generation. Therefore, there is no clear understanding of where the physical waste pressures of a local pollutant occur within the economy. We argue that the EU Directive and national and/or regional policies based on them miss a fundamental step in addressing the waste problem. There should be a clear understanding of the nature and structure of waste in the process of addressing waste generation and ultimately arriving at waste prevention, including its causes and demand drivers as externalities. Moreover, with the EU waste hierarchy and even with other waste strategies and policies (e.g. integrated waste management), government seems to have mostly focused more on the direct polluter with no clear consideration of the indirect polluter.

If policy makers reconsider and adopt a method that can simultaneously consider the direct and indirect polluter in respect to waste generation, it would be useful in answering key questions of which economic sectors may be considered responsible

[4] EU Waste Framework Directive (2008) available at http://ec.europa.eu/environment/waste/framework/

[5] The waste hierarchy ranks the main waste management option according to the best environmental performance and outcome considering the entire lifecycle of materials (WFD 2008).

for waste generation by determining consumption patterns of different types of final consumers. To be specific, it may assist policy makers in identifying both the direct and indirect polluters, which may in turn, cause reconsideration of how the ‘Polluters’ and ‘Users’ are identified and defined in the economy. In addition, it may help policy makers in monitoring, assessing, and considering how their decisions and policies influence waste generation.

To demonstrate the above argument, we are proposing that the traditional attribution environmental input-output approach that is commonly used for carbon emission accounting, which follows the production based principle (Munksgaard and Pedersen, 2001) and partial consumption-based principle (Turner et al., 2014), can be applied to the case of waste. Waste is a pollutant that – in contrast to carbon – has greater impacts within the local economy as opposed to impacting globally via international supply chains. In this context, we believe that application of the environmental input-output method in this way may also point out the importance of complementing the territorial-based accounting approach with a partial consumption perspective that focuses on domestic supply chain activity.

3. Waste generation and input-output framework

There is a growing literature on the use of the environmental input-output model to consider various dimensions of the waste problem (Beylot et al., 2017; Delahaye et al., 2011; Duchin, 1990; Kondo & Nakamura, 2005; Munksgaard et al., 2005; Reynolds et al., 2016). However, this have been largely limited to considering waste management issues, particularly in determining the appropriate measures for waste reduction based on either reuse, recycling and recovery that promote sustainable society and green consumption (Duchin, 1990; Li, 2012; Nakamura & Yamasue, 2010; Ni et al., 2001; Xu & Zhang, 2009). This may reflect the fact that waste policies and strategies tended to focus on moving from the high dependence on the use of landfill to the use of the EU waste hierarchy that prioritize waste treatment options. Recently, focus is now shifting to resource efficiency and circular economy approaches in waste management, which means considering waste as a resource input rather than a pollution output (Li, 2012; Bastein et al., 2013; Ham et al., 2013; Agrawal et al., 2013).

A study conducted by Duchin (1990) applies the environmental input-output method to examine the impact of technological change on multiple waste treatment systems. In addition, the author evaluated the physical and economic feasibility of alternative strategies for dealing with biological waste. In a pioneering contribution, Nakamura, (1999) and Nakamura & Kondo, (2002) develop a waste input-output modelling approach, to analyse the interactions between waste emissions and economic activity of the Japanese economy. Their model is used to evaluate the effects of alternative waste disposal and recycling options on the various levels of industrial production. Their later work by Nakamura & Kondo (2009) provides a comprehensive literature of the extended use of waste input-output models, for example in terms of analysis of sustainable consumption, life cycle, materials flows analysis and linear programming (for example see Takase et al., 2005; Nakamura & Kondo, 2006; Kondo & Nakamura, 2004; Nakamura & Nakajima, 2005). Choi et al. (2010), on the other hand, describes how to use baseline input-output model and environmental input-output accounts to analyse geographical e-waste recycling systems for end-of-life commodities. This author, had the specific objective of addressing the potential conceptual and practical issues that may arise when attempting to recycle end-of-life) commodities and related activities are incorporated into the standard IO model framework

A key advantage of studies that use waste input-output model is that it captures the integration of waste generation and creation, and management options so that waste can be tracked through the economic system from origin to destination or end of life. While this constitutes a necessary part of the broader or wider evidence base in considering the economy-waste-environmental nexus, such analyses do not attempt to consider demand drivers of waste generation aligned with national accounting principles. There has been other studies that consider that the disposal and treatment of waste cause the generation of several greenhouse gases and can potentially contribute to global climate change (see Dietzenbacher, 2005; Finnveden et al., 2007; Williams, 2013). It is argued that the most significant greenhouse gas produced from waste is methane. It is released during the breakdown of organic matter in landfills (Mühle et al., 2010). Other forms of waste disposal and treatment also produce greenhouse gas, in the form of carbon dioxide (Dijkgraaf and Vollebergh, 2004).However, these study are not based on the input-output framework, rather based on assessment approaches and integrated waste management options. Moreover, in our case we focus on physical waste and not pollution components and aspects of waste generation.

Among the previous studies, several of them consider international dimensions to waste management, where waste (such as hazardous waste) is shipped internationally for management in a different geographical locations (for example see Alberini and Bartholomew 1999, Fischer et al. 2008). However, in the case of a local pollutant (e.g. waste), the impacts primarily lie at the local level and so they may not require international trade component of any kind. In the context of waste treatment and green accounting, Allan et al. (2007) consider resource cost and economy-wide implications of waste management. Specifically, they identify the sectors that pay or do not pay the actual cost for waste cleaning services implied by the waste generated and consider sectors that ultimately bears the cost of managing waste. Delahaye et al. (2011) introduce Dutch waste accounts that show the origin, destination, and treatment methods of waste types categorized according to the adopted European waste regulations. Other studies consider the development of physical input-output systems to properly assess waste flows in input-output framework (Dietzenbacher, 2005; Hubacek & Giljum, 2003; Weisz & Duchin, 2006; Xu & Zhang, 2009).

Previous studies that have explicitly attempted to apply environmental input-output model to attribute the responsibility of waste to economic activities are scarce. We review some existing examples here. Jensen et al. (2011) apply a regional input-output framework and data derived on waste generation by industry to analyse different aspects of regional waste accountability. In addition, they estimate a series of industry output–waste multipliers, using some variety methods for waste attribution from production and consumption perspectives. As a case study, this paper focuses on Wales, a region of the UK. Court (2012) argues that although multiple modelling techniques can be employed to relate to environmental outcomes of economic activity, it is important to select a method that is transparent, easily interpreted, and consistent with economic-environmental policy objectives. For these reasons, the author applies environmental accounting methods based on an input-output framework as a means to examine the relationships between economic activity and hazardous waste generation in the US. The author accounts for hazardous waste generation not only in terms of direct generation and intensity (hazardous waste generated per unit of output), but also in terms of indirect and total generation intensity by industry, as well as generation attributed to final demand for an industry's output. The results are analysed from multiple perspectives and discussed in terms of policy relevance. Court et al. (2014) also focus on hazardous waste. However, they use an approach similar to Jensen et al. and they apply the input-output framework to attribute hazardous waste streams to regional production and consumption activity, and to connect these same waste streams to different management options. These authors raise the point that a method which uses the input-output framework provides useful intelligence for decision-makers seeking to connect elements of the management of the hazardous waste hierarchy to production and to different patterns and types of final consumption (including domestic household consumption).

Other studies attempt to determine the direct and indirect waste generated along the supply chain, in order to identify what industries create high demand for incineration and landfill waste management options (Lee et al., 2012; Liao et al., 2015). On the other hand, Salemdeeb et al., (2016) examine the direct and indirect waste arising across the UK supply chain using waste input-output table developed by (Nakamura, 1999; Nakamura & Kondo, 2002). There is a need to consider waste input-output accounting within the waste management literature. More generally, in the existing and vast literature on waste management, there are only limited attempts to apply attribution analysis for waste accounting at regional level and within the context of considering appropriate input-output measures when the focus is on a local pollutant as physical waste. Our contribution in this paper is to fill in such gaps in the input-output literature, at least at a regional level through the methodology set out in this paper. In this respect, we identify production and final consumption demand pressures for Scottish physical waste generation following the production based accounts Munksgaard & Pedersen (2001) and partial consumption based account Turner et al. (2014).

4. Extending the conventional demand driven input-output model to consider economic-environmental issues

In this section, we describe the way in which environmental 'bads' (e.g. physical waste) is being incorporated into the standard demand driven input-output analysis. Ultimately, we show how the input-output methods are developed in order to examine and assess the relationship between economic sectors and waste generation (i.e. direct waste generation), inter-industry waste generation relationship (indirect waste generation) and Type I output waste multipliers (direct and indirect).

In what follows, note that the symbols in the equations in this paper refer to either vector, matrices, or scalar. A bold lower case character denotes a vector, e.g. **x.** A bold upper case character, such as **A**., denotes a matrix**.** All non-bold characters are scalars, such as a_{ij}. With this notation in mind, let us consider an economy divided into N number of sectors. Each sector produce output that goes to satisfy final demand and the remainder is to meet intermediate demand that servers as input to other sectors. We can then write the basic demand driven input-output equation that describes the way in which a sector output is distributed to final demand and other sectors as:

$$\mathbf{x} = \mathbf{A}\mathbf{x} + \mathbf{y} \qquad (1)$$

Where the N × 1 vector of total output is $\mathbf{x}$, $\boldsymbol{y}$ is the N× 1 vector with each element representing final demand (e.g. households, governments, capital and exports) and **A** is the N ×N matrix of input coefficients:

$$\mathbf{A} = [\mathrm{a_{ij}}], \mathrm{a_{ij}} = \frac{\mathrm{X_{ij}}}{\mathrm{X_j}} \qquad (2)$$

When solved for total output, equation (2.1) yields:

$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{y} = \mathbf{L}\mathbf{y} \tag{3}$$

In equation 3, **I** is the identity matrix of the same order as **A**. **L** =$(\mathbf{I} - \mathbf{A})^{-1}$, it has elements l_{ij} , describing the amount of output generated in each sector i per unit of final demand for the output of sector j. Then, the sum of the elements in the j^{th}column of the Leontief inverse matrix, given the output multiplier for sector j is:

$$l_{ij} = \sum_{i=1}^{N} l_{ij} \tag{4}$$

Equation 4 describes the total output from all sectors generated from one unit of final demand of sector $j's$ output. Similarly, if the total waste (or another environmental impact) generated in a single region, ($\mathrm{W^R}$) consist of waste directly generated by production activities, $\mathrm{W^P}$ and waste directly generated by consumption activities,$\mathrm{W^C}$ in a given accounting year (usually accounting year for which the input-output data is reported), then:

$$\mathrm{W^R} = \mathrm{W^P} + \mathrm{W^C} \tag{5}$$

However, this paper focuses on the production or industry-level aspects of waste generation such that, in line with the production-based accounting, the total waste generated in a region $\mathrm{W^R}$ can be directly attributed to production activities or the total waste generated in production as:

$$\mathrm{W^P} = \Omega \mathrm{x} \tag{6}$$

Where $\mathrm{W^p}$ is a Kx1 vector, with elements, w_k^p and K=1,…,K representing the total waste generated by all production activities in the economy. Ωx is a K×N matrix where element $\omega_{k,i}$ represents the ratio of waste type K per unit of total output in sector i. Thus, with the production-based account, the standard input-output attribution

(Leontief 1970, Miller and Blair 2009) can be employed, such that the equation (3) is extended to:

$$W^{R} = w^{p}[\mathbf{I} - \mathbf{A}]^{-1} \tag{7}$$

If a partial consumer-based principle is considered, then the IO system is set-up to consider the impact of different types of final demand in the economy. Production of output is to meet final demand and thus driven by final demand. Therefore, the amount of waste generated by production activities can also reflect waste generated in production that is attributable to final consumption demand, thus

$$W^{R} = w^{p}[\mathbf{I} - \mathbf{A}]^{-1}y \tag{8}$$

Note that equation (7) and (8) is based on standard Type I approach. A common feature of input-output environmental attribution is that household consumption expenditure is treated as an element of exogenously determined final demand in the system. Particularly, Type II involves looking at the impacts of increase in employment and employment income which funds consumption expenditure. However, in input-output framework, this involves removing household consumption as a driver of pollution. This would seem to be inconsistent with the popular view that human behaviour lies at heart of environmental problems (Emonts-Holley et al., 2015; McGregor et al., 2008). Nonetheless, the income from employment associated with final demand for one unit of any sector's output affects the total level of household expenditure and thus pollution in the economy. This is because households are responsible for generating domestic waste both directly by purchasing and burning fuels and indirectly by purchasing locally produced goods and services, which entails waste generation in their production and they may do so to greater degree if income from employment grows. However, for the attribution analysis here we maintain the traditional Type I focus.

5. Data for the allocation of waste generated to production and final consumption demand

The dataset we use in this paper forms a crucial part of the analysis and ultimately contributes to the accuracy of the findings and outcome in this paper. The Scottish Government produces and publishes input-output data periodically. The dataset comprises of Scottish Supply tables, Use tables and Symmetric input-output analytical tables that has been produced annually from 1998-2014[6]. The 2014 data, is the most recent input-output data published. In this paper, we employ the industry-by-industry analytical Scottish input-output analytical table of 2011.

The 2011 input-output table reports transaction data for 97 input-output categories (IOC) mapped to the Standard Industrial Classification (SIC) of 2007 (see Table A1 in the Appendix for sectoral breakdown). The input-output table reports where each industry sold its output, across the 97 Scottish industry categories (intermediate sales) and different types of final consumption (including household and government demands, capital formation and exports, etc.). In addition, it reports where each industry bought its inputs, again across all 97 Scottish IOC (intermediate purchases), as well as imported goods and services, net taxes on products/production, payments to labour, and other value added (generally capital, and land, equating as 'gross operating surplus').

In terms of the waste data, we have established that the production of waste creates both direct and indirect environmental impacts and a range of strategies are available to reduce the generation of waste by industry and households, and to select waste treatment approaches that minimize environmental harm. However, evaluating these strategies requires reliable and detailed data on waste generation and its management.

Scottish Environment Protection Agency and Zero Waste Scotland collect and report robust data annually from 2011-2015 on Scottish Business Waste Arising. The dataset

[6] input-output tables available for download at http://www.gov.scot/Topics/Statistics/Browse/Economy/input-output/Downloads

covers tonnes of 33 different types of waste generated by 29 industrial groups in Scotland. It consists mainly of waste from households; commercial industries and construction and demolition for each of the 32 local councils in Scotland as well as the entire region. This aligns the data with the sources of waste that will be targeted by policies, landfill restrictions, and other involvements designed to optimise resource utilisation and waste prevention based on the objective of the Scotland Zero Waste Plan (ZWP)[7] under the Scotland Climate Change Act (2009). We use Scottish Business Waste Arising data for the accounting year 2011. To our knowledge, 2011 is the most recent year where comprehensive national waste data is available in Scotland. In perspective, we consider the data as comprehensive because it reported in sectoral breakdown that is consistent with the SIC used in developing the economic accounts.

In preparing the dataset for analysis, we have mapped waste generated in each sector per £1million of sectoral output, i.e. direct waste intensities to each of the 29 groupings using output data from the input-output account. These waste intensities were then applied to each of the sub-sectors of input-output category (IOC) that belong to each grouping (e.g., the third grouping in the Business Waste Arising data is 'Food and drink' and this maps to IOCs 9-18). This means that sectors in the same input-output grouping share the same waste coefficient across the economy. Thus, the waste generated is reported for each of the 97 sectors in the input-output tables, which gave a 33 (K, types of waste) rows by 97 columns (N, Scottish input-output industries) matrix of direct waste intensities figures. More generally, we are using the data in this way to show that the input-output multiplier analysis can be used for more than just direct and total multiplier analysis as we show in Section.6.

[7] Scotland's Zero Waste Plan (2010) Available at http://www.gov.scot/Topics/Environment/waste-and-pollution/Waste-1/wastestrategy

6. Waste generated and application to the demand-driven environmental input-output model

6.1 Production based accounts

In this section, we present the findings from the input-output waste accounting analysis. First, we focus on an analysis that displays and examines waste generation in Scotland supported by industry level activities. This is then extended to consider Type I output-waste multipliers that captures direct and indirect waste generation in each sector per £millions of final demand. Finally, we consider the final demand sectors that drive waste generation in the direct waste intensive sector as a result of their demand for that sectors output.

Table 1, presents the waste generation by all 97 industries in Scotland in 2011. In Table 1, the first column of results reports the direct total waste intensity of output in different sectors. The second column reports the total amount of waste generated. The third column reports each of these entries (i.e. total waste generation) as a percentage of total industrial waste generation across the 97 Scottish industries. The results are ranked from highest to lowest in terms of total waste generation. Evidently, the 'Construction' industry waste generation is the largest across all 97 sectors. Of the total industry-level waste generation, the 'Construction' industry's waste generation is 6,051,440 tonnes (57%) of total waste generation. This is followed by the 'Electricity', 'Retail', 'Wholesale', 'Mining', 'Spirit and Wine' sectors respectively. Of the total waste generation, these top five (excluding construction) are accountable for around 1,658,426.76 tonnes of waste (15.66%).

There are several possible explanations for the 'Construction' sector result. First, from the base year data, the 'Construction' sector contributed £18,950 million in economic output to Scotland. This is the largest output across intermediate sectors. Reflecting the importance of the 'Construction' sector to the Scottish economy. Secondly, the 'Construction' sector reported in the input-output accounts covers SIC codes 41-43, which cover construction of buildings, civil engineering and specialised construction services (the later including demolition, site preparation, electricals, plumbing and plastering etc.). Perhaps, it is then safe to say that the type of activities of the ‘Construction’ sector contribute to the level of its waste generation in Scotland. In fact, from the underlying dataset, ‘Construction and Demolition’, ‘Soil Waste’ and ‘Metallic Ferrous’ are the largest waste-types generated by the ‘Construction’ sector. Policies shaping the plans and strategies for waste management and reduction should consider ‘Construction’ as the main driver of industry-level waste generation.

The ‘Electricity’ sector is the second largest contributor to total industry waste generation. This industry generates 485,250 tonnes of waste, which is just 4% of total industrial waste generation and 3% of the total industry waste generation by the top five. In comparison to the ‘Construction’ sector, there are plausible reasons for the lower contribution of the ‘Electricity’ sector to total industry waste generation. We know that electricity is one of the major sources of energy in Scotland. However, in the time period of the study (i.e. 2011), Scotland underwent a period of decarbonisation of the electricity industry and increased generation of electricity from renewable sources which are less waste intensive than electricity generation through fossil fuels.

In fact, in 2011, the Scottish Government set an ambitious target aiming for an output equivalent to 100% of Scotland’s demand for electricity to be met from renewables (Scottish Government, 2011)[8]. Moreover, given that electricity in Scotland can be generated by burning waste i.e. energy from waste (EfW), the ‘Electricity’ sector may be considered a self-cleaning sector. A study by Sustainable Development Commission Scotland shows that EfW in Scotland could contribute approximately 2.0 Terawatt hour (TWh) of useful heat and 0.90 TWh of electricity per year. This is equivalent to approximately 3% of Scotland’s total heat demand and total electricity demand (Sustainable Development Commission, 2010)[9].

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[8] Scottish Government (2011), 2020 routemap for renewable energy in Scotland available at http://www.gov.scot/Resource/Doc/917/0120033.pdf

[9] Sustainable Development Commission Scotland (2010) report to the Scottish Government in energy from waste potential in Scotland is available at http://www.gov.scot/resource/doc/311011/0098129.pdf

Table 1 97 sector direct waste intensity, total waste generation and percentage share of total waste generation in Scotland in 2011

Sector number	Sector name	Direct	Total Direct Waste Generated	Share of Total Direct Waste generated
1	Construction	319.33	6,051,440.01	57.14%
2	Electricity	60.36	495,250.81	4.68%
3	Retail	37.92	338,224.28	3.19%
4	Wholesale	37.92	312,094.51	2.95%
5	Mining Support	40.91	281,504.22	2.66%
6	Spirits & wines	63.24	231,352.94	2.18%
7	Agriculture	68.73	194,969.24	1.84%
8	Food & beverage services	43.74	170,873.77	1.61%
9	Water and sewerage	133.93	165,646.38	1.56%
10	Education	14.16	119,030.00	1.12%
11	Fabricated metal	43.67	117,422.50	1.11%
12	Health	9.25	110,793.23	1.05%
13	Wholesale & Retail	37.92	102,843.21	0.97%
14	Wood and wood products	108.17	99,482.71	0.94%
15	Accommodation	43.74	93,946.23	0.89%
16	Gas	60.36	90,185.25	0.85%
17	Public administration	6.26	87,776.00	0.83%
18	Textiles	106.69	81,735.38	0.77%
19	Meat processing	63.24	81,088.04	0.77%
20	Fish & fruit processing	63.24	69,727.95	0.66%
21	Bakery & farinaceous	63.24	62,494.58	0.59%
22	Residential care and social work	9.25	57,700.77	0.54%
23	Employment services	25.91	49,095.68	0.46%
24	Coke, petroleum & petrochemicals	6.63	47,586.79	0.45%
25	Imputed rent	5.24	47,424.05	0.45%
26	Sports & recreation	36.08	45,050.32	0.43%
27	Architectural services	6.73	41,413.48	0.39%
28	Gambling	36.08	41,378.29	0.39%
29	Dairy products, oils & fats	63.24	38,602.18	0.36%
30	Rental and leasing services	25.91	38,313.17	0.36%
31	Other land transport	10.34	36,400.59	0.34%
32	Wearing apparel	106.69	35,692.32	0.34%
33	Support services for transport	10.34	34,294.59	0.32%
34	Building services	25.91	31,716.21	0.30%
35	Paper & paper products	32.52	29,600.26	0.28%
36	Business support services	25.91	28,991.04	0.27%
37	Other transport equipment	11.59	28,255.18	0.27%
38	Other food	63.24	27,525.86	0.26%
39	Travel & related services	25.91	25,728.29	0.24%
40	Real estate - own	5.24	25,528.78	0.24%
41	Aquaculture	68.73	25,236.28	0.24%
42	Machinery & equipment	11.59	25,112.65	0.24%
43	Computers, electronics	11.59	24,686.20	0.23%
44	Oil & gas extraction, metal	40.91	22,300.32	0.21%
45	Repair & maintenance	14.57	21,907.01	0.21%
46	Other personal services	20.54	21,089.74	0.20%
47	Telecommunications	6.72	21,019.39	0.20%
48	Soft Drinks	63.24	18,736.59	0.18%
49	Fishing	68.73	18,100.79	0.17%

Table 1 continued

Sector number	Sector name	Direct	Total Direct Waste Generated	Share of Total Direct Waste generated
50	Glass, clay & stone	36.65	16,189.38	0.15%
51	Forestry harvesting	68.73	13,900.12	0.13%
52	Creative services	36.08	13,413.89	0.13%
53	Membership organisations	20.54	13,072.81	0.12%
54	Insurance & pensions	1.61	12,603.82	0.12%
55	Computer services	6.72	12,253.25	0.12%
56	Cultural services	36.08	12,149.50	0.11%
57	Printing and recording	32.52	11,973.85	0.11%
58	Post & courier	10.34	11,578.51	0.11%
59	Financial services	1.61	11,532.27	0.11%
60	Air transport	10.34	11,093.18	0.10%
61	Coal & lignite	40.91	10,981.74	0.10%
62	Cement lime & plaster	36.65	10,880.57	0.10%
63	Head office & consulting services	6.73	10,538.10	0.10%
64	Iron & Steel	43.67	10,388.38	0.10%
65	Rail transport	10.34	9,700.11	0.09%
66	Electrical equipment	11.59	8,938.25	0.08%
67	Water transport	10.34	8,862.02	0.08%
68	Forestry planting	68.73	8,844.17	0.08%
69	Waste management	5.42	8,586.37	0.08%
70	Leather goods	106.69	8,115.18	0.08%
71	Other manufacturing	14.57	8,067.34	0.08%
72	Beer & malt	63.24	7,978.01	0.08%
73	Animal feeds	63.24	7,521.18	0.07%
74	Legal activities	6.73	7,319.03	0.07%
75	Other metals & casting	43.67	6,336.39	0.06%
76	Research & development	6.73	5,782.52	0.05%
77	Accounting & tax services	6.73	5,740.96	0.05%
78	Security & investigation	25.91	5,704.61	0.05%
79	Motor Vehicles	11.59	4,847.21	0.05%
80	Grain milling & starch	63.24	3,894.52	0.04%
81	Other professional services	6.73	3,801.53	0.04%
82	Real estate - fee or contract	5.24	3,724.17	0.04%
83	Repairs - personal and household	20.54	3,715.80	0.04%
84	Publishing services	6.72	3,185.84	0.03%
85	Film video & TV etc; broadcasting	6.72	2,854.77	0.03%
86	Furniture	14.57	2,286.06	0.02%
87	Auxiliary financial services	1.61	2,009.91	0.02%
88	Advertising & market research	6.73	1,736.01	0.02%
89	Veterinary services	6.73	1,321.37	0.01%
90	Information services	6.72	1,099.75	0.01%
91	Rubber & Plastic	0.01	15.65	0.00%
92	Pharmaceuticals	0.01	13.36	0.00%
93	Inorganic chemicals, dyestuffs	0.01	3.62	0.00%
94	Other chemicals	0.01	3.23	0.00%
95	Cleaning & toilet preparations	0.01	1.58	0.00%
96	Paints, varnishes and inks	0.01	0.53	0.00%
97	Tobacco	0.00	0	0.00%
	Total	3255.69	10,590,928.48	100%

The remaining 92 sectors in Table 2.1, individually contribute a modest share to waste generation in Scotland. This ranges from about 0.53 to 194,969.24 (i.e. 1% to 0%) of total waste generation. We can also notice from Table 1, that many of the industries that generate the largest amount of waste are also the industries with the highest waste intensities. However, some cases are different. For instance, the 'Water and Sewerage', 'Agriculture', 'Spirit and Wine' and 'Mining' industries. These industries are the 9th, 7th, 6th, and 5th largest waste generation sectors respectively in terms of direct physical tonnes of total industry waste generation. These same sectors have waste intensity of 134 (2nd) for 'Water and Sewerage', 60 (3rd) for 'Agriculture', 63 (4th) for 'Spirit and Wine', and 41 (7th) tonnes per £million of industry output for 'Mining', which is considerably higher than that of the top three after the 'Construction' sector.

As we explained in the data section (Section 5), a number of sectors in the same input-output grouping share the same waste coefficient or direct waste intensity. In Table 1, 'Retail' and 'Wholesale' sectors are one example. Although these service sectors have the same direct intensity per million of output, their direct waste generation is quite different. 'Retail' accounts for about 338,224 tonnes (3.2%) of total industrial waste generation and 'Wholesale's is slight lower at 312,094 tonnes (3.0%). More generally, the 'Retail' sectors contributes about 26,130 tonnes more to total industry-level waste generation than the 'Wholesale' sector.

The Cleaning and Toilet Preparation' and 'Paint, Varnishes and inks' sectors share and/or contribution to total waste generation is only a small fraction of 1.58 and 0.53 tonnes respectively and are the sectors with the lowest waste intensity across all 97 sectors. Overall, in this section, the implications are that if industry level waste generation is examined at total waste generation or intensity. It is clear that only a few industries (in particular 'Construction' sector) are accountable for most of the waste generation in Scotland.

6.2 Type I industry-by-industry output-waste multipliers

What we show in the previous result section is how input-output method can be used to consider industrial-level waste analysis that provides insight into not only how much waste is produced in the Scotland, but also into producer, or industry, responsibility. The overall implications of the information in the previous section is that, whether waste generation by industry is examined based on either total generation or direct waste intensity, it is clear that only a few industries are responsible for most of the waste in the Scotland. However, what do the results look like when we focus on the multiplier analysis; to consider further direct and indirect responsibilities for waste generation?

Table 2 below displays the breakdown of the Type I industry-by-industry multipliers for all 97 sectors in terms of direct and indirect responsibility and the results are ranked from highest to lowest based on Type I output-waste multipliers determined in equation (7). Essentially, we move from direct intensity, w^p to $\mathrm{W}^{\mathrm{R}} = \mathrm{w}^{\mathrm{p}}[\mathbf{I} - \mathbf{A}]^{-1}$, the Type I output-waste multiplier. The Type I output-waste multipliers capture (a) direct effects that is the tonnes of waste directly generated by industry in its production process. This column of result is the same or directly comparable with the results showed in the previous Table 2.1. However, here the focus is to show that multipliers can be used to derive not only direct, but also indirect waste generation. The Type I output-waste multipliers also capture (b) indirect effects. The indirect column on the other hand that is the amount of waste generated by the production processes of all other industries to supply direct production (Court, 2012; Miller & Blair, 2009). Note that the rationale underlying input-output attribution analysis is that in order to produce output to meet final demand, each production sector requires inputs from other sectors of the economy (as well as primary inputs capital and labour and imports).

Table 2 Type I output-waste multipliers tonnes per 1 million

Sector number	Sector name	w^p Direct	$w^p[\mathbf{I}-\mathbf{A}]^{-1} - w^p$ Indirect	$w^p[\mathbf{I}-\mathbf{A}]^{-1}$ Total (Type I output waste multiplier
1	Construction	319.33	104.25	423.58
2	Water and sewerage	133.93	23.49	157.42
3	Wood and wood products	108.17	45.34	153.51
4	Textiles	106.69	32.82	139.51
5	Wearing apparel	106.69	27.09	133.78
6	Leather goods	106.69	27.21	133.90
7	Agriculture	68.73	26.90	95.63
8	Forestry planting	68.73	35.18	103.91
9	Forestry harvesting	68.73	61.44	130.17
10	Fishing	68.73	14.26	82.98
11	Aquaculture	68.73	21.43	90.15
12	Meat processing	63.24	49.88	113.11
13	Fish & fruit processing	63.24	30.33	93.56
14	Dairy products, oils & fats processing	63.24	51.28	114.52
15	Grain milling & starch	63.24	39.38	102.61
16	Bakery & farinaceous	63.24	21.00	84.23
17	Other food	63.24	28.21	91.45
18	Animal feeds	63.24	27.41	90.65
19	Spirits & wines	63.24	12.68	75.91
20	Beer & malt	63.24	13.77	77.01
21	Soft Drinks	63.24	20.64	83.87
22	Electricity	60.36	54.96	115.31
23	Gas etc	60.36	14.24	74.59
24	Accommodation	43.74	19.07	62.81
25	Food & beverage services	43.74	17.83	61.57
26	Iron & Steel	43.67	17.52	61.19
27	Other metals & casting	43.67	21.88	65.56
28	Fabricated metal	43.67	18.67	62.34
29	Coal & lignite	40.91	32.86	73.77
30	Oil & gas extraction, metal ores & other	40.91	18.88	59.79
31	Mining Support	40.91	41.56	82.47
32	Wholesale & Retail - vehicles	37.92	11.16	49.09
33	Wholesale - excl vehicles	37.92	19.25	57.18
34	Retail - excl vehicles	37.92	25.59	63.51
35	Cement lime & plaster	36.65	28.50	65.15
36	Glass, clay & stone etc	36.65	22.70	59.35
37	Creative services	36.08	14.51	50.58
38	Cultural services	36.08	21.87	57.95
39	Gambling	36.08	5.62	41.70
40	Sports & recreation	36.08	13.77	49.85
41	Paper & paper products	32.52	31.38	63.90
42	Printing and recording	32.52	18.98	51.50
43	Rental and leasing services	25.91	8.12	34.03
44	Employment services	25.91	7.02	32.93
45	Travel & related services	25.91	19.28	45.19
46	Security & investigation	25.91	6.32	32.23
47	Building & landscape services	25.91	9.98	35.90
48	Business support services	25.91	6.98	32.89

Table 2 Continued

Sector number	Sector name	w^p Direct	$w^p[\mathbf{I}-\mathbf{A}]^{-1} - w^p$ Indirect	$w^p[\mathbf{I}-\mathbf{A}]^{-1}$ Total (Type I output waste multiplier
49	Membership organisations	20.54	15.10	35.64
50	Repairs - personal and household	20.54	8.80	29.35
51	Other personal services	20.54	8.91	29.46
52	Furniture	14.57	33.72	48.29
53	Other manufacturing	14.57	17.01	31.58
54	Repair & maintenance	14.57	13.16	27.73
55	Education	14.16	6.14	20.30
56	Computers, electronics & opticals	11.59	10.84	22.43
57	Electrical equipment	11.59	14.37	25.96
58	Machinery & equipment	11.59	18.93	30.51
59	Motor Vehicles	11.59	14.75	26.34
60	Other transport equipment	11.59	22.11	33.70
61	Rail transport	10.34	16.32	26.66
62	Other land transport	10.34	11.10	21.44
63	Water transport	10.34	19.22	29.56
64	Air transport	10.34	14.59	24.93
65	Support services for transport	10.34	14.84	25.18
66	Post & courier	10.34	11.11	21.45
67	Health	9.25	8.50	17.75
68	Residential care and social work	9.25	11.70	20.94
69	Legal activities	6.73	7.04	13.77
70	Accounting & tax services	6.73	4.77	11.50
71	Head office & consulting services	6.73	10.21	16.93
72	Architectural services etc	6.73	11.18	17.90
73	Research & development	6.73	11.06	17.78
74	Advertising & market research	6.73	7.44	14.17
75	Other professional services	6.73	5.85	12.58
76	Veterinary services	6.73	10.72	17.45
77	Publishing services	6.72	10.57	17.30
78	Film video & TV etc; broadcasting	6.72	11.14	17.86
79	Telecommunications	6.72	21.41	28.13
80	Computer services	6.72	6.91	13.63
81	Information services	6.72	7.51	14.23
82	Coke, petroleum & petrochemicals	6.63	5.59	12.21
83	Public administration & defence	6.26	18.98	25.23
84	Waste, remediation & management	5.42	18.32	23.75
85	Real estate - own	5.24	67.80	73.04
86	Imputed rent	5.24	17.71	22.95
87	Real estate - fee or contract	5.24	5.96	11.20
88	Financial services	1.61	9.42	11.03
89	Insurance & pensions	1.61	21.14	22.75
90	Auxiliary financial services	1.61	6.36	7.98
91	Paints, varnishes and inks etc	0.01	9.35	9.36
92	Cleaning & toilet preparations	0.01	14.72	14.73
93	Other chemicals	0.01	5.20	5.21
94	Inorganic chemicals, dyestuffs & agrochemicals	0.01	17.31	17.32
95	Pharmaceuticals	0.01	4.86	4.88
96	Rubber & Plastic	0.01	16.80	16.81
97	Tobacco	0.00	0.00	0.00

Again, 'Construction' sector is ranked 1st or the sector with the highest Type I output-waste multiplier. Thus, in order to directly and indirectly produce output, the 'Construction' sector will generate 423.6 tonnes of waste per £million of output. However, there are a number of differences across other sectors. The ranking of most of the sectors have changed when we compare Table 1 and Table 2. For instance, consider the 'Waste & Sewerage' industry, which was ranked 9th in the previous table (Table 2.1), is now second in terms of its Type I output-multipliers, while the 'Electricity' sector drops from 2nd in Table 1 to 8th in Table 2. Interestingly, all but these three 'Construction', 'Water and Sewerage', and 'Electricity' sectors in Table 1 dropout of the top largest waste generation group when we consider them in terms of Type I output-waste multipliers. Whereas sectors that were within the 50th to 70th rank in Table 1 have now moved up the charts to the top twelve in Table 2. For instance, the 'Leather Goods', 'Forestry Planting', and 'Forestry Harvesting' sectors which were ranked 70th, 68th and 51st respectively in Table 1 are now ranked 5th, 11th and 7th in Table 2.

In terms the indirect effects, let us discuss some examples. The 'Construction' sector has a direct waste intensity of (319.3) tonnes and an indirect effect of (104.3). This means that while some of Construction's direct waste generation is allocated to other production sectors that use its outputs as intermediate inputs, it also receives a share of the waste generated in other sectors to produce outputs that it uses as intermediates. Essentially, the 'Construction' sector is highly waste-intensive and the sectors within its supply chain are also relatively waste intensive. Consider the 'Water & Sewerage' industry, it is the industry with the second highest direct waste intensity (133.9), but it has a relatively low indirect waste intensity (23.5). This result indicates that the 'Water and Sewerage' industry itself is highly waste intensive. However, the industries within its supply chain are not. Another example is the 'Real Estate' sector which embodies opposite relationship, very low direct waste intensity (5.2) but relatively high indirect waste intensity (67.8). This industry does not directly generate large amounts of waste but purchases its inputs from highly waste intensive sectors such as (e.g. 'Construction' and 'Water and Sewerage'). Other sectors that exhibit relatively large differences when indirect effects are incorporated using a Type I analysis include 'Furniture' (43rd), 'Telecommunications' (58th)' and 'Insurance &Pension' (68th). We also find that in the 'Inorganic Chemical' (78th), 'Rubber and Plastic' (82nd), 'Cleaning and Toilet Preparation' (83rd), 'Paints' (93rd), 'Other Chemical' (95th) and 'Pharmaceuticals' (96th) sectors show that even a sector that produces zero waste directly, is indirectly responsible for some waste generation. Over all this type of analysis above helps us answers how waste is generated within Scotland and how we can begin to attribute responsibility across industries (or producers). Furthermore, input-output analysis comes from the recognition that output is used as intermediate inputs and that this intermediate activity can be attributed to final demands through multiplier analysis (Miller and Blair, 2009). Thus, in the next section, we go on to determine why these industries are producing output in general and in turn waste. To answer this question, the partial consumption attribution approach is employed

6.3 Partial consumption accounts

In this section, we now move from the production based analysis (using equation (7)) and with direct waste generation in each Scottish production sector reported in Table 2 above to the partial consumption based analysis (using equation (8)). Essentially, we use the Type I output multipliers to examine the waste that is supported by final demand for each sector's output, rather than the direct waste generation associated with the production of that output as in Table 2.

The first question we address in this section is how is total waste generated in production or at the industrial level attributable to the different types of final consumers, whose demand for particular output may be directly or indirectly driving this waste generation? Table 3 presents the results from the attribution analysis for five categories of final demand determined using equation (8): household consumption, government expenditures, gross fixed capital investment, non-resident households (tourists), and exports. These results are calculated as $\mathrm{W}^{\mathrm{R}} =$

$w^p[\mathbf{I}-\mathbf{A}]^{-1}$y, where **y** has been disaggregated into the five components mentioned above.

In Table 3, there are a number of significant differences we should discuss. First, let us consider the ranking in Table 3 relative to the direct waste generation in Table 1. In Table 3, eight out of the twelve sectors that dominated in the direct ranking still dominate when we take into account the share attributable to final demand for industry output. We can also notice that the share of total waste generation attributable to the top waste generation sector (e.g. the top twelves sectors, falls from just over 81% to just under 77%. This is because some of the main direct waste generators still dominate, mainly because there is a lot of waste generation to service own-sector output demands. However, note, for example, that in the cases of sectors like 'Construction' and 'Electricity', the share attributable falls because of the importance of downstream linkages – i.e. these sectors are producing output (and waste) to service the demands of other sectors. For example, 'Construction' is servicing the intermediate demands of IOC 70, the 'Real Estate' sector, which now appears in Table 3 and is ranked 7th, jumping up the waste chart from no.40 in the direct case where it didn't make top twelve group.

Apart from letting us see what type of commodity output demands are really driving waste generation in the system, the Type I attribution results in Table 3 also reflect the importance of different types of final consumers. In the case of Construction, the final three columns in Table 3 show that capital formation is the main driver of the waste ultimately attributable this sector. On the other hand, in the case of 'Real Estate', domestic (mainly households in the underlying results) demand is the main driver. 'Public Administration' also jumps up the chart from 17^{th} to 6^{th} under the Type I attribution, with domestic consumption (but here this will be mainly government consumption) being the main driver. On the other hand, as noted above for 'Spirits and Wines', exports are the main sources of sectoral commodity outputs driving waste generation in Table 3. Waste in the backward supply chain relative to forward supply chain also causes the share attributable in 'Retail' to increase as we move from direct to final demand attribution, and this involves it moving up the chart from 3^{rd} in Table

1 to 2nd in Table 3. Scottish household consumption and export demand together drive 94% (315,752 tonnes) of waste associated with 'Wholesale' and move it up from 13th in Table 1 to 5th in Table 3.

Table 3 Type I waste attribution to final demand for industry output (tonnes)

				Breakdown by type of final consumption				
Sector numer	Sector name	Attributable to total final demand	Share attributable to total final demand	Household	Government	Gross fixed Capital Formation	Non-resident households	Exports
1	Construction	4752981	44.9%	130,411	21	4,022,764	3,938	595,847
2	Retail	555939	5.2%	504,503	1,403	5,345	18,220	26,469
3	Mining Support	521075	4.9%	12,191	0	6,157	655	502,072
4	Electricity	374038	3.5%	211,861	0	6,657	618	154,903
5	Wholesale	335264	3.2%	142,243	1	15,274	4,236	173,509
6	Public administration	318206	3.0%	10,246	300,564	7,030	19	347
7	Real estate	257771	2.4%	227,868	0	86	1,443	28,374
8	Spirits & wines	244715	2.3%	22,436	0	947	710	220,623
9	Food & beverage services	214503	2.0%	182,698	0	880	30,232	693
10	Imputed rent	207656	2.0%	207,656	0	0	0	0
11	Health	201123	1.9%	15,104	185,884	3	111	21
12	Agriculture	154280	1.5%	78,129	0	11,247	1,091	63,814
13	Education	146559	1.4%	35,661	96,579	63	282	13,973
14	Water and sewerage	133492	1.3%	130,551	0	1,642	102	1,197
15	Insurance & pensions	120855	1.1%	55,077	0	203	273	65,303
16	Meat processing	111312	1.1%	55,244	0	186	632	55,250
17	Accommodation	106124	1.0%	56,510	0	78	49,085	451
18	Residential care and social work	91870	0.9%	31,106	60,624	18	0	121
19	Fish & fruit processing	85700	0.8%	23,404	0	111	260	61,926
20	Wholesale & Retail -	77424	0.7%	43,789	0	17,755	383	15,497
21	Fabricated metal	75242	0.7%	6,441	0	19,642	231	48,928
22	Coke, petroleum & petrochemicals	70970	0.7%	9,776	0	473	726	59,995
23	Bakery & farinaceous	68041	0.6%	30,259	0	-44	896	36,931
24	Financial services	67337	0.6%	4,658	0	336	36	62,306
25	Wood and wood products	66784	0.6%	10,123	0	2,180	363	54,119
26	Architectural services etc	65867	0.6%	1,462	11	14,633	100	49,661
27	Textiles	63884	0.6%	29,159	0	1,054	1,489	32,181
28	Other transport equipment	58926	0.6%	5,242	0	11,890	34	41,760
29	Gas etc	57574	0.5%	30,145	0	337	55	27,038
30	Dairy products, oils & fats processing	56809	0.5%	28,747	0	836	383	26,842
31	Sports & recreation	50400	0.5%	29,939	12,492	1,144	1,408	5,417
32	Telecommunications	50213	0.5%	27,514	2	3,524	462	18,711
33	Machinery & equipment	46790	0.4%	4,643	0	12,444	373	29,330
34	Wearing apparel	41207	0.4%	29,701	0	290	1,674	9,542
35	Gambling	37086	0.4%	30,478	23	695	1,346	4,545
36	Computers, electronics & opticals	31493	0.3%	2,974	0	4,004	60	24,455
37	Other land transport	28803	0.3%	15,808	0	361	656	11,979
38	Waste, remediation & management	27503	0.3%	549	12,913	104	9	13,927
39	Travel & related services	26046	0.2%	2,007	0	125	379	23,535
40	Other food	25958	0.2%	11,176	0	63	230	14,489
41	Paper & paper products	24490	0.2%	1,835	0	198	50	22,407
42	Rental and leasing services	24394	0.2%	9,821	1	155	570	13,847
43	Other personal services	23809	0.2%	22,450	6	260	304	788
44	Aquaculture	23307	0.2%	785	6	134	64	22,317
45	Support services for transport	22791	0.2%	2,324	0	1,055	152	19,260
46	Soft Drinks	21952	0.2%	15,750	0	-443	292	6,352
47	Employment services	20807	0.2%	388	320	390	3	19,706
48	Air transport	20024	0.2%	9,426	0	154	92	10,352

Table 3 Continued

Sector number	Sector name	Attributable to total final demand (y)	Share of total waste attributed	Breakdown by type of final consumption				
				household	Government	Gross fixed Capital Formation	Non-resident households	Exports
49	Repair & maintenance	19652	0.2%	1,492	0	3,689	19	14,451
50	Computer services	18728	0.2%	532	257	2,961	19	14,959
51	Water transport	18540	0.2%	8,426	0	781	251	9,083
52	Business support services	17917	0.2%	1,087	414	1,350	22	15,043
53	Rail transport	17376	0.2%	15,202	0	125	806	1,244
54	Fishing	17173	0.2%	1,071	3	90	52	15,957
55	Cultural services	16712	0.2%	9,452	5,784	-541	1,405	612
56	Creative services	16105	0.2%	10,868	821	31	972	3,414
57	Other manufacturing	15227	0.1%	9,177	0	923	244	4,883
58	Membership organisations	12269	0.1%	11,869	19	79	16	285
59	Forestry harvesting	11811	0.1%	5,520	0	336	938	5,017
60	Glass, clay & stone etc	11610	0.1%	3,116	0	640	196	7,657
61	Printing and recording	10925	0.1%	1,323	24	326	305	8,946
62	Electrical equipment	10795	0.1%	1,721	0	1,983	42	7,049
63	Research & development	10439	0.1%	295	15	154	2	9,974
64	Rubber & Plastic	10049	0.1%	1,859	0	603	50	7,537
65	Oil & gas extraction, metal ores	9874	0.1%	1,156	0	286	50	8,382
66	Auxiliary financial services	9104	0.1%	397	0	64	12	8,632
67	Leather goods	8757	0.1%	4,892	0	47	424	3,393
68	Head office & consulting services	8616	0.1%	184	254	428	2	7,747
69	Motor Vehicles	8192	0.1%	3,459	0	1,775	17	2,940
70	Coal & lignite	8072	0.1%	507	0	2,481	27	5,056
71	Film video & TV etc; broadcasting	6697	0.1%	3,410	1,736	270	25	1,256
72	Building & landscape services	6481	0.1%	2,058	0	985	16	3,423
73	Real estate - fee or contract	6318	0.1%	331	0	4,947	39	1,002
74	Furniture	6258	0.1%	3,833	0	1,456	42	928
75	Iron & Steel	6137	0.1%	296	0	200	27	5,614
76	Publishing services	5941	0.1%	3,399	0	130	3	2,409
77	Beer & malt	5741	0.1%	1,929	0	46	96	3,670
78	Post & courier	4952	0.0%	2,229	1	85	210	2,428
79	Legal activities	4133	0.0%	149	0	841	2	3,140
80	Animal feeds	3992	0.0%	1,833	0	136	24	2,000
81	Other professional services	3810	0.0%	476	25	92	34	3,184
82	Cement lime & plaster	3504	0.0%	232	0	243	14	3,016
83	Repairs - personal and household	3326	0.0%	1,363	0	50	2	1,911
84	Grain milling & starch	3265	0.0%	1,690	0	21	28	1,525
85	Other metals & casting	2887	0.0%	161	0	389	8	2,329
86	Forestry planting	2645	0.0%	384	36	1,896	12	317
87	Veterinary services	2632	0.0%	2,622	0	6	0	4
88	Inorganic chemicals, s& agrochemicals	2477	0.0%	259	0	123	6	2,090
89	Accounting & tax services	2394	0.0%	32	6	57	0	2,298
90	Pharmaceuticals	2290	0.0%	246	0	29	8	2,007
91	Advertising & market research	1873	0.0%	31	1	-18	3	1,857
92	Cleaning & toilet preparations	1713	0.0%	875	0	30	16	792
93	Security & investigation	1712	0.0%	48	6	23	0	1,635
94	Information services	1270	0.0%	91	14	46	5	1,114
95	Other chemicals	1021	0.0%	220	0	32	3	767
96	Paints, varnishes and inks etc	134	0.0%	23	0	11	2	98
97	Tobacco	0	0.0%	0	0	0	0	0
	Total	10,590,938	100%	2,672,092	680,267	4,203,177	131,219	2,904,182

More generally, the final row in Table 3, shows that from attributing all industrial waste generation to final demand categories indicate that overall waste generation in Scotland is largely attributable to gross fixed capital investment at 39%. Another 25% was attributable to Scottish household consumption demand. 27% was attributable to export demand for Scottish output (rest of the UK (19%) and rest of the world (8%)). While government expenditure was 7% and non-residential household (i.e. tourist) drive only 1%. It is important to note that the accountability of the different sectors of final demand varies widely across industries. Should policy makers attempt any type of consumption-based waste reduction approach, they can easily identify the final demand category or categories that are accountable for waste generation within a certain industry with this information.

Therefore, what is the implication of the finding in this Section? Generally, we learn or gain knowledge in this section of the distribution of waste generation across industries not only in terms of direct waste generation, but also incorporating indirect waste intensities. As we explained in the introduction section, if policy focus is to consider the production and in turn, waste generation in order to meet final demand, then a partial consumption policy approach should be considered for reducing industrial waste generation. Hence, in addition to imposing regulations and restrictions on producers, policymakers may also direct waste reduction strategies at the final consumption of goods that are directly or indirectly produced by waste intensive sectors.

7. Conclusion

In this chapter, we consider how input-output multiplier methods (using national accounting principles) may be used to develop an understanding of demand drivers of a local pollutant (taking physical waste as an example) and the final consumption demand for industry output that contributes to waste generation. There are a number of conclusions drawn from this paper. First, the information within the production-based accounts allows us to go beyond the ability to rank industries in terms of waste generation and to also consider direct waste intensity and indirect and output-waste multipliers in the decision-making process. The results and finding from the production accounting approach indicate that only a few industries are accountable for much of the direct waste generation in Scotland. The output-waste multiplier analysis provides additional insights into the allocation of waste generation associated with intermediate demands and introduces information highlighting the differences between direct and total waste intensity.

Secondly, policymakers have mainly focused on the production side of the waste-economy nexus. However, they should also consider the information available through the partial consumption accounting analyses. The results and findings from this approach consistently attribute all industrial waste generation to final demand. Policy makers can use this type of information to determine which categories of final demand are accountable for waste generation within industries of interest.

Lastly, we conduct a comparative regional analysis of the structure of direct and indirect waste generation and how this is driven by different types of final demand (domestic or export demand) for the output of regional production sectors. This presents an original contribution to the development and application of regional-specific waste input-output framework for Scotland. However, we believe that there is nay be important insights gained, if we extend the analysis in this paper to consider the resource costs and implications of actually cleaning or disposing of the pollutant. On this basis, we propose future applications of the environmental input-output to internalise the negative externalities and consider the economy-wide implication when externalities are accounted for in the economic process. This may be particularly useful in considering the economy-wide implications if the polluter is forced to pay for the resource costs for waste management based on their implied demand and/or according to alternative responsivity for waste cleaning.

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Table A1: Classification of the 97 input-output industry (IOC) group in Scottish input-output tables by SIC (2007) classes

SIC07 Section			Input-Output Classification	Standard Industrial Classification of Economic Activities 2007					
Agriculture, forestry and fishing	A	1	Agriculture, hunting and related services	01					
		2	Silviculture and other forestry activities and support services	02.1	02.4				
		3	Logging and gathering	02.2	02.3				
		4	Marine and freshwater fishing	03.1					
		5	Marine and freshwater aquaculture	03.2					
Mining and quarrying	B	6	Coal and lignite	05					
		7	Crude petroleum, natural gas and metal ores; other mining and quarrying	06	07	08			
		8	Mining support services	09					
Manufacturing	C	9	Preserved meat and meat products	10.1					
		10	Processed and preserved fish, crustaceans, molluscs, fruit and vegetables	10.2	10.3				
		11	Dairy products, vegetable and animal oils and fats	10.4	10.5				
		12	Grain mill products, starches and starch products	10.6					
		13	Bakery and farinaceous products	10.7					
		14	Other food products	10.8					
		15	Prepared animal feeds	10.9					
		16	Alcoholic beverages - spirits, wines and cider	11.01	11.02	11.03	11.04		
		17	Alcoholic beverages - beer and malt	11.05	11.06				
		18	Soft drinks	11.07					
		19	Tobacco products	12					
		20	Textiles	13					
		21	Wearing apparel	14					
		22	Leather and related products	15					
		23	Wood and of products of wood and cork, except furniture; articles of straw and plaiting materials	16					
		24	Paper and paper products	17					
		25	Printing and recording services	18					
		26	Coke, refined petroleum products and petrochemicals	19	20.14	20.16	20.17	20.6	
		27	Paints, varnishes and similar coatings, printing ink and mastics	20.3					
		28	Soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations	20.4					
		29	Other chemical products	20.5					
		30	Industrial gases, inorganic chemicals, fertilisers, dyestuffs and agrochemicals	20.11	20.12	20.13	20.15	20.2	
		31	Basic pharmaceutical products and pharmaceutical preparations	21					
		32	Rubber and plastic products	22					
		33	Manufacture of cement, lime, plaster and articles of concrete, cement and plaster	23.5	23.6				
		34	Glass, refractory, clay, other porcelain and ceramic, stone and abrasive products	23.1	23.2	23.3	23.4	23.7	23.9
		35	Basic iron and steel	24.1	24.2	24.3			
		36	Other basic metals and casting	24.4	24.5				
		37	Fabricated metal products, including weapons and ammunition	25					
		38	Computer, electronic and optical products	26					
		39	Electrical equipment	27					
		40	Machinery and equipment not elsewhere classified	28					
		41	Motor vehicles, trailers and semi-trailers	29					
		42	Other transport equipment	30					
		43	Furniture	31					
		44	Other manufactured goods	32					
		45	Repair and installation of machinery and equipment	33					
Electricity, Gas, Steam and Air Conditioning supply	D	46	Electricity; generation, transmission, distribution and trade	35.1					
		47	Gas; distribution of gaseous fuels through mains; steam and air conditioning supply	35.2	35.3				
Water Supply, Sewerage, Waste Management and Remediation	E	48	Natural water treatment and supply services, sewerage services	36	37				
		49	Waste collection, treatment and disposal; materials recovery; remediation and other waste management	38	39				

Table A1. Continued

SIC07 Section		Input-Output Classification		Standard Industrial Classification of Economic Activities 2007		
Construction	F	50	Construction	41	42	43
Wholesale and Retail Trade; Repair of Motor Vehicles and Motorcycles	G	51	Wholesale and retail trade and repair services of motor vehicles and motorcycles	45		
		52	Wholesale trade services, except of motor vehicles and motorcycles	46		
		53	Retail trade services, except of motor vehicles and motorcycles	47		
Transportation and Storage	H	54	Rail transport services	49.1	49.2	
		55	Land transport services and transport services via pipelines, excluding rail transport	49.3	49.4	49.5
		56	Water transport services	50		
		57	Air transport services	51		
		58	Warehousing and support services for transportation	52		
		59	Postal and courier services	53		
Accommodation and Food Service activities	I	60	Accommodation services	55		
		61	Food and beverage serving services	56		
Information and Communication	J	62	Publishing services	58		
		63	Motion picture, video & tv programme production, sound recording & music publishing activities; programming and broadcasting activities	59	60	
		64	Telecommunications services	61		
		65	Computer programming, consultancy and related services	62		
		66	Information services	63		
Financial and Insurance activities	K	67	Financial services, except insurance and pension funding	64		
		68	Insurance, reinsurance and pension funding services, except compulsory social security and pension funding	65		
		69	Services auxiliary to financial services and insurance services	66		
Real Estate activities	L	70	Real estate services, excluding on a fee or contract basis and imputed rent	68.1	68.2	
		71	Imputed rent services	-		
		72	Real estate activities on a fee or contract basis	68.3		
Professional, Scientific and Technical activities	M	73	Legal services	69.1		
		74	Accounting, bookkeeping and auditing services; tax consulting services	69.2		
		75	Services of head offices; management consulting services	70		
		76	Architectural and engineering services; technical testing and analysis services	71		
		77	Scientific research and development services	72		
		78	Advertising and market research services	73		
		79	Other professional, scientific and technical services	74		
		80	Veterinary services	75		
Administrative and Support Service activities	N	81	Rental and leasing services	77		
		82	Employment services	78		
		83	Travel agency, tour operator and other reservation services and related services	79		
		84	Security and investigation services	80		
		85	Services to buildings and landscape	81		
		86	Office administrative, office support and other business support services	82		
Public Administration and Defence	O	87	Public administration and defence services; compulsory social security services	84		
Education	P	88	Education services	85		
Human Health and Social Work activities	Q	89	Human health services	86		
		90	Residential care activities and social work activities without accommodation	87	88	
Arts, Entertainment and Recreation	R	91	Creative, arts and entertainment services	90		
		92	Libraries, archives, museums and other cultural services	91		
		93	Gambling and betting services	92		
		94	Sports services and amusement and recreation services	93		
Other Service activities	S	95	Services furnished by membership organisations	94		
		96	Repair services of computers and personal and household goods	95		
		97	Other personal services	96		
Activities of Households	T	98	Services of households as employers of domestic personnel	97		