Augmenting the Input-Output Framework for "Common Pool" Resources: Operationalising the Full Leontief Environmental Model

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Abstract: In its initial formulation, the full Leontief (1970) environmental model augments the conventional Input-Output (IO) table by introducing pollution generation and separately identified pollution elimination sectors. Essentially it extends IO analysis to incorporate the use of a "common pool" resource. Subsequent literature has either been analytical in nature or has concentrated on pollution generation but not cleaning activity. In this paper we generate an empirical full Leontief environmental IO system, based on augmenting the existing Scottish IO tables through endogenising waste generation and waste disposal activity. Due to weaknesses in data, our empirical results need to be treated with some caution. However, the construction of the extended IO system and the interpretation of the output and price multiplier results raise a number of interesting practical and conceptual issues. The analysis undertaken here can be extended to other "common pool" resources such as the use of highway use and irrigation systems.

Key words: input-output, environment, pollution, waste disposal, common pool resources

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1. Introduction

In a seminal paper, Leontief (1970) extends the standard Input-Output (IO) accounts to incorporate pollution as an additional commodity ("bad") that accompanies production and consumption activities. His extended system also separately identifies sectors that clean up or prevent these unwanted outputs, sectors that will be referred to in this paper generically as "cleaning sectors". The Leontief approach therefore links pollution directly to economic activity and suggests methods to endogenise cleaning behaviour.

The environment is an example of a "common pool" resource and the services it provides are intermediate between those provided by "public" and "private" goods (Stiglitz, 2000). A "common pool" resource supplies services in which consumption is rival, so that utilizing the resource imposes costs on other users. However, because of ineffective or incomplete property rights, the use of the resource is not fully excludable.[1] Typically the user of such a resource does not have to pay the full cost. This has two implications. First, the resource use is not optimally determined through the market mechanism. Second, the use of the resource is not tracked through the expenditures that are typically employed to construct IO tables. The well-known "tragedy of the commons" is a common pool resource problem, as is traffic congestion, spam and global warming (Hardin, 1968).

The power of the full Leontief extension is that it shows, using pollution as an example, how a common pool resource can be incorporated in Input-Output analysis. Governments are aware of the inherent market failure associated with the provision of "common pool" resources and adopt various mechanisms, including using public expenditure to replenish these resources, to reinforce the market processes. The full Leontief environmental extension incorporates this replenishment activity, which will be at least partly demand driven. Moreover, the extended Input-Output accounts - and the associated price dual - can be used to assess more accurately those costs imposed by the use of common pool resources that are not directly reflected in the price mechanism.

However, much of the empirical work on the environmental extension to IO subsequent to Leontief (1970) identifies pollution generation but not cleaning/replenishment. This normally involves using a matrix of physical pollution-output coefficients to compute a vector of pollutants from the vectors of gross outputs and final demands. For example, McNicoll and Blackmore (1993)

[1] Pure public goods provide services that are non-rival and non-excludable. Defence is an example. Private goods provide services that are rival and excludable

and McGregor *et al.* (2001) adopt such an approach to model air pollution in Scotland.[2] This type of work quantifies the impact of the economy on the environment, in terms of the amount of pollution emitted as a result of economic activity. However, it does not track the subsequent feedback from the environment to the economy, with respect to the activity generated in environmental cleaning. If we are interested in this aspect, we need to specify the input structure of any pollution abatement or cleaning activities and enter these as columns in the IO tables to represent cleaning sectors.

A literature has developed around the full Leontief environmental model (Flick, 1974; Steenge, 1978; Lowe, 1979; Qayum, 1991; Arrous, 1994; and Luptacik & Böhm, 1999).[3] This work is analytical and based on illustrative IO systems in which both the goods and pollution are measured in physical terms. It considers the operation of both the quantity and "dual" price models under different assumptions about the organisation and financing of anti-pollution (disposal and cleaning) activities. In the present paper we attempt an empirical application of the full Leontief environmental IO method using a table that incorporates one pollutant, waste, and its accompanying cleaning sector.[4] This extension is based around the conventional 1999 IO tables for Scotland measured in value terms (Scottish Executive, 2002).

The primary objective of this paper is to discuss the practical and conceptual issues involved in providing a full Leontief environmental extension to an existing IO table, so as to identify separately the existing cleaning activity embedded in the table, whilst retaining the accompanying accounting identities. We employ the augmented IO accounts to simulate impacts on outputs and prices under various assumptions about the institutional (primarily non-market) arrangements for dealing with pollution abatement. Whilst data problems limit the usefulness of the results derived for Scotland from this framework, the empirical work does allow us to give an alternative illustrative applied perspective on the existing analytical debates.

2. The Full Environmental Leontief Model

[2] McGregor *et al.* (2004) extend this to a Scottish environmental Social Accounting Matrix (SAM) approach, but again do not fully endogenise pollutant cleaning, as is done in Leontief (1970).

[3] By "full" we mean an IO system where the additional environmental elements include both the production of pollutants and their cleaning. A "full environmental system" does not mean that we cover all pollutants. This is unfortunately not possible at present in Scotland because of data constraints.

[4] We select waste as an illustrative pollutant on the basis of data availability. Other authors (e.g. Kondo and Nakamura (2005) and Kagawa (2005)) offer more specific analyses of waste problems.

Leontief (1970) first proposed using an extended IO framework to analyse pollution or waste generation, taking air pollution as an example. In this section we discuss the problems raised in constructing a set of IO physical accounts based on this system. For simplicity we follow Leontief's example by restricting the analysis to one pollutant (air pollution) and a corresponding cleaning sector, although adjusting the model to incorporate many pollutants and cleaning sectors is conceptually straightforward. The Leontief approach involves expanding and partitioning the standard IO accounts in two ways. First an extra row is inserted to record the air pollution generated as an additional output in each production and final demand sector. The elements of this row are calculated using the appropriate physical pollution-output coefficients. Second, an additional column is created, showing the inputs committed to air pollution elimination or prevention.

The initial full Leontief environmental approach poses a number of problems. One is the introduction of pollution as an additional (unwanted) output. Subsequent authors (Qayum, 1991; Arrous, 1994; and Luptacik & Böhm, 1999) argue that the analysis is more straightforward if we reinterpret the pollution generation row and pollution elimination column as reflecting the activity of a single sector that, in this case, produces clean air. From our perspective, clean air is a "common pool" resource and the row entries show the demand for replenishing the clean air implied by each sector's production activity (which corresponds to the amount of pollution generated in each sector). The additional column shows the actual inputs used to supply these cleaning activities.

More formally, we can generate an expression for the output x_k of the cleaning sector k that takes the standard IO form:

$$x_k = \sum_{i \neq k} a_{ki} x_i + a_{kk} x_k + a_{kf} f + \Delta s_k \qquad (1)$$

Where x_i is the output of production sector i, f is total final demand and Δs_k is the change in the stock of clean air. The implied direct demand for the activities of cleaning sector k per unit of output of the ith production sector, the cleaning sector k itself, and final demand expenditure f, are given by a_{ki}, a_{kk} and a_{kf}, respectively.

It is important to understand how equation (1) is to be interpreted. Imagine that this relates to the base year data incorporated in an IO table that is wholly specified in physical units. Equation (1) can be reformulated as:

$$x_k - (\sum_{i \neq k} a_{ki} x_i + a_{kk} x_k + a_{kf} f) = \Delta s_k \qquad (2)$$

This equation simply says that the difference between the output x_k of the cleaning sector and the cleaning requirements generated by production and final demand consumption (that is, $\Sigma_{i\neq k} a_{ki} x_i + a_{kk} x_k + a_{kf} f$) gives the change in clean air associated with domestic production and consumption.

If Δs_k is positive, this means that there was net cleaning of the environment in the base year. This might have been in order to repair earlier environmental damage or to deal with concurrent pollution by sources other than domestic production and final demand expenditure. This pollution could be caused by economic activity in other jurisdictions, for example through air pollution up wind, or through natural causes, such as volcano eruptions. If Δs_k is negative, this indicates that the stock of clean air fell as a result of domestic production and consumption activity. However, this does not necessarily mean that the environment suffers. "Common pool" resources typically have some carrying capacity, a level of use that does not affect their overall provision of services. For example, the environment has some facility to naturally treat pollutants. If Δs_k is zero the output of the cleaning sector is just enough to clean the pollutants generated in current domestic production and final demand consumption.

A second issue relating to equation (1) is that it does not in itself indicate the responsibility for financing the cleaning sector, nor the institutional arrangements for deciding the actual level of cleaning activity.[5] As argued already, the level of pollutant production and cleaning is not generally determined through standard market mechanisms. In particular, the fact that production sector *i*, for example, generated pollutants that would require $a_{ki} x_i$ output of the cleaning sector to treat does not mean that such treatment will necessarily take place, or that if it does, that the cost is borne by the polluting sector. Essentially, adding a row to the IO accounts indicates the pollutants associated with different types of production and consumption activity, and the net change in stocks identifies the net burden on the environment in the base year. However, information in this row does not show who has practical responsibility for the cleaning that does take place nor the nature of these responsibilities.

Up to now we have focussed on the row added to the IO accounts to identify the production of the pollutant (or the implied demand for cleaning sector). Leontief (1970) also separately identifies the column of inputs used in the air pollution cleaning industry. In his pedagogic

[5] Analyses of responsibility issues can also be found in Gallego and Lenzen (2005) and Hoekstra and Jansen (2006).

approach, Leontief proceeds as though the cleaning sector were newly introduced; that is, as though a cleaning sector were introduced into a system that previously generated untreated pollution. However, typically cleaning activity will already occur in the economy. In some cases cleaning sectors are separately identified in the IO accounts, but even when they are not, cleaning activity is likely to be included somewhere in the IO table, aggregated in with the data for one or more other sectors. Separating out the inputs used in the cleaning sector is then primarily a practical issue.

Whilst detaching the cleaning sector column in the conventional IO table, one should also separate out a row that shows the current sales for this sector. This is so as to identify correctly the remaining intermediate input use by individual sectors and the remaining sectoral composition of final demand. This issue is foreshadowed, but not developed, in Leontief (1970) where he discusses the "dual" price vector. He argues that commodity prices might include as intermediate costs part-payment for the cleaning required for the pollutants that are generated by the corresponding production sectors. However, in analysis with a conventional, value-measured, I-O table, these payments are interpreted as the intermediate demands for these services. We use a bar to label the appropriate entry for the actual expenditures on cleaning, so that for the *i*th production sector this is $\bar{a}_{ki} x_i$ and from final demand it is $\bar{a}_{kf} f$. Recall that these expenditures at this point are still measured in physical terms. The relationship therefore holds that:

$$x_k = \sum_{i \neq k} \bar{a}_{ki} x_i + \bar{a}_{kk} x_k + \bar{a}_{kf} f \qquad (3)$$

Only under exceptional circumstances will the elements of the row identifying existing sales of the output of the cleaning sector, shown in equation (3), be the same as those in the row of implied demands identified in equation (1).[6] Their reconciliation is discussed in greater detail in the next section.

3. An Empirical Application of the Full Leontief Environmental Approach

The full environmental IO method is rarely used for empirical applications. In standard IO accounts, appropriate data are generally not available to separate the specific inputs used for pollution

[6] However, by construction, the total existing sales of the cleaning sector equals the total implied demand.

abatement from other sectoral input expenditures (Leontief & Ford, 1972).[7] However, the Scottish Executive – the devolved government for Scotland - has responsibility for meeting Scotland's environmental objectives. In Allan *et al.* (2004a, b) we attempt a pilot study to identify the practical and methodological problems that would accompany building on the existing Scottish IO base (for 1999) to produce a full Leontief environmental system. We again simply identify one pollutant and cleaning sector, in this case waste and the waste removal sector.

Our primary concern in the Allan *et al.* (2004a, b) study is to generate the full Leontief environmental set of accounts for Scotland 1999, with waste generation and the waste removal sector separately identified.[8] There are three general problems. The first is to identify the existing inputs committed to environmental cleaning (waste disposal) and the sources of expenditure on these existing services in the IO accounts. The second is to assemble the required data on physical pollutant (waste) generation by source of generation. The third is to introduce these data in an IO system measured in value terms and already constrained by familiar accounting identities.

In the standard IO accounts, outputs are measured in money values, rather than in the physical terms we have assumed so far. This requires a little additional notation. We identify the gross output of sector *i*, measured in money values, as q_i and the value of household consumption expenditure as q_f, Further, we label the input coefficients of sector *i*, per unit of output of sector *j* and household consumption as α_{ij} and α_{if} respectively, when measured in value terms. Aside from the standard IO accounts, the additional data requirements are: the vector of inputs to the cleaning sector *k* (where the *i*th element would be $\alpha_{ik}q_k$), and any consequent adjustments in the vectors of inputs to other sectors; the existing expenditure flows to the cleaning sector (where the element for the *i*th sector would be $\overline{\alpha}_{ki}q_i$), and the corresponding adjustment in the vector of other intermediate inputs in the same sectors and final demand categories; the physical pollution directly generated by each sector and final demand type (where the amount for the *i*th sector would be $a_{ki}x_i$); the change in stock of cleared waste (Δs_k); and the price p_k of a physical unit of the pollutant, measured as the unit cost of cleaning.

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7 Schäfer and Stahmer (1989) provide a notable counter example. They used very detailed satellite accounting data on environmental protection expenditure collected and collated by the (then) Federal Republic of Germany. However, their analysis focuses entirely on the economic implications of environmental protection activities, and does not relate these to physical pollution or waste generation at the aggregate or sectoral level.

8 There are a number of potential policy applications of such a framework. In Appendix 1 we discuss how the basic accounts can be used to calculate a measure of "pollution-adjusted GDP".

Allan *et al*. (2004a,b) details the construction of this framework and the associated data problems. Here, it is sufficient to note that none of these additional required data is ideally measured at present in Scotland. However, for the reasons already given, the results provide a useful illustrative function.[9]

3.1 Identifying existing resource use by, and expenditure on, waste disposal

We use the industry-by-industry Scottish IO tables, for the year 1999 (Scottish Executive, 2002). These are presented in analytical/symmetric form, with quantities valued at producer (basic) current prices for 128 IO categories (IOC) that map to the 1992 UK Standard Industrial Classification (SIC). These industries have been aggregated to the 19-sector breakdown detailed in Table 1. This disaggregation is chosen for consistency with UK data on sectoral waste intensities.

INSERT TABLE 1

We then split Sector 19 into two sub-sectors given in Table 1 as the new Sector (19), named "Sewage, Sanitation etc." (SIC 90001 and 90003) and an additional Sector (20), named "Waste Disposal" (SIC 90002). It is this last sector, Sector (20), which we treat as a cleaning sector in the full Leontief environmental sense.[10] Here, the adjustment is shown in a compact representation of the Scottish IO accounts given in Table 2. In this table, for heuristic reasons, in each production-sector and final-demand column we have combined the entries for purchases from Sectors 1 to 18. These are now represented in the first single row. The row entries for the two new Sectors (19) and (20) are shown in rows 2 and 3, and the column entries in columns 19 and 20. Subsequent adjustments to the table are discussed later, but the conventional IO accounts, with the Waste Disposal sector separately identified, are given by rows 1-3, 6 and 7 in Table 2.

INSERT TABLE 2

3.2 Waste generation by source

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[9] The paucity of environmental information and the non-compatibility of economic and environmental data in Scotland seriously hinder reliable work on economic and environmental interaction.

[10] See Allan *et al* (2004a,b) for full details of how these two sectors were separated. The simplest and most transparent methods have been used. Allan *et al*. (2004a) is the full report of our study and a more detailed discussion of data issues is given in Allan *et al*. (2004b).

Next we add the row that corresponds to the waste production (and the implicit demand for cleaning). This involves three steps. First we identify the physical waste generated directly by each production and final demand sector. These figures are shown in Table 3.[11] Second, we quantify the change in the stock Δs_f of untreated waste, which, in the absence of other information, we assume here to be zero. Finally, we convert each of these physical quantities to a monetary value by multiplying by the price p_k of waste. This relevant price is the unit cost of waste disposal, which is found by dividing the total value q_k of the output of the waste disposal sector, by the physical quantity $x_k - \Delta s_k$ of waste disposed. The values of q_k and x_k are given in Table 2 and 3 respectively and the value of Δs_k is assumed here to be zero. The unit price of waste disposal is therefore:

$$p_k = \frac{q_k}{x_k - \Delta s_k} = \frac{\text{£}374{,}934{,}000}{10{,}990{,}134} = \text{£}34.12 \qquad (4)$$

INSERT TABLE 3

Each element in the waste generation row gives the value of waste created in the corresponding production sector or final demand category. Each of these elements can then divided by the appropriate value of sectoral output or final demand expenditure to produce a value based waste-output coefficient α_{ki} for each sector. This coefficient can be used in conventional IO multiplier or attribution analysis. If the physical output of waste directly generated by sector i is given as x_{ki}, then:

$$\alpha_{ki} = \frac{x_{ki}\, p_k}{q_i} \quad \text{and} \quad \alpha_{kf} = \frac{x_{kf}\, p_k}{q_f} \qquad (5)$$

The full Leontief environmental IO accounts can now be constructed in a consistent manner.

[11] At present there is no national waste survey or any other statistical vehicle that collects data on physical waste generated by all SIC-classified economic activities in Scotland. Therefore we have used a hybrid technique, integrating data from various Scottish and UK sources. This is detailed in Allan et al (2004a,b).

3.3 The full Leontief environmental table, maintaining the accounting identities

The full Leontief environmental approach involves replacing the actual expenditures on Waste Disposal (row 3) with a set of implied expenditures calculated from the waste generated by the corresponding production or final demand sector. Essentially we replace a vector of row entries derived from equation (3) with a vector reflecting equation (1). In Table 2, this involves substituting row 4 for row 3.

The implicit demands are valued in terms of the cost of treatment and in aggregate this equals the cost of payments in the conventional table. Therefore the overall financial balance embodied in the accounts is not affected. However, for individual sectors, the value of output now will not generally equal the value of inputs, once we have attributed to the production of a good the cost of the implicit waste disposal. We therefore insert an additional row in the value-added block labelled "Additional payments for waste collection, treatment and disposal" (which will be referred to as the "Additional Payments" row). This is row 5. For sector *i*, the value p_i entered in this row, equals $(\overline{\alpha}_{ki} - \alpha_{ki})q_i$ and there are similar additions to the final demand columns.

The relevant full Leontief environmental accounts, with Waste Disposal separately identified, are therefore given as rows 1, 2, 4, 5, 6 and 7 in Table 2. This table is now fully balanced. However, this payments adjustment represents more than an arbitrary, but convenient, accounting fix. The terms in this Additional Payments row sum to zero. Where there is a negative entry, this means that the corresponding production or final demand sector is not directly paying the full amount for the environmental resources that it is using. On the other hand, where the entries are positive, this means that the sector is purchasing more waste-disposal resources than are needed to treat the waste it produces. If the entry in the "Additional Payments" row under the "change in stocks of cleaned waste" column is positive, this identifies the cost paid by the environment (which, as we have argued in Section 2, might be more or less than the environment can bear without environmental degradation). On the other hand, a negative entry in this column indicates environmental improvement.

The only situation in which we expect all the elements of this row to be zero, so that the conventional and full Leontief environmental IO tables coincide, is where both a "polluter pays" system is imposed *and* the waste generated is fully disposed of (Steenge, 1978; Lowe, 1979). However, as argued earlier, because they are "common pool" resources, we do not expect pollutants and waste to be fully dealt with through the market mechanism. More detail on the full Leontief environmental accounts as a set of green accounts is given in Appendix 1.

4. Characteristics and Issues arising from the Scottish Full Leontief Environmental Accounts

With a "common pool" resource, we would expect the following pattern of entries in the Additional Payments row. In general, production and household consumption sectors should have negative entries that are balanced by positive entries for government expenditure and changes in stocks. This would mean that private demand for waste services is less than the waste that is produced in production and household consumption. But this is offset by the public sector taking on the responsibility for the dispose of waste, or the costs being borne by the environment in terms of greater stocks of untreated waste.

Whilst the Scottish data shown in Table 2 broadly support these prior expectations, there are a worrying number of exceptions. First, there is a zero entry in the Additional Payments row for Gross Government Final Consumption. However, this simply reflects the way that the government sector is treated in these accounts. Almost 100% of government expenditure goes to Sector 18, "Public Administration, Health and Education", and this sector has a large positive entry in the Additional Payments row.[12] This is consistent with the government's purchasing more waste disposal output than it requires to clean the waste it produces itself because it also disposes of waste generated in other production and final demand sectors. If the figure for the Public Administration, Health and Education sector, is subtracted, what remains is a large negative Additional Payment figure for all the other production sectors combined.

However, if we look at the Additional Payments row in greater detail, some individual results are problematic. There is a large negative element for Sector 13, Construction, but many other sectors have small positive entries. Table 2 suggests that these sectors are paying more for waste disposal than the value of the waste they generate. There are at least three possible explanations for this.

First, in any time period, a market-driven production or final demand sector could possibly be performing net cleaning, particularly if the waste relates to activity in a previous period. Second, as argued by Dietzenbacher (2005), in a slightly different context, the unit cost of waste disposal might vary across different types of waste, and also maybe across different types of public and private waste disposal organisations. The positive entries in the Additional Payments row might simply indicate expensive waste disposal in that sector. Of course this is still troublesome because the assumption of constant within-sector prices is central to the conventional interpretation and manipulation of the value-based IO system. Third, it is also very likely that these Additional Payments anomalies reflect problems of inadequate data. Recall that we have to estimate both the coefficients α_{ik} and $\overline{\alpha}_{ik}$, and that the corresponding Additional Payments entry depends on the difference between the two. The appearance of so many positive entries here suggests that either coefficient is, or both coefficients are, inadequately estimated.[13]

5. Full Leontief Environmental Modelling

Once a set of full Leontief environmental accounts has been constructed, as in Table 2, the data can be used for full environmental IO modelling, using the whole suite of techniques associated with the Leontief inverse approach. The full Leontief environmental accounts allow a greater variety of endogeneity in modelling the activity of the environmental cleaning sectors, in this case, the Waste Disposal sector.

Two points are important. First, as we argue in Section 2, the particular form of the accounts does not typically imply a specific organisational relationship for dealing with pollutants. To give an example, imagine that the base-year accounts show an increase in the stock of waste equal to 25% of the value of the output of the waste disposal sector. This is consistent with a rule suggested by Leontief (1970), that the government has a "tolerated" level of waste, after which all waste is cleared. However, it is also observationally equivalent, in the base year, with a rule that 80% of all waste is disposed (Steenge, 1978).[14] Second, the information in the full Leontief environmental accounts can be used for a variety of speculative simulations. For example, the waste coefficients derived from Table 2 can be adjusted to model marginal changes that differ from the average relationships that are identified in the base-year accounts.

In this section we report the results from some simple indicative simulations using the output and "dual" price models. Remember first that elements of the data are unreliable, so that the results must be treated with particular care. Second, the degree of environmental endogeneity

[12] Also almost 70% of the output of Sector 18 goes to Gross Government Final Consumption

[13] We did attempt more sophisticated, but still essentially *ad hoc*, adjustments to the estimation processes used to create the full Leontief environmental accounts. However, none were universally successful and we have stuck with the most transparent estimates here.

[14] The full Leontief environmental accounts could also be generated by a wide range of other, more complex, rules that are amenable to IO modelling. For example, waste collection from individual sectors might be some combination of a tolerated level plus a subsequent proportionate rule, which could differ across sectors.

modelled here is low: only one cleaning sector is fully endogenised. This means that in the output simulations we do not discuss the effects on aggregate activity of differing rules for determining the level of waste disposal activity, as the impact at this level is slight. Rather we highlight the effect on the waste disposal sector itself, where in some cases dramatic differences occur.

5.1 Results from the output model

Table 4 reports the Type I and Type II output multiplier results for the impact on the waste disposal sector (Sector (20)) of a £1 million expansion in final demand in each of the 20 production sectors. Figures are reported for varying forms of endogeneity for this cleaning sector. Columns 1 to 3 calculate the impacts based upon Type I multiplier values whilst columns 4 to 6 show the corresponding results using Type II multipliers.[15] The first column gives the results using the coefficients from the conventional IO accounts. In column 2, we impose the assumption of 100% cleaning for marginal changes in activity. This is the assumption underlying analysis in Leontief (1970) once the "tolerated" level of waste has been reached. In column 3, we impose the assumption of 90% cleaning for marginal waste.

INSERT TABLE 4

The most illuminating comparison is between columns 1 and 2. Here we are contrasting the impact on the demand for waste disposal services that would be given with the conventional IO approach, with one where there is an explicitly recognised commitment to dispose of all net waste. The two models predict very different impacts for the waste disposal sector. Whilst some of this is undoubtedly due to data deficiencies, much is not.

First, there are 8 sectors where the Type I multiplier value is greater with the standard IO accounts. As we expect, the biggest difference, in both absolute and proportionate terms, is for "Public Administration, Health and Education". Here the implied direct and indirect demand from waste disposal services per £1million of final demand expenditure in this section is £4,000 less than the amount produced using the conventional IO calculation. As argued in Section 4, this reflects the channelling of government expenditure on waste disposal through this sector in the Scottish IO accounts. However, there are other sectors with a significantly bigger conventional, as against full

[15] Type I multipliers are calculated on the basis that household consumption is exogenous; Type II multipliers have household consumption endogenous (Miller and Blair, 1985).

Leontief, multiplier value. The most prominent example is Sector 12, "Electricity, Gas and Water Supply, Coke and Petrol Products". It is more difficult to explain the pattern of results for these sectors.

There are twelve sectors where the full Leontief environmental Type I multiplier impact on the demand for waste disposal is greater than that for the conventional IO model. The most dramatic difference is for Sector 13, "Construction". With the conventional Scottish IO table, construction is identified as a sector generating very low direct and indirect demands for waste disposal. A £1 million increase in final demand in this sector produces a £856 increase in demand for the waste disposal sector. With the full Leontief environmental accounts, this impact is increased to £18,140. This is because in the Scottish-specific data on net waste production just under 39% of all waste treated is generated in construction and demolition activities, all of which we have allocated to the Construction sector. This compares with less than 1% of payments to Waste Disposal coming from the Construction Sector in our adjusted IO table. Again, however, these results are subject to the date problems outlined above. For most other sectors, the difference is much more modest, though Sectors 8, (19) and 16 ("Metal Products", "Sewage, Sanitation etc." and "Transport and Communications") all register substantially higher direct and indirect demands for waste disposal using the full Leontief environmental approach.

If the government changed the procedures for waste disposal, such that only 90% of marginal waste was disposed of, the Type I multiplier results are given in column 3 of Table 4. There are no surprises here: the proportionate fall in the multiplier values is uniform across sectors. When we calculate the corresponding Type II impacts, the qualitative results are very similar. The only source of some concern in these simulations is that the households' implicit demand for waste disposal is actually less than their actual demands, so that endogenising households' expenditure slightly boosts the standard IO multipliers as against the full Leontief environmental results.

5.2 Results from the price model

Table 5 gives results using the price "dual" of the quantity Input-Output system. The figures reported are the percentage changes in the vector of output prices generated by the price IO system when we replace the conventional price inverse with the inverses derived from the full Leontief environmental IO system with 100% and 90% cleaning. Columns 1 and 2 calculate the impacts on the prices of sectoral outputs using the Type I price multiplier values for the adjusted system. Columns 3 and 4 show the corresponding Type II results. Columns 1 and 3 give the percentage changes from the vector of initial (unitary) output prices from the conventional accounts where it assumed that 100% of marginal waste is cleaned. Columns 2 and 4 give the changes under the assumption that only 90% of marginal waste is cleaned.

INSERT TABLE 5

The figures in column 1 of Table 5 are therefore obtained on the assumption that 100% of the waste is cleaned and the polluter pays. The price changes clearly reflect the results identified in the corresponding Type I output multiplier analysis. First, there are 8 sectors where the price of output is lower than under the existing, standard, IO accounts. Again, the biggest difference is observed in the "Public Administration, Health and Education" sector, through which government expenditure on waste disposal is channelled; the output price for this sector is 0.4% lower than with the conventional IO calculation.

For the other 12 sectors the price of output is higher than for the conventional IO model. Again, this is consistent with the outcomes from the output model. Essentially the price results indicate that, for these 12 sectors, the commodity prices in the conventional IO model do not fully incorporate the costs of using the common pool resource. Instead, in the conventional IO model the external cleaning costs are incorporated in the output prices of the other 8 sectors. These costs will be borne by the final consumers of the outputs of these sectors. In the case of sectors such as "Public Administration, Health and Education", where government is the main consumer, the external cleaning costs are transferred to the local taxpayers. However, in other sectors domestic household or foreign consumption bears the additional cleaning cost.

The distinction between external cleaning costs (i.e. the resource requirements of waste disposal) and the full social costs, including environmental degradation, are highlighted in the results in column 2. If the government changes its commitment to waste disposal, so that not all waste is disposed of, the price of output in all sectors will fall relative to the 100% cleaning case. Column 2 gives the price outcomes under a regime of 90% waste disposal, paid for by the polluting production and consumption sectors. All of the positive price impacts, relative to the conventional IO, are smaller and all of the negative impacts are larger. Prices fall to the taxpayer and consumers, but a higher "price" is paid by the environment.

To calculate the corresponding Type II price impacts, we endogenise the nominal wage, keeping the real wage constant. In our Scottish data, the households' implicit demand for waste disposal is less than their actual demand. Therefore in this case in the full Leontief environmental analysis, Type II output prices are lower than Type I. In Table 5, the Type I and II results for 100% cleaning are given in columns 1 and 3 respectively. Note that the positive price effects are smaller -

and the negative effects larger – in column 3 than in column 1. The corresponding figures for the 90% cleaning case are given in columns 2 and 4 of Table 5. Again we have lower prices in column 4 and some examples of sectors - Sector 2, "Mining and Quarrying", for example – with a positive entry in column 2 but a negative entry in column 4.

6. Summary and conclusions

In this paper we attempt to operationalise the full Leontief environmental model based around the standard Scottish IO accounts. Although data problems mean that the empirical results reported here must be regarded with caution, constructing these illustrative accounts generates important insights. First, the full Leontief extension is required because the services the environment provides relate to a "common pool" resource. Because of limited property rights, the use of "common pool" resources is not typically fully allocated through the market mechanism. Therefore whilst the use of these services is associated with production and final consumption levels, this link is not made directly through expenditures. Further, the method used for the Leontief full environmental extension could be used for the endogenising the use of other "common pool" resources, such as road capacity and irrigation systems.

Second, if a "polluter pays" scenario exists, where it is the direct responsibility of polluters to clean, there is no need for adjustment. The existing payments to the cleaning sector(s) recorded implicitly or explicitly in the IO accounts will coincide with the demand for cleaning services created by pollution generation. If we have "polluter pays", for example through the introduction of a tax, commodity prices will match those from the full Leontief "dual". However, if the government, rather than the private sector, still retains some commitment to clean, a full Leontief quantity analysis is still required to identify the true output multiplier values.

Third, extending the existing IO database essentially incorporates elements of green accounting. Waste production and cleaning already occur in the Scottish economy: but the full Leontief environmental approach involves identifying the direct sectoral or final demand sources of that waste and who bears the cost of its cleaning. Similarly the full Leontief environmental accounts give a large degree of flexibility for environmental modelling. In particular, adjustments to the degree of endogeneity, reflecting alternative responsibility and administrative mechanisms for dealing with environmental cleaning, have important output implications for the cleaning sector and have potential price implications.

Finally, in terms of the specific problem that initially motivated this study, we note that whilst the Scottish Executive has a formal responsibility for the delivery of environmental policy in Scotland, a lack of compatible industry-environment data severely hinders a more thorough and accurate enumeration and analysis of environmental problems at the Scottish level.[16] This information problem is likely to be mirrored in many other economies, particularly at the regional level.

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References

Allan, G., Hanley, N.D., McGregor, P.G., Swales, J.K. and Turner, K.R. (2004a) Modelling the relationship between economic activity and waste generation, treatment and disposal, Policy paper published by the Scottish Economic Policy Network (Scotecon) at www.scotecon.net.

Allan, G., Hanley, N.D., McGregor, P.G., Swales, J.K. and Turner, K.R. (2004b) An extension and application of the Leontief pollution model for waste generation and disposal in Scotland,

[16] For example, McGregor *et al* (2005) also draw attention to this problem in attempting to incorporate sustainability indicators into a computable general equilibrium model of the Scottish economy.

Strathclyde Discussion Papers in Economics, No.04-05, available at http://www.economics.strath.ac.uk/Research/Discussion_papers/discussion_papers.html

Arrous, J. (1994) The Leontief pollution model: a systematic formulation, *Economic Systems Research,* 5, pp. 105-107.

Dietzenbacher, E. (2005) Waste treatment in physical input-output analysis, *Ecological Economics,* 55, pp. 11-23.

Flick, W.A. (1974) Environmental repercussions and the economic structure: an input-output approach: a comment, *Review of Economics and Statistics,* 56, pp.107-109.

Gallego, B. and Lenzen, M. (2005) A consistent input-output formulation of shared producer and consumer responsiblity, *Economic Systems Research,* 17, pp. 365-391.

Hardin, G. (1968) The tragedy of the commons, *Science,* 162, pp. 1243-1248.

Hoekstra, R. and Jansen, M. (2006) Environmental responsility and policy in a two-country dynamic input-output model, *Economic Systems Research,* 18, pp. 61-84.

Kagawa, S. (2005) Inter-industry analysis, consumption structure, and the household waste production structure, *Economic Systems Research,* 17, pp. 409-423.

Kondo, Y. and Nakamura, S. (2005) Waste input-output linear programming model with its application to eco-efficiency analysis, *Economic Systems Research,* 17, pp. 393-408.

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

Leontief, W. and Ford, D. (1972) Air pollution and the economic structure: empirical results of input-output computations, in A. Brody and A.P. Carter (Eds) *Input-Output Techniques* (Amsterdam: North-Holland).

Lowe, P.D. (1979) Pricing problems in an input-output approach to environmental protection, *Review of Economics and Statistics,* 61, pp. 110-117.

Luptacik, M. and Böhm, B. (1999) A consistent formulation of the Leontief pollution model, *Economic Systems Research,* 11, pp. 263-275.

McGregor, P.G, McLellan, D., Swales, J.K. and Turner, K.R. (2004) Attribution of pollution generation to local private and public demands in a small open economy: results from a SAM-based neo-classical linear attribution system for Scotland, *Strathclyde Discussion Papers in Economics,* No. 04-08, available at http://www.economics.strath.ac.uk/Research/Discussion_papers/discussion_papers.html.

McGregor, P.G., McNicoll, I.H., Swales, J.K. and Turner, K.R. (2001) Who pollutes in Scotland? A prelude to an analysis of sustainability policies in a devolved context, *Fraser of Allander Institute, Quarterly Economic Commentary,* 26 (3), pp. 23-32.

McGregor, P.G., McNicoll, I.H., Swales, J.K., Turner, K.R. and Yin, Y.P. (2005) Incorporating sustainability indicators into a computable general equilibrium model of the Scottish economy, *Economic Systems Research,* 17, pp. 203-140.

McNicoll, I.H. and Blackmore, D. (1993) A pilot study on the construction of a Scottish environmental input-output system, Report to Scottish Enterprise, Department of Economics, University of Strathclyde, Glasgow.

Miller, R.E. and Blair, P.D. (1985) *Input-Output Analysis: Foundations and Extensions* (Englewood Cliffs, NJ: Prentice-Hall).

Qayum, A. (1991) A reformulation of the Leontief pollution model, *Economic Systems Research,* 3, pp. 428-430.

Schäfer, D. and Stahmer, C. (1989) Input-output model for the analysis of environmental protection activities, *Economic Systems Research,* 1, pp. 203-228.

Scottish Executive (2002) *Input-Output Tables and Multipliers for Scotland 1999* (Glasgow: Government Statistical Services).

Steenge, A.E. (1978) Environmental repercussions and the economic structure: further comments, *Review of Economics and Statistics,* 60, pp. 482-486.

Stiglitz, J. (2000) *Economics of the Public Sector,* 3rd edition (London: W.W. Norton).

United Nations (2003) Integrated environmental and economic accounting (final draft version), Studies in Methods: Handbook of National Accounting, Series F, No 61, New York.

Appendix: Environmental Accounts

The full environmental IO system identified in Table 2 has a number of strengths from a green accounting perspective. As argued already, we can see from the entries in the Additional Payments row those sectors whose price fails to fully reflect the direct resource use in their production.[17] The information in the table should also allow the GDP measure to be recalculated to take into account cleaning activity (United Nations, 2003). We will call this "pollution-adjusted GDP" (PAGDP).

The standard GDP figure is calculated as the sum of the final demand elements in the IO accounts (Miller and Blair, 1985). We use the notation adopted in the text to identify the actual payments by a bar. Therefore:

$$GDP = \bar{q}_f \quad \text{(A1)}$$

However, this calculation includes as a positive entry the final demand expenditure on waste disposal, an activity which repairs one element of the environmental damage imposed by other forms of final consumption. Environmentalists have argued that such expenditures should be excluded from GDP calculations. Further, any net change in the stock of clean space is not valued in the conventional GDP figures, so that:

$$PAGDP = \bar{q}_f - \bar{q}_{kf} + \Delta qs_k \quad \text{(A2)}$$

where $\Delta qs_k = p_k(\Delta s_f)$. These adjustments mix actual final demand expenditures and the value of any net environmental cleaning. Of course in this case if there is an increase in the stock of waste, then Δqs_k takes a negative sign.

An alternative way of presenting this accounting measure using only the Leontief full environmental accounts is as follows. For each production sector, the value added equals the actual expenditures on wages and other value added from the standard IO system plus the Additional Payments entry. Therefore:

$$v_i = \bar{v}_i + b_i \quad \text{(A3)}$$

where v_i is value added and b_i is the additional payment. If there are n sectors, the sum of the value added recorded in the IO table equals the unadjusted GDP, so that from (A1)

$$\sum_{i=1}^{n} \bar{v}_i = \bar{q}_f \quad \text{(A4)}$$

Also we know that the additional payments entries sum across all the production sectors and final demands to zero, so that

[17] This does not account for the effect of indirect non-payment for resource use, in the sense that the price of intermediate inputs might not reflect their resource inputs. For a more extended discussion of pollution attribution see McGregor *et al*. (2001).

$$\sum_{i=1}^{n} b_i + b_f + b_{\Delta qs_k} = 0 \qquad (A5)$$

Rearranging (A5) gives $\Sigma_i b_i = -b_f - b_{\Delta qs_k}$, where

$$b_{\Delta qs_k} = -\Delta qs_k \qquad \text{and} \qquad b_f = \bar{q}_f - q_f \qquad (A6)$$

It is straightforward to show that the sum all the sectoral value added entries minus the final demand entry for the cleaning sector in the Leontief full environmental accounts equals the pollution adjusted GDP. Using equations (A1) – (A6) produces this result:

$$\sum_{i=1}^{n} v_i - q_{kf} = \sum_{i=1}^{n} \bar{v}_i + \sum_{i=1}^{n} b_i - q_{kf} = \bar{q}_f - b_f - b_{\Delta qs_k} - q_{kf} = \bar{q}_f - \bar{q}_{kf} + \Delta qs_k = PAGDP$$

This means that the contribution of individual sectors to PAGDP can be identified, which equals their full Leontief environmental GVA figures. This takes into account the direct implied environmental costs.

If we use the results from Table 2 in the text, the 1999 Scottish GDP at basic prices equals £96,068.3 million. If adjustments are made for the waste disposal, under the assumption of no change in the stock of waste, the Scottish PAGDP is 0.14% lower at £95,932.8 million.

Table 1. Production Sectors/Activities Identified in the Scottish Waste IO Tables, 1999

Sector	SIC (1992) codes	Scottish IO categories
1 Agriculture	1-5.02	1-3.2
2 Mining and quarrying	10-14	4-7
3 Food, drink and tobacco	15.1-16	8-20
4 Textiles and clothing etc	17.1-19.3	21-30
5 Paper and printing	21.2-22	32-34
6 Chemicals	24.11-24.6	36-45
7 Non-metallic mineral products	24.7-26.8	46-53
8 Metal Products	27.1-28.7	54-61
9 Machinery and equipment	29.1-33	62-76
10 Transport equipment	34-35.3	77-80
11 Other manufacturing	36.1-37, 20	81-84, 31
12 Electricity, gas and water supply, coke and petrol products	40.1-41, 23	85-87, 35
13 Construction	45	88
14 Wholesale and retail	50-52	89-91
15 Hotels, catering, pubs etc	55	92
16 Transport and communications	60.1-64.2	93-99
17 Finance and other services	65.11-74.8, 91-93, 95	100.1-114, 120-123
18 Public administration, health & education	75, 80, 85.1-85.3	115-118
19 Sewage, sanitation and refuse disposal	90	119
(19) Sewage, sanitation etc	90001, 90003	part of 119
(20) Waste disposal	90002	part of 119

Table 2. The conventional and full Leontief environmental and Scottish industry-by-industry (20x20) IO table for 1999 (£million, condensed)

	1. Agriculture	2. Mining and Quarrying	3. Food, drink and tobacco	4. Textiles and clothing	5. Paper and printing	6. Chemicals	7. Non-metallic mineral products	8. Metal products	9. Machinery and equipment	10. Transport equipment	11. Other manufacturing	12. Electricity, Gas and water supply, coke and petrol product	13. Construction	14. Wholesale and retail	15. Hotels, catering, pubs, etc	16. Transport and communications	17. Finance and other services
1. Payments to Sectors 1-18	1447.612	1397.447	2543.555	152.613	461.420	564.867	208.505	478.843	1648.980	704.264	303.789	2785.692	5554.817	2161.688	767.765	4765.927	10010.308
2. Payments to Sewage, Sanitation etc	1.166	4.334	30.546	5.042	12.864	18.157	2.860	6.908	9.330	3.946	6.617	50.455	1.321	12.508	2.749	30.932	36.211
3. Payments to Waste Disposal	0.675	2.509	17.681	2.919	7.446	10.510	1.655	3.999	5.401	2.284	3.830	29.205	0.765	7.240	1.591	17.904	20.960
4. Implicit demand for Waste Disposal	1.069	0.941	11.608	1.300	3.910	5.225	3.331	10.641	6.820	1.448	2.059	10.779	145.914	10.758	5.026	33.378	10.056
5. Additional payment for waste collection, treatment and disposal	-0.394	1.568	6.073	1.619	3.535	5.284	-1.676	-6.642	-1.419	0.836	1.771	18.426	-145.149	-3.518	-3.435	-15.473	10.904
6. Other primary inputs	2124.438	1500.566	3448.472	1185.679	2056.325	2374.616	1566.302	2030.318	12560.783	1596.146	811.536	3217.429	4549.874	9970.002	2416.065	6641.428	20611.058
7. Total inputs	3573.891	2904.857	6040.253	1346.253	2538.054	2968.150	1779.322	2520.067	14224.494	2306.641	1125.772	6082.780	10106.776	12151.438	3188.170	11456.191	30678.537

	18. Public administration, health, education	19 Sewage, sanitation etc	20. Waste disposal	Total Intermediate Demand	Households	Tourist Exp	GGFC*	GDFCF*	Change in inventories	RUK	RoW	Total Final Demand	Total Demand for Products
1. Payments to Sectors 1-18	8235.771	205.893	119.372	44519.127	23802.717	2010.653	17979.459	6463.163	163.953	23049.804	22230.134	95699.882	140219.009
2. Payments to Sewage, Sanitation etc	177.740	0.040	0.023	413.750	226.414	2.869	0.000	4.033	-1.061	0.208	0.472	232.934	646.685
3. Payments to Waste Disposal	102.881	0.023	0.013	239.491	131.055	1.661	0.000	2.334	0.000	0.120	0.273	135.443	374.934
4. Implicit demand for Waste Disposal	7.421	1.073	0.622	273.380	101.554	0.000	0.000	0.000	0.000	0.000	0.000	101.554	374.934
5. Additional payment for waste collection, treatment and disposal	95.460	-1.050	-0.609	-33.889	29.501	1.661	0.000	2.334	0.000	0.120	0.273	33.889	0.000
6. Other primary inputs	16710.970	440.728	255.525	96068.260	19952.394	1383.120	83.043	4722.871	73.167	1098.395	295.511	27608.501	123676.761
7. Total inputs	25227.362	646.685	374.934	141240.628	44112.580	3398.302	18062.501	11192.401	236.059	24148.527	22526.390	123676.761	264917.389

* GGFC stands for Gross Government Final Consumption; GDFCF stands for Gross Domestic Fixed Capital Formation

Table 3. Direct waste intensity of production and final consumption activities, Scotland 1999

Sector/Activity		Net waste generation (tonnes)	Tonnes net waste (treated by the Waste Disposal sector) per £1million output/expenditure waste-output coefficients)
1	Agriculture*	31,332	8.77
2	Mining and quarrying*	27,590	9.50
3	Food, drink and tobacco	340,258	56.33
4	Textiles and clothing etc	38,105	28.30
5	Paper and printing	114,621	45.16
6	Chemicals	153,169	51.60
7	Non-metallic mineral products	97,646	54.88
8	Metal Products	311,900	123.77
9	Machinery and equipment	199,906	14.05
10	Transport equipment	42,448	18.40
11	Other manufacturing	60,367	53.62
12	Electricity, gas and water supply, coke and petrol products	315,954	51.94
13	Construction	4,277,051	423.19
14	Wholesale and retail	315,327	25.95
15	Hotels, catering, pubs etc	147,324	46.21
16	Transport and communications	978,377	85.40
17	Finance and other services	294,764	9.61
18	Public administration, health & education, sewage and sanitation	217,523	8.62
19	Sewage, sanitation and refuse disposal	49,702	48.65
(19)	Sewage, sanitation etc	31,461	48.65
(20)	Waste disposal	18,241	48.65
	Houshold final consumption expenditure*	2,976,769	67.48
	TOTAL WASTE GENERATED	10,990,134	

Note: Asterix indicates sectors/activities where Scottish-specific data are available

Sources: See Allan *et al* (2004a,b)

Table 4. Output multiplier effects in the waste disposal sector of £1million final demand for sectoral outputs

	Demand for Waste Disposal services (£) per £1million final demand for sector output					
	Type I effects (households exogenous)			Type II effects (households endogenous)		
	Unadjusted IO	Adjusted IO		Unadjusted IO	Adjusted IO	
		Case 1 - clean all additional waste	Case 2 - 90% waste cleaned		Case 1 - clean all additional waste	Case 2 - 90% waste cleaned
Sector/Activity						
1 Agriculture	997	1,558	1,416	2,819	3,140	2,853
2 Mining and quarrying	1,646	2,159	1,962	4,273	4,437	4,032
3 Food, drink and tobacco	3,684	2,863	2,602	5,604	4,526	4,113
4 Textiles and clothing etc	2,414	1,250	1,136	4,655	3,190	2,899
5 Paper and printing	3,426	2,009	1,825	5,564	3,859	3,507
6 Chemicals	4,080	2,329	2,117	5,617	3,658	3,324
7 Non-metallic mineral products	1,237	2,203	2,002	3,206	3,912	3,555
8 Metal Products	1,959	4,919	4,471	4,426	7,064	6,418
9 Machinery and equipment	564	765	695	1,732	1,778	1,615
10 Transport equipment	1,446	1,208	1,098	3,723	3,182	2,891
11 Other manufacturing	4,070	2,573	2,338	6,404	4,594	4,174
12 Electricity, gas and water supply, coke and petrol products	6,334	3,612	3,283	7,978	5,032	4,573
13 Construction	856	18,140	16,486	3,618	20,570	18,690
14 Wholesale and retail	1,010	1,588	1,443	3,538	3,781	3,436
15 Hotels, catering, pubs etc	1,131	2,537	2,306	3,951	4,985	4,530
16 Transport and communications	2,419	4,401	3,999	5,324	6,923	6,291
17 Finance and other services	1,304	1,847	1,679	3,589	3,830	3,480
18 Public administration, health & education	5,267	1,253	1,139	9,071	4,543	4,128
(19) Sewage, sanitation etc	718	3,495	3,176	3,028	5,503	5,000
(20) Waste disposal	1,000,718	1,003,495	911,978	1,003,028	1,005,503	913,637

Table 5. Impact on output prices of adjustment to full Leontief environmental IO accounts

		Percentage change in price relative to unadjusted price IO			
		Type I effects		Type II effects	
		Case 1 - clean all additional waste	Case 2 - 90% waste cleaned	Case 1 - clean all additional waste	Case 2 - 90% waste cleaned
Sector/Activity					
1	Agriculture	0.056	0.040	0.035	0.012
2	Mining and quarrying	0.051	0.030	0.020	-0.011
3	Food, drink and tobacco	-0.082	-0.111	-0.105	-0.140
4	Textiles and clothing etc	-0.116	-0.129	-0.143	-0.163
5	Paper and printing	-0.142	-0.162	-0.167	-0.195
6	Chemicals	-0.175	-0.198	-0.193	-0.222
7	Non-metallic mineral products	0.097	0.074	0.073	0.044
8	Metal Products	0.296	0.246	0.267	0.208
9	Machinery and equipment	0.020	0.012	0.006	-0.006
10	Transport equipment	-0.024	-0.036	-0.051	-0.071
11	Other manufacturing	-0.150	-0.175	-0.177	-0.211
12	Electricity, gas and water supply, coke and petrol products	-0.272	-0.308	-0.291	-0.333
13	Construction	1.727	1.545	1.694	1.502
14	Wholesale and retail	0.058	0.042	0.028	0.003
15	Hotels, catering, pubs etc	0.140	0.115	0.107	0.072
16	Transport and communications	0.198	0.154	0.164	0.109
17	Finance and other services	0.054	0.036	0.027	0.001
18	Public administration, health & education	-0.401	-0.414	-0.446	-0.472
(19)	Sewage, sanitation etc	0.277	0.242	0.250	0.207
(20)	Waste disposal	0.277	0.242	0.250	0.207