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The Impact of Alternative Electricity Generation Technologies on the Scottish Economy: An Illustrative Input-Output Analysis*

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by

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1 INTRODUCTION

UK Energy policy is at a critical juncture, with major changes in the electricity generation mix in prospect. In Scotland significant reductions in electricity generating capacity are expected as coal- and nuclear-powered stations close, and although rapid growth of renewable capacity continues, it does so from a very small base. There is no doubt that Scotland faces very substantial shifts in the composition of its electricity generating capacity, and very probably also a major contraction in the level of that capacity in the absence of further changes in UK energy policy (such as a move to commission new nuclear generating stations). The choices made will have important economic, as well as environmental, consequences.

The current electricity generating stations in Scotland are reaching the end of their original design life. Until very recently, the nuclear and coal powered stations, which currently provide over 60% of Scottish electricity generation, were scheduled for closure or decommissioning within the next 20 years [1, 2]. Subsequent announcements by British Energy on the Hunterston B nuclear power station and Scottish Power on coal-powered Longannet suggest mitigating factors that will delay the loss of this capacity[1]. However, unless there is a significant change in UK energy policy Scotland faces a major shift in the level and mix of its generating capacity from power station closures.

Environmental concerns and commitments have, of course, influenced energy policy in the UK, not least in the form of renewable obligations. These are designed to foster the new renewable technologies, including wave, tidal, wind and biomass, that offer the potential to generate electricity with significantly reduced greenhouse gas emissions, although, of course, any energy generating mechanism is likely to have some adverse environmental consequences. The policy is particularly important for Scotland because of the significant concentration of renewable resources there [3]. While onshore wind currently dominates the new renewables technologies, and is set to continue to grow rapidly (subject to grid connectivity and associated costs), new marine technologies are emerging and may be further encouraged through targeted ROC policies. However, a key issue here is the anticipated scale of this growth.

[1] As of February 2006, Scottish Power announced that it would be opting Longannet into the Large Combustion Plant Directive, securing it at least 5, but potentially 15, more years operation up to 2025.

While energy is strictly a matter reserved to the UK Parliament, the Scottish Executive has targets for renewable generation (to provide 18% of electricity generated in Scotland by 2010 and 40% by 2020 [4]) that appear ambitious[2]. Expressed in absolute terms, the Scottish Executive have accepted [5] the FREDS' [6] target of 6GW of installed renewables capacity, a substantial growth given current capacity of 2.8GW[3].

Despite the radical nature of the likely changes in Scotland's electricity generating capacity and mix, there has as yet been no assessment of their likely implications for the Scottish economy. What are the likely economic consequences of a decline in nuclear-generated supply? How would significant growth in onshore wind impact on the Scottish economy, and how does this compare with other renewable technologies? This paper provides the first attempt to explore the system-wide economic consequences of such changes. This should be an element in the debate on the appropriate future generating mix and capacity for Scotland [7]. Since input-output (IO) analysis is able to track the interdependencies among different industries [8] and Scotland is unique among UK regions in regularly publishing IO tables, it seems a useful method in the present context. However, its appropriate implementation in this case requires considerable augmentation of the current treatment of the electricity sector in official economic accounts.

Section 2 of the paper outlines the Input-Output (IO) method. Section 3 discusses the construction of the Input-Output table, in particular, the disaggregation of the single electricity sector in the official Scottish IO table to allow alternative electricity generating sources to be identified separately. Section 4 presents the results of the IO analysis, which quantify the economic impact of the electricity generating sectors and allow assessment of the impact of e.g. substituting onshore wind for nuclear technologies, as well as assessing the consequences of significant losses of generating capacity. Conclusions and suggestions for further research are presented in Section 5.

[2] We note that total electricity generation capacity from renewable technologies is not the same as total capacity from technologies eligible for ROCs.
[3] As of end April 2005.

2 THE INPUT-OUTPUT METHOD

2.1 The basic IO system

Input-Output (IO) is a standard method for examining the interrelationships between sectors of an economy and final demand [8]. If certain assumptions are imposed, it provides a powerful tool for examining how changes in the final demand for products can affect the outputs of other sectors within an economy. Whilst it has traditionally been used for economic impact analysis [9] recent extensions in IO methodology have seen it applied to energy and environmental areas. In the case of Scotland, recent IO work has covered the generation and treatment of waste [10] and CO_2 [11].

For IO analysis, the output of each sector of the economy in question is given by an equation relating total output to the demands for that sector's goods from both intermediate demand (i.e. other industrial sectors) and final demand. Imposing constant returns to scale, a passive supply side and unchanging technology allows specification of a set of linear equations of the sort:

$$
\begin{array}{l}
\boldsymbol{X}_1 = a_{11}\boldsymbol{X}_1 + a_{12}\boldsymbol{X}_2 + a_{13}\boldsymbol{X}_3 + a_{14}\boldsymbol{X}_4 + \ldots + a_{1n}\boldsymbol{X}_n + \boldsymbol{Y}_1 \\
\boldsymbol{X}_2 = a_{21}\boldsymbol{X}_1 + a_{22}\boldsymbol{X}_2 + a_{23}\boldsymbol{X}_3 + a_{24}\boldsymbol{X}_4 + \ldots + a_{2n}\boldsymbol{X}_n + \boldsymbol{Y}_2 \\
\vdots \qquad \vdots \qquad \vdots \qquad \vdots \qquad \vdots \qquad \ddots \qquad \vdots \qquad \vdots \\
\boldsymbol{X}_n = a_{n1}\boldsymbol{X}_1 + a_{n2}\boldsymbol{X}_2 + a_{n3}\boldsymbol{X}_3 + a_{n4}\boldsymbol{X}_4 + \ldots + a_{nn}\boldsymbol{X}_n + \boldsymbol{Y}_n
\end{array}
$$

where $\boldsymbol{X}_i$ represents the output of sector i, and where a_{ij} represents the amount of sector i's output that is required to produce one unit of output of sector j[4]. In matrix notation, the input-output system can be expressed as:

$$\boldsymbol{X} = \mathbf{A}\boldsymbol{X} + \boldsymbol{Y}$$

This says that gross output ($\boldsymbol{X}$) is the sum of all intermediate sales ($\mathbf{A}\boldsymbol{X}$) (used in the production of all other industries' outputs) and sales to final demand ($\boldsymbol{Y}$), including, for

[4] The a_{ij} are calibrated by dividing the value of the relevant intermediate purchases by the value of industry j's output.

example, consumption, government expenditures and export demands. Solving for gross output ($\boldsymbol{X}$) yields:

$$\boldsymbol{X} = (\mathbf{I} - \mathbf{A})^{-1}\boldsymbol{Y}$$

where $\mathbf{I}$ is an identity matrix, and the term $(\mathbf{I} - \mathbf{A})^{-1}$ is known as the Leontief inverse matrix. The Leontief inverse matrix can be used to examine the extent of interrelationships between sectors within an economy, showing, as it does, the degree to which one sector relies upon the other sectors within an economic space for its inputs.

The system described above is the “open” Leontief system in which all elements of final demand are considered to be exogenous and therefore are determined entirely outwith the system. The Leontief system can be “closed” with respect to households, where the values of the Leontief inverse include not only the direct and indirect purchases necessary to meet changes in final demand, but where induced impacts, arising from endogenous consumption demands being linked to disposable incomes, are also included.[5] These induced impacts reveal the wider effect of the increased incomes of workers in sectors that have experienced increased demand for their outputs. We now turn to using the features of the Leontief inverse to examine interrelationships among sectors in the Scottish economy, specifically examining the degree to which the electricity generating sectors are embedded into the economy.

2.2 IO multipliers

Rasmussen proposes to use the open (Type 1) Leontief inverse to estimate the direct and indirect backward linkages [12]. These are more commonly referred to as output multipliers, in that they show the additional gross output generated across an economy from an additional unit of final demand for an individual sector. They are calculated as the column sums of the Leontief inverse matrix, thus:

$$O_j = \sum_{i=1}^{n} \alpha_{ij}$$

[5] The income from employment row and consumer expenditure column from the IO table are, in this case, incorporated into the $\mathbf{A}$ matrix. The induced consumption effects are thereby incorporated in the multipliers.

where α_{ij} identifies the element located at row i and column j in the Leontief inverse matrix. The output multiplier is defined as “the total value of production in all sectors of the economy that is necessary to satisfy a (pounds) worth of final demand for sector j’s output” [13]. This Type 1 output multiplier incorporates both the direct and indirect impacts of the increased demand for sector j’s output, while taking household consumption to be exogenous. Closing the model with respect to households implies that the induced consumption effect of extra household income coming from a raising of the aggregate output of a sector is included in the Type 2 output multiplier.

While gross output is of interest, as a measure of turnover, it says nothing about how the changes in output affect gross value added (GVA) and employment. These can be calculated by multiplying the Type 1 and Type 2 Leontief inverses by the GVA-Output and Employment-Output coefficients. Thus the open GVA multiplier, M_j^G, is:

$$M_j^G = \sum_{i=1}^{n} v_i \alpha_{ij}$$

where v_i is the value added to gross output ratio in sector i. The value-added multiplier gives the increase in total value-added (GVA) resulting from a (pounds) worth of final demand for sector j’s output.

Employment multipliers can be found in a similar way, using physical employment/output coefficients (e_i). Thus we use a vector of employment-output coefficients (e_i) and multiply this by the open (for Type 1) or closed (for Type 2) Leontief inverse.

$$E_j = \sum_{i=1}^{n} e_i \alpha_{ij}$$

3 CONSTRUCTION OF DATASET

The Scottish Executive have, over recent years, produced annual Input-Output tables for Scotland [14]. IO tables provide a snapshot of an economy at a given point in time. However, the published tables identify only a single electricity sector, which covers all economic activities in Standard Industrial Classification (SIC 92) sector 40.1. This includes all generation, transmission, distribution and supply activities related to the production and use of electricity. This IO table is thus unsuitable for examining the economic impacts of different electricity generation technologies. The table does not distinguish between generation and distribution and *a fortiori* is unable to identify individual generation technologies.

The approach adopted here follows a number of recent contributions in seeking to disaggregate the electricity sector by generating technology [15, 16, 17]. All of these analyses allocate non-generation activities to generation technologies despite the fact that the former, which includes transmission, distribution and supply, would be necessary even in the limiting case of an economy that generates no electricity itself. This approach to disaggregation of the electricity sector would only be valid if each generating technology had a unique network associated with it. The present study overcomes this weakness by adopting Cruz's [18, 19] assumption that all electricity generated is sold to the non-generation activities of the aggregate electricity industry, so that final demands for the electricity generating sectors are zero by construction. However we extend this analysis by disaggregating to a number of generating sectors.

When the project began the most recent Scottish IO tables were those for 2000, a year in which the full range of electricity generating technologies were used in Scotland (albeit at an extremely small scale for some). Confidential data from official surveys of businesses, including the Annual Business Inquiry, were investigated, but two main problems were encountered. First, firms involved in electricity generation in Scotland are also involved in non-generation electricity activities and survey replies often relate to a composite of all such activity, and could not be allocated to generation activities alone. Secondly, the major firms that generate electricity in Scotland typically use a combination of generating technologies. So official data sources do not allow separate identification of generating technologies, and an alternative approach is required.

The approach adopted was first to identify the IO entries for each of the eight generating technologies by using information from various secondary sources and our own surveys. These estimates are then removed from the original electricity sector in the IO accounts, leaving a residual sector that we interpret as capturing transmission, distribution and supply, or non-generation activities. A brief account of this process follows as applied first to sales of electricity by generators (row entries in the IO table) and then purchases (column entries).

The disaggregated IO table was constructed with the sixteen production sectors identified in Appendix 1 and this is the basis of our subsequent analysis. However, we only present an aggregated version of the table for reasons of confidentiality. Table 1 reports the IO table aggregated to 3 sectors, with no disaggregation by generation technology.

Table 1 here

Inputs to each sector are shown in each column, with intermediate purchases from each sector and then purchases of imports, taxes, wages and other value added making up total inputs. The rows show the destination of output produced by each sector. This includes sales to local production sectors, and then to final demand categories (including households, government and export demand). This table reports the results of disaggregating the single electricity sector of the original Scottish IO table into a generation sector (containing a full range of technologies in the 16-sector version) and a non-generation sector.

Our treatment of sales governs the sectoral forward linkages of the generation technologies. As already noted our assumptions constrain final demands for the electricity generation technologies to be zero as all sales are to the non-generating sector.[6]

Disaggregation uses published sources of data [2, 20, 21, 22] on the total generation of electricity by each technology augmented by surveys (postal, telephone and interviews) of companies and facilities involved in electricity generation in Scotland in 2000. Crucial for the IO and linkage work, the surveys requested information on the pattern and origins of purchases made by the respondent. The overall response rate was enhanced by follow up calls and, as appropriate, interviews.

In the case of a typical electricity-generating sector, total sales were taken, where possible, from the completed surveys of relevant firms. Otherwise, the amount of electricity generated in 2000 was estimated from secondary sources - see Table 2 - and the value of those sales

[6] There is a small exception, reflecting the sale of £5.6m to the non-electricity sector, but this represents less than 0.5% of the generating sub-sector's gross output.

estimated using the values from returned surveys. (The surveys showed only a 5% difference in the value in sales received from sales of a MWh of electricity.)

Table 2 here

Our next step was to calculate the total value of payments to employees for each generating technology. Employment was estimated from surveys and other data sources (including company websites). Of total employment in the Electricity sector in the original IO table for Scotland, we estimate that around one-third are directly employed in electricity generation activities.

Together with information on the total labour costs the employment data allowed us to estimate total employment compensation paid by each generation technology. For the large facilities (nuclear, coal and gas) we derived an average total labour cost per employee of around £42000, while for hydro, wind and other renewables (with the exception of marine) we assumed a lower amount of £34000 per worker.

The level and origins of intermediate purchases by each technology were based on surveys for facilities using nuclear and hydro generation technologies. For coal and gas technologies estimates were based on data obtained from the Scottish Executive. For wind, experimental data from the Scottish Executive were available, but these seemed unrealistic in the light of our discussions with individuals involved in the wind farm development process. For wind, landfill gas, biomass and marine technologies, we based sectoral purchases on a combination of published sources [2], and discussions with developers active in this area. The estimates for these generation technologies should therefore be regarded as tentative. As a consequence our subsequent analysis should be interpreted as illustrative of the power of IO techniques. As soon as superior information becomes available, as technologies mature, it can be incorporated.

Taxes on products and production were obtained directly from surveys or calculated from a combination of survey work and secondary sources, leaving the gross operating surplus of each technology to be determined residually. Survey work suggested that this figure was considerable for several technologies, and this is reflected in a high ratio of gross operating surplus to turnover in some cases.[7]

Fig. 1 provides the percentage shares of total output accounted for by various inputs, including domestic intermediate inputs, imports, labour, capital and taxes, derived from the 16-sector electricity-disaggregated IO table. There are clearly wide variations among the broad categorisations of generating technologies.

Table 3 and Fig. 1 here

For most technologies nearly half of their inputs are intermediate purchases from sources within Scotland, although nuclear and wind are exceptions. In the case of nuclear, fuel inputs are imported into Scotland from the fuel processing facilities at Springfields and Capenhurst in England [23]. None of these activities of the uranium fuel cycle take place in Scotland. Wind generation on the other hand does not rely on intermediate inputs. Extraction of energy from the wind means that there are no fuel inputs, and any intermediate purchases would be in the form of replacement parts or maintenance equipment. Evidence from wind developers suggests that, while there will be some labour inputs directly for operation and maintenance, spare parts are imported into Scotland.

Value added-output coefficients, showing the portion of total inputs that are income to employees or operating surplus in each generation sector, also show considerable variation – ranging from less than ten per cent to almost two-thirds of output. Not surprisingly, wind and nuclear are the outliers, with value-added a proportionately greater input into total output than either domestic or imported intermediates. Table 3 also shows that there are large differences in employment-output coefficients across the eight generation technologies. Fossil fuel generation technologies appear to be particularly capital intensive, and are associated with lower employment-output coefficients.

[7] The negative non-generating activity could reflect a number of things, including the possibility of an effective subsidy to generating activity. Without further detailed survey work, however, it is not possible to be certain about its source.

4 RESULTS

Type 1 and 2 output multipliers derived from the disaggregated IO model, and their ranks within the sixteen-sectors of the IO model for Scotland in 2000, are shown in Table 4 and Figure 2.

Table 4 and Figure 2 near here

In the original (published) IO table Type 1 (and Type 2) output multipliers are greatest for the electricity sector, reflecting high internal purchases in this sector. The fact that disaggregation has apparently had a negligible impact on these multipliers for the electricity distribution sector is not surprising given that nearly all sales by generating technologies are channelled through the non-generating sector, and so the full set of backward linkages continue to be embedded there. We can see that the there is considerable heterogeneity among the output multipliers for the electricity generation sectors, which effectively amount to a decomposition of the generating component of the overall electricity multiplier. Without disaggregation of the table, the economic impact of changes in electricity generation would be constrained to the multiplier value for the original sector (2.43 and 2.84 for Type 1 and Type 2 respectively), thereby masking the striking differences among generating technologies.

For Type 1 multipliers the key issue is the percentage and composition of domestically purchased inputs. The most striking results are those for nuclear and wind, ranked second last and last out of the 16 industries reflecting limited local purchases: they are, in this sense, not well integrated into the host economy. The other technologies have intermediate purchases of 40-50%, with marine the highest at 65%. While marine has the highest multiplier, the difference from gas is much smaller than would be expected from the aggregate breakdown in costs alone.

For Type 2 output multipliers, the percentage output allocated to domestic inputs and wages are key determinants. From Fig. 1 biomass and marine have significant shares going to wages, and these sectors do show the biggest Type 2 multiplier values (and differences from Type 1 values), although recall that these technologies are very small in the base year and the underlying data are limited. While nuclear pays high wages, it is capital intensive and so overall the Type 2 multiplier is modest, as is that for wind. The ranking of coal falls under Type 2, while that of landfill gas rises, reflecting their very different labour intensities of production.

The extent of variation in output multipliers by generating capacity militates against the use of an aggregate electricity sector. Furthermore, some of the most marked differences in output multipliers are those *within* the fossil-fuel based generating technologies and *within* renewables, so that even aggregation over either sub-sector may be highly misleading (though, of course, the data on renewables is less reliable).

What are the likely output effects of the projected decline in nuclear and coal-generating capacities? These are clearly quite different, with £10m reduction in coal generation resulting in a £20.5m loss of aggregate Scottish output, whereas a comparable contraction in nuclear would generate only a £12.5m reduction in aggregate output (on the basis of Type 2 multipliers). This largely reflects the different extents of their embeddedness in the Scottish economy, with nuclear having one of smallest knock-on (indirect) effects. Similarly, it would matter a great deal, on our admittedly provisional estimates, whether this loss were to be compensated for by comparable increases in the output of onshore wind (which would generate a beneficial output effect of £12.2m) or marine generation technologies (associated with an output stimulus of £24.2m). Indeed, in terms of output effects wind is an even more limiting case than nuclear with a negligible indirect impact on the Scottish economy. Solely from the perspective of impact effects on output, reducing nuclear and replacing the output with marine would appear to maximise the net benefit to Scotland if these data are indicative. Of course, these estimates relate to variations in output at the margin assuming variable capacity: they do not take account of the costs of providing new capacity to stimulate renewables, for example, nor the costs of decommissioning nuclear or coal- based generating facilities. Furthermore, they make no allowance for the qualitative difference between nuclear and marine outputs, specifically the variability of the latter.

GVA-output and employment-output multipliers and their ranks are reported in Table 5 below, and in Figs. 3 and 4. Sectors which have high value-added to output ratios exhibit higher GVA-output multipliers, with nuclear and wind consequently improving their overall rankings. The top ranked sector in terms of GVA-multiplier values is landfill gas, which reflects a combination of high output multipliers and moderate value-added intensity.

Table 5 near here

Fig. 3 here

Sectors with high employment to output ratios experience a bigger employment boost, explaining the major rise in the ranking of marine, and the decline in nuclear and wind as compared to the GVA-output multiplier values.

Figure 4 here

Looking at the GVA-output and employment-output effects from Table 5, replacing nuclear and coal with hydro, landfill gas or wind would suggest an economic boost to GVA, while the employment effects would be greatest from marine, landfill gas and hydroelectric generation. Again, the caveat that these differences relate solely to the operational stages of electricity generation applies [24, 25].

5 CONCLUSIONS

Scotland faces significant shifts in the level and mix of its electricity-generating capacity over the next twenty years or so. This paper explores the likely system-wide economic impact of such shifts through an input-output analysis that separately identifies eight generating technologies. The results suggest that in order to obtain an accurate account of how the electricity sector interacts with the wider economy, the first step is careful further disaggregation. The results also emphasise the distinctiveness of individual generation technologies, and confirm the potential for misleading results if these are aggregated with transmission, distribution and supply activities (as is done in published IO tables). Indeed, our results warn against aggregation of technologies even into non-renewable and renewable aggregates, since within these groupings there are very striking differences in economic impacts.

The general impression that onshore wind technologies have stimulated little in the way of backward linkages to Scottish industries receives broad support from our analysis: the size of output multipliers suggest little connection to indigenous industries. However, the mature nuclear industry also has weak backward linkages. While we do not analyse this scenario explicitly, even if new plants are ultimately commissioned, the technology seems likely to be imported, so that the local economic impacts would be limited. Of course, substantial construction expenditures would be likely to have a significant, if temporary, impact while installation of new wind turbines is associated with little economic impact.

In contrast, mature coal-based generation of electricity has significantly larger output multipliers and indicators of embeddedness in the Scottish economy. In fact, given the requirements for coal generation in Scotland to use coal with lower sulphur content, these backward linkages will have diminished somewhat since 2000, but will be stimulated again once there is compliance with LCPD. Some of the new renewable energy technologies appear to have better linkages locally, though these are as yet in their infancy. Partly for this reason, we would be wary of drawing overly strong conclusions from the differences in estimated economic impact of the alternative electricity generating technologies.

While our analysis invites discussion of the impact of shifting the generating mix from (high economic impact) coal and (low impact) nuclear to (low impact) wind and (possibly high impact) marine, data limitations, particularly for the new renewables technologies should be borne in mind. Furthermore, considerations of security of supply and a desire for a balanced portfolio of generation technologies would guard against naïve interpretations of economic impacts leading to specialisation in generation provision. Nonetheless the analysis is indicative of what it is possible to do with appropriately disaggregated data sets and an IO modelling approach.

While the analysis of this paper therefore adds significantly to an understanding of the likely economic impact of alternative electricity generating technologies, it is subject to a number of limitations that future research should seek to address, both in terms of the database and the modelling techniques employed. First, the database relates to a single year, 2000.[8] Since our measures of linkage and the impact of alternative technologies are typically independent of the scale of generating activities, the fact that (with the exception of hydroelectricity) renewables account for very small absolute contributions to generation in the base year is not necessarily in itself a matter for great concern. However, given that a number of the new renewables technologies were then in their infancy, the technology they employed then has no doubt been subject to quite rapid change, so that an analysis based on an IO table for 2000 may give a misleading impression of the impact of current technologies.

[8] Since our surveys were conducted official Scottish tables for 2002 have been published.

This is a problem that is not easy to resolve short of waiting for the publication of more up-to-date IO tables. In fact, in the fullness of time, provided that the tables are suitably disaggregated, it will be possible to track the impact of the renewables technologies and compare their effects over selected time periods. The IO approach is ideally suited, for example, to tracking the extent to which the development of marine renewables succeeds in stimulating an indigenous cluster of upstream and downstream activities that extends well beyond generation activity *per se*, and perhaps involves substantial exporting activity. In the meantime, it may be possible to use projections of future energy scenarios (using a knowledge of the new technologies) to explore a range of alternative energy futures and their likely impact on the Scottish economy.

While instructive, the modelling approach explored in this paper is capable of further extension to relax some of the assumptions on which it is based. First, the single region analysis can be extended to the multi-region case, encompassing, for example, all of the countries of the UK. This would allow an analysis of, among other things, the impact of alternative generation mixes on the regional distribution of trade in electricity, and on regional and national economic activity.

Further, while a useful device for describing linkages among industries, the inherent assumptions of IO modelling, while having the attraction of yielding a transparent linear system that is comparatively simple to interpret, limit its applicability. In particular, the assumption that, in effect, “only demand matters” rules out any meaningful analysis of markets that are characterised by scarcity and relative price endogeneity. In turn, this precludes a proper analysis of supply-side policies such as a carbon tax or the climate change levy. Computable general equilibrium models, which share the input-output table as a database, can overcome these limitations and allow the choice of generation technology itself to become responsive to market forces (e.g [26], [27]).

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Table 1 Aggregated Input-Output table for Scotland, 2000, £millions

	Non-electricity	Electricity, non-generation	Electricity generation	Total Intermediate Demand	Final Demand	Gross Output
Non-electricity	40127.00	335.40	360.92	40823.32	100435.99	141259.31
Electricity, non-generation	748.59	605.48	5.68	1359.75	1228.20	2587.95
Electricity generation	5.60	1140.92	0.00	1146.52	0.00	1146.52
Total intermediate inputs	40881.19	2081.80	366.60	43329.60	101664.19	144993.78
Imports	30782.45	136.65	143.18	31062.28	22734.29	53796.58
Taxes	4537.53	131.78	43.35	4712.66	7639.01	12351.67
Wages	42302.79	324.75	105.46	42733.00	0.00	42733.00
Other value added	22755.35	-87.03	487.93	23156.25	0.00	23156.25
Gross Inputs	141259.31	2587.95	1146.52	144993.78	132037.48	277031.27

Source: Input-Output tables and multipliers for Scotland, Scottish Executive

Table 2 Electricity generated by technology in Scotland, 2000

Generation technology	Total electricity generated (GWh) in 2000	Share of total electricity generated
Nuclear	16644.0	34.13%
Coal	15813.0	32.60%
Hydro	4665.3	9.62%
Gas	11081.6	22.84%
Biomass	21.2	0.04%
Wind	216.7	0.45%
Landfill gas	68.5	0.14%
Marine	0.3	0.00%
Total	48510.6	100%

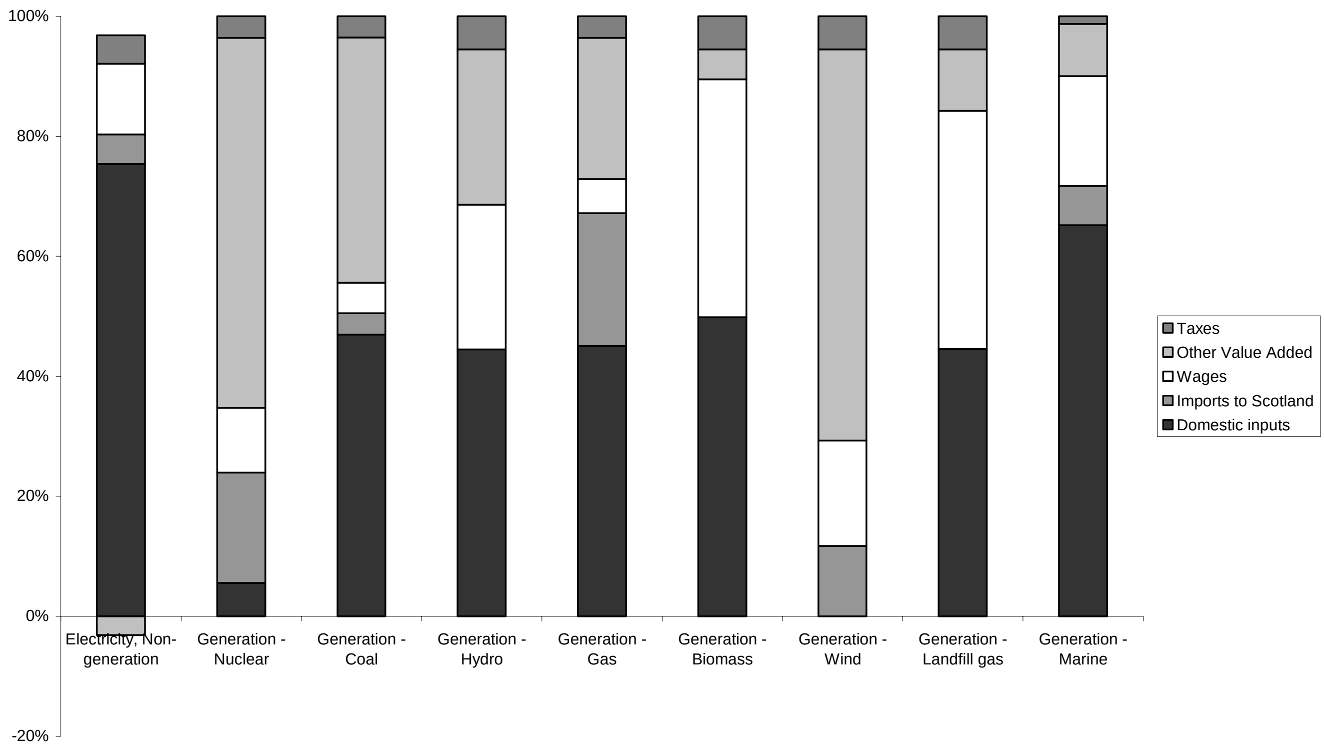
Sources: DTI (2001), Scottish Executive (2004) and authors' calculations

Table 3 Descriptive statistics of Input-Output electricity generation sectors in Scotland, 2000

Generation technology	Share of total inputs which are intermediate inputs sourced in Scotland	Direct employment/output coefficients (jobs per £ million output)	Value added as share of total inputs	kg CO_2 per kWh of electricity generated
Nuclear	5.5%	2.55	61.7%	0.00
Coal	46.9%	1.21	40.8%	0.30
Hydro	44.5%	7.14	25.9%	0.00
Gas	44.5%	1.34	23.5%	0.19
Biomass	49.9%	9.36	5.0%	0.00
Wind	0.0%	4.15	65.2%	0.00
Landfill gas	44.6%	9.36	10.3%	0.00
Marine	65.2%	36.22	8.7%	0.00

Sources: Authors' calculations and kg CO2 per kWh of electricity generated from Scottish Energy Study, 2006

Figure 1 Portion of inputs by type to turnover for Electricity transmission, distribution and supply and Generation sectors by technology



Source: Authors' calculations

Table 4 Output multipliers and ranks for each sector in Scotland in 2000

Sector	Type 1	Rank (1-16)	Type 2	Rank (1-16)
Primary	1.62	10	2.09	9
Manufacturing	1.29	14	1.66	14
Utilities and transport	1.42	13	1.98	12
Services	1.47	12	2.11	8
Coal extraction	1.56	11	2.12	7
Oil processing	1.66	7	1.92	13
Gas	1.89	2	2.23	6
Electricity transmission, distribution and supply	2.44	1	2.90	1
Generation – Nuclear	1.08	15	1.25	15
Generation – Coal	1.72	5	2.05	11
Generation – Hydro	1.69	6	2.26	5
Generation – Gas	1.82	4	2.06	10
Generation – Biomass	1.65	9	2.33	4
Generation – Wind	1.00	16	1.22	16
Generation – Landfill gas	1.65	8	2.44	2
Generation – Marine	1.88	3	2.42	3
Original “Electricity” sector	2.43	-	2.84	-

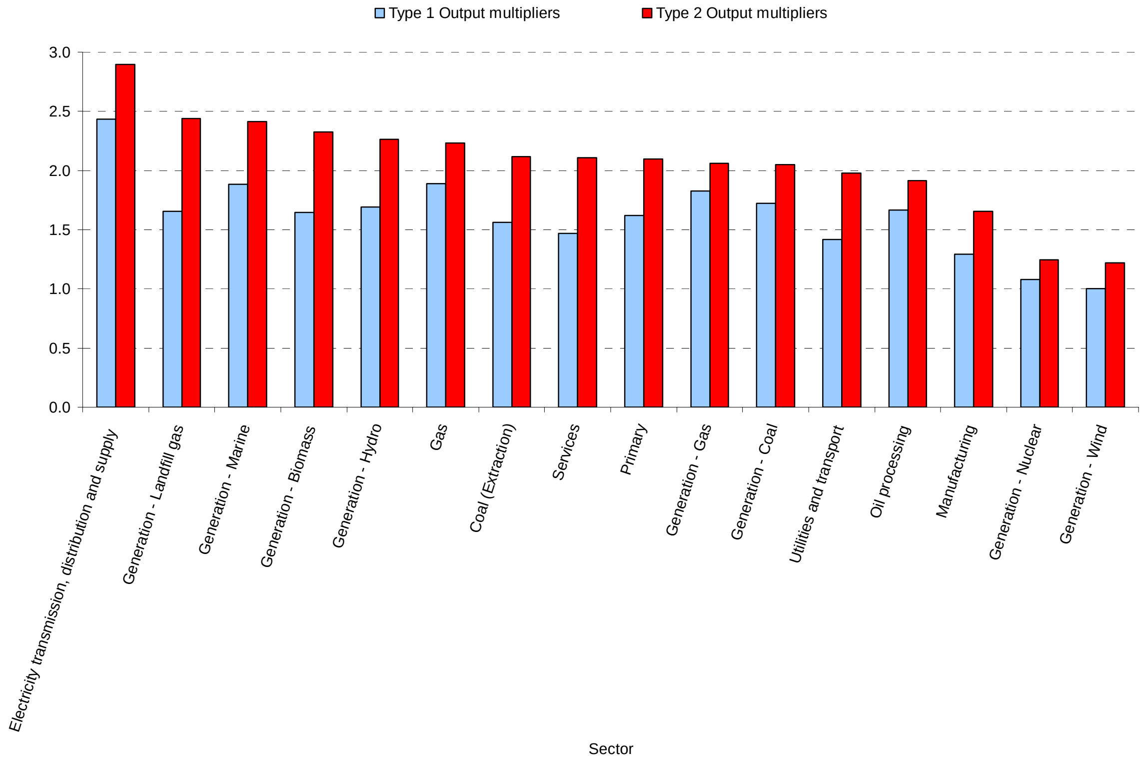
Source: Authors’ calculations

Table 5 GVA-output and Employment-output multipliers and ranks for each sector in Scotland in 2000

	GVA-output multiplier				Employment-output (per £million output)			
Sector	Type 1	Rank	Type 2	Rank	Type 1	Rank	Type 2	Rank
Primary	0.66	9	0.89	8	16.20	7	23.11	8
Manufacturing	0.45	15	0.62	15	11.77	9	17.02	10
Utilities and transport	0.66	8	0.93	6	23.01	2	31.08	2
Services	0.78	4	1.09	3	21.74	3	31.05	3
Coal extraction	0.50	14	0.77	12	16.26	6	24.31	7
Oil processing	0.32	16	0.44	16	8.44	12	12.08	13
Gas	0.57	12	0.73	13	7.45	13	12.37	12
Electricity transmission, distribution and supply	0.66	10	0.88	10	10.42	10	17.12	9
Generation – Nuclear	0.76	5	0.84	11	3.83	16	6.25	16
Generation – Coal	0.75	6	0.91	7	9.60	11	14.38	11
Generation – Hydro	0.83	3	1.10	2	16.42	5	24.67	6
Generation – Gas	0.56	13	0.67	14	5.52	14	8.97	14
Generation – Biomass	0.67	7	1.00	4	15.23	8	25.09	5
Generation – Wind	0.83	2	0.93	5	4.15	15	7.36	15
Generation – Landfill gas	0.85	1	1.23	1	19.05	4	30.45	4
Generation – Marine	0.63	11	0.89	9	47.55	1	55.24	1
Original “Electricity” sector	0.66	-	0.87	-	9.37	-	15.67	-

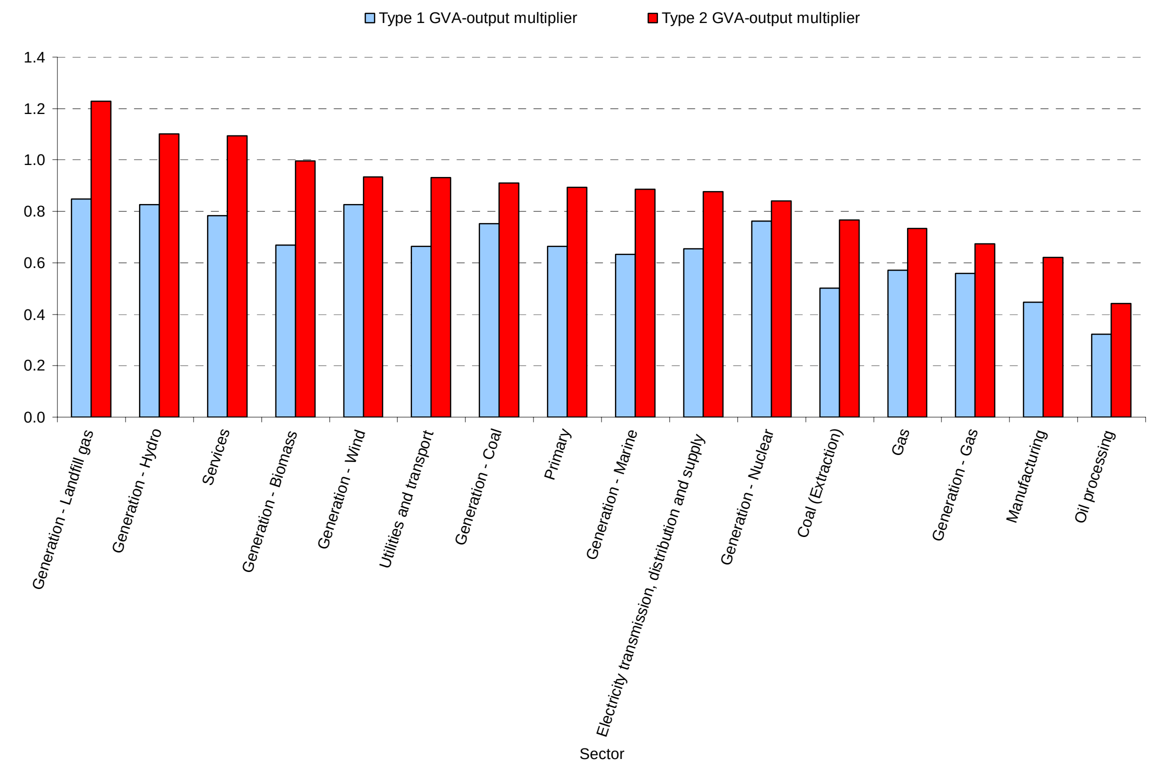
Source: Authors’ calculations

Figure 2 Output multipliers for Scotland, 2000



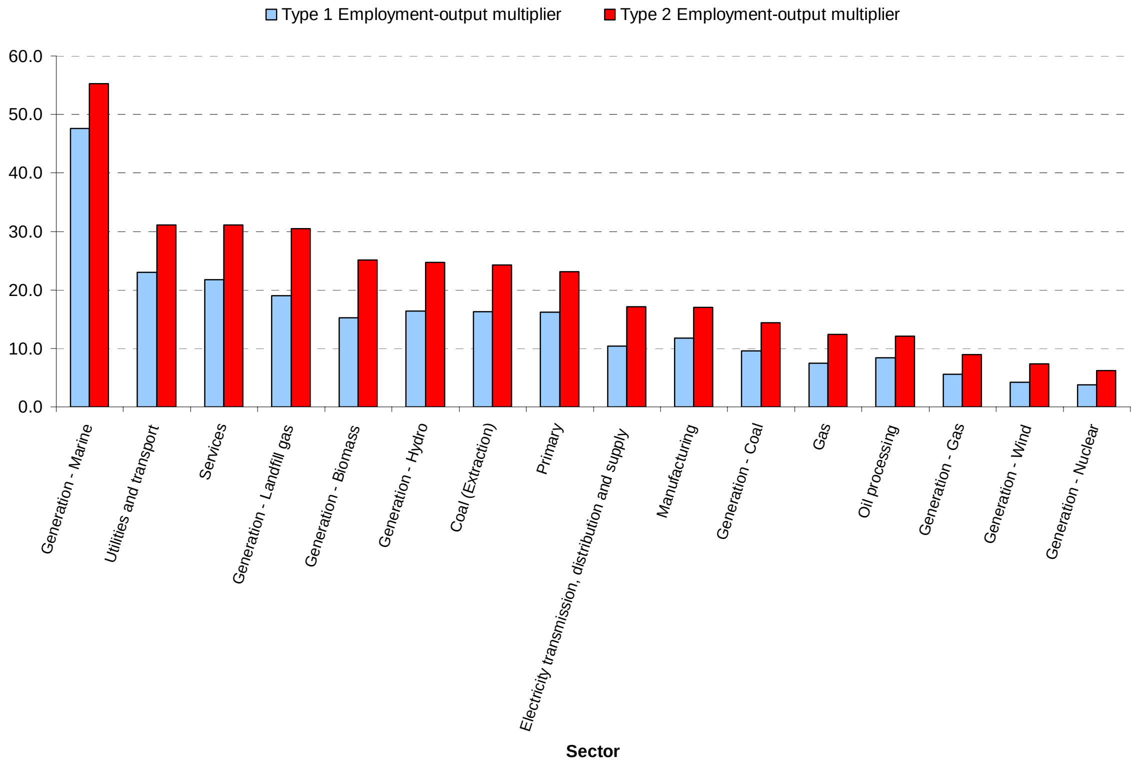
Source: Authors' calculations

Figure 3 GVA-Output multipliers for Scotland, 2000



Source: Authors' calculations

Figure 4 Employment-output multipliers for Scotland, 2000



Source: Authors' calculations

Appendix 1 The 16 sectors of the 2000 I-O table for Scotland

	Sector name	Sectors in original 123x123 I-O table
1	Primary	1-3, 6-7
2	Manufacturing	8-34, 36-84
3	Utilities and transport	87-97
4	Services	98-123
5	Coal extraction	4
6	Oil processing	35
7	Gas	86
8	Electricity transmission, distribution and supply	85
9	Generation – Nuclear	85
10	Generation – Coal	85
11	Generation – Hydro	85
12	Generation – Gas	85
13	Generation – Biomass	85
14	Generation – Wind	85
15	Generation – Landfill gas	85
16	Generation – Marine	85

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