Grant Allan[1,2], Michelle Gilmartin[1,2], Peter McGregor[1,2] and Kim Swales[1]

The Formation of a Domestic and International Market for Tidal Energy Technologies: the UK Economic Impact

[1] Department of Economics, University of Strathclyde
130 Rottenrow, Glasgow, Scotland, G40GE
E-mail: michelle.gilmartin@strath.ac.uk

[2] Fraser of Allander Institute, University of Strathclyde
130 Rottenrow, Glasgow, Scotland, G40GE
E-mail: michelle.gilmartin@strath.ac.uk

Abstract

World-wide interest in tidal power has increased in recent years, and this is particularly true in the UK, where the vast tidal energy resource around the coast is ranked among the best in the world. An important part of the case for renewable energy is the UK-wide socio-economic opportunities that would be associated with the deployment of devices such as tidal turbines. Domestic expenditures on research and development, production, installation and maintenance of tidal turbine devices could provide an important demand stimulus for the local, regional and national economies, and this expectation helps to motivate public and private sector investment. In addition, a key driver in developing the UK tidal sector is the economic gain that could flow from the export of tidal devices, technologies and expertise. In this paper, we quantify such potential economy-wide benefits of the deployment of tidal energy in the UK, using a twenty-five sector computable general equilibrium (CGE) model, UKENVI. The results of the analysis provide a new and important knowledge base for policy makers and investors' decision-making.

Keywords: Computable general equilibrium modelling, energy policy, renewable energy and the macroeconomy.

1. Introduction

The benefits of various renewable energy technologies have previously been estimated for a number of projects - most notably wind power developments - with these estimates often used to argue in favour of projects during the planning process. However, it is not always clear from publicly available documents how these impacts have been calculated, making it difficult to compare and evaluate the results, and creating information barriers for policy makers and investors. Numerous uncertainties are involved in estimating the potential effects of such projects, and the overall benefits can be highly dependent on wide-ranging factors, including policy support and the availability of investment funds. As such, estimates of the impact of projects are frequently speculative in nature and/or based only on surveys and consultations with industry insiders. In some cases they attempt to quantify the local employment effects of domestic expenditures, though there are few economy-wide analyses, and, to our knowledge, no explicit assessments of the economic impact of the development of an export market for specific renewable energy technologies. For the UK tidal sector, as yet there are no formal estimates of potential job creation or economic impact assessments, and no estimates of potential export demand that could be associated with the development of the sector.

In this paper, we use a twenty-five sector computable general equilibrium model, UKENVI, to estimate the UK economy-wide benefit from a domestic and export demand stimulus to the UK tidal power industry. We consider the impact of expenditures related to domestic tidal device installations on the UK economy, and incorporate estimates of potential export demand. In doing so, we focus on the development of the tidal industry over the eighteen year period 2008 – 2025 inclusive, and draw on a range of estimates relating to: the tidal resource capacity in UK waters; the installation timepath for domestic devices; and the production and maintenance expenditures for domestic device installations. We use export data for the Danish wind turbine industry to infer the potential export demand for UK tidal turbines. At present, there are no examples in the literature of this kind of analysis relating to the impact of the development of a domestic and export demand for tidal turbine production.

2. The capacity for tidal power extraction in the UK in 2008-2025

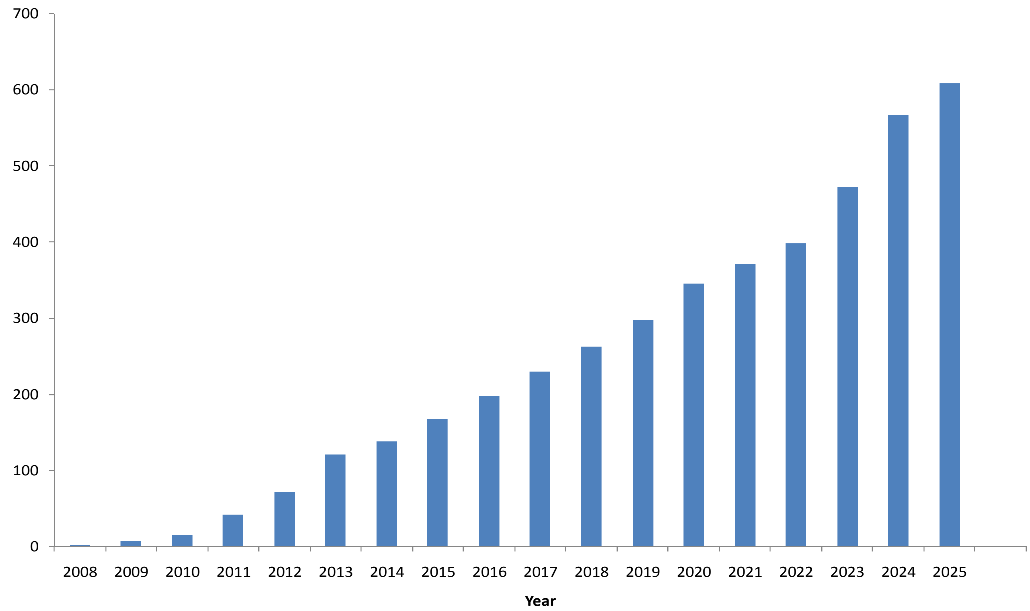
The features required for tidal energy extraction combine in a number of coastal areas of the UK, producing a vast amount of technically extractable tidal resource. In this analysis, we consider UK resource estimates from a number of key sources (ABPmer, 2007; Black and Veatch, 2004; Environmental Change Institute, 2005; and European Commission, 1996), and we assume that the average of these estimates (a capacity of 5,320MW) is representative of the total UK tidal power resource. Further, we assume that 3000MW of this resource can feasibly be installed in UK waters during our simulation period of 2008-2025. This timescale is in line with renewable energy deployment (in particular for the onshore wind industry) in countries such as Denmark and Germany.

3. Estimating the domestic expenditure shock

To quantify the expenditure demand shock associated with our installation timepath, we use industry estimates of the capital, maintenance and decommissioning costs associated with a generic 1MW tidal device. Using an average of estimates from Binnie, Black and Veatch, 2001; Department for Trade and Industry, 2007; and Electric Power Research Institute, 2008, we assume a capital cost of £1,199,117 per MW and operation and maintenance (O&M) cost of £57,392pa. There is, however, considerable variation in and uncertainty about these costs, since they will likely be site-specific and determined by the type of technology used.

In our simulations, these expenditures (which include, for example, the cost of materials, production, insurance and seabed rents) are assigned to the appropriate sector of out twenty-five sector UKENVI CGE model. We acknowledge that some aspects of early tidal energy developments in the UK have been outsourced abroad and, accordingly, we assume that a share of the tidal installation expenditures is spent on imported inputs. This share varies from 505 assumed imports for inputs that have a high electronic component, to 0-10% imports for other expenditure components such as insurance and seabed rents. Combined, our assumptions regarding: the average cost of a generic 1MW tidal device; the timescale for installation; and the degree of local sourcing of inputs provides the total domestic expenditure timepath that is illustrated in Fig. 1.

Figure 1. Domestic Expenditures on UK tidal installations (£m)

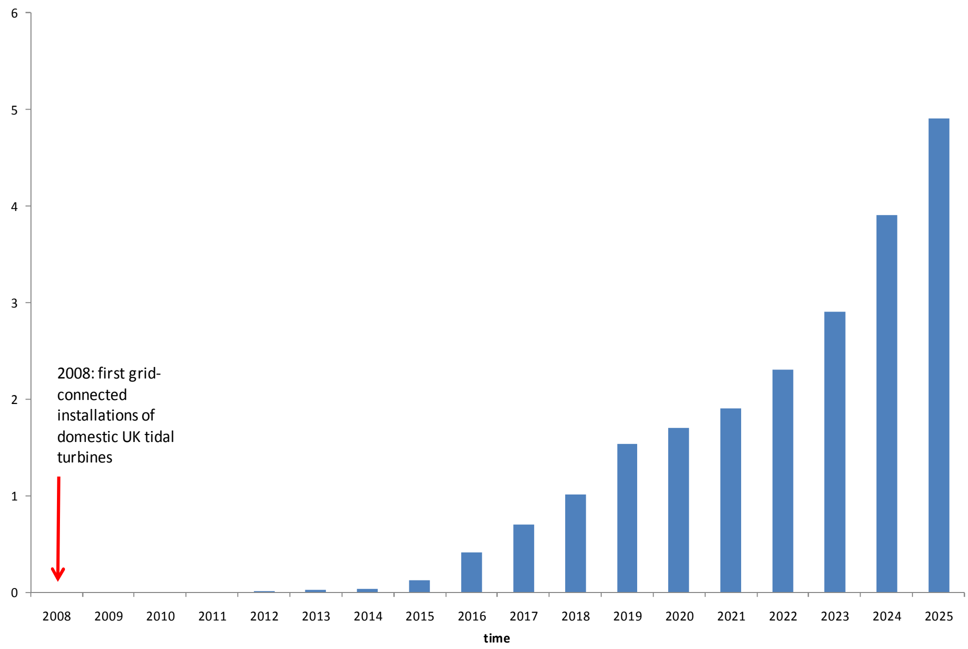


4. Estimating the export demand for UK-manufactured tidal turbines

An additional part of the case for renewable energy is the potential for industrial development of the tidal turbine sector on an international basis. A strong domestic market for commercial scale tidal farms could be a precursor to and provide a firm base for exporting UK tidal devices, technologies and expertise.

To estimate the potential magnitude of export demand for UK tidal turbines, we draw on the experience of the Danish export market for wind turbines. We assume that UK exports of tidal turbines over the simulation period follow a similar path to Danish exports of wind turbines over the period 1980-2008 in absolute terms. That is, by 2025 the UK is assumed to be exporting around £5bn worth of tidal turbines (Fig. 2), which is equivalent to the value of turbine exports in the Danish wind turbine industry in 2007. Thus the main difference in the trajectory of the growth of the export sector for each country is the timepath: whilst the Danish export industry grew to its current size over a twenty-five to thirty year period, we assume that the UK export market grows much more quickly, over the eighteen year simulation period to 2025. This is to reflect the significantly increased size of the worldwide renewable energy market as a whole compared to in the 1980s. The presence of international CO_2 reduction targets and increasing environmental pressures has greatly increased public and private investment in renewable energy devices across the world. This therefore makes for a larger, and higher-growth, international market for renewable energies.

Figure 2. Assumed demand for UK-manufactured tidal turbine exports, £bn



5. The UKENVI CGE model

The usefulness of CGEs in this context reflects their multi-sectoral nature combined with their fully specified supply-side, facilitating the analysis of the system-wide effects of economic shocks. Here, we employ UKENVI, a CGE modelling framework parameterised on UK data. UKENVI has three transactor groups, namely households, corporations and government; 25 commodities and activities, and one exogenous external transactor, the rest of the world (ROW). Commodity markets are taken to be competitive. We do not explicitly model financial flows.

The UKENVI framework allows a high degree of flexibility in the choice of key parameter values and model closures. However, a crucial characteristic of the model is that, no matter how it is configured, we impose cost minimisation in production with multi-level production functions. There are four major components of final demand: consumption, investment, government expenditure and exports. Real government expenditure is taken to be exogenous. Consumption is a linear homogenous function of real disposable income. Exports (and imports) are generally determined via an Armington link and are therefore relative-price sensitive (Armington, 1969). Each sector's capital stock is updated between periods via a simple capital stock adjustment procedure, according to which investment equals depreciation plus some fraction of the gap between the desired and actual capital stock. We impose a single UK labour market characterised by perfect sectoral mobility. In our central case scenario, wages are determined via a bargained real wage function in which the real consumption wage is directly related to workers' bargaining power, and therefore inversely to the unemployment rate (Blanchflower and Oswald, 1994).

6. CGE simulation results

The impact of increased domestic and export activity in the UK tidal energy industry is modelled via a series of exogenous demand shocks in the UKENVI model. The demand shocks are entered annually, for each period from 2008 to 2025. The simulation results are compared to a counterfactual in which the long-run equilibrium position recreates itself, such that if the model is run forward without any disturbances it will replicate the base year values. Thus, no change in the composition or size of the UK economy is assumed. Nor is any exogenous disturbance imposed in the counterfactual simulation. Any changes relative to the base year can therefore be taken to be solely the result of the demand shock associated with the developments in the UK tidal sector that are described above. The approach that I use implies that the developments in the tidal industry are costless for the public sector, and that they are financed entirely through commercial investments. In practice, there may be additional impacts related to, for example, public sector investment which is financed through an increase in taxation. However, the use of a counterfactual which incorporates no other policy change is a necessary first step, since this isolates the effects which can be specifically attributed to the increase in demand for tidal turbine deployment.

6.1 Central case results

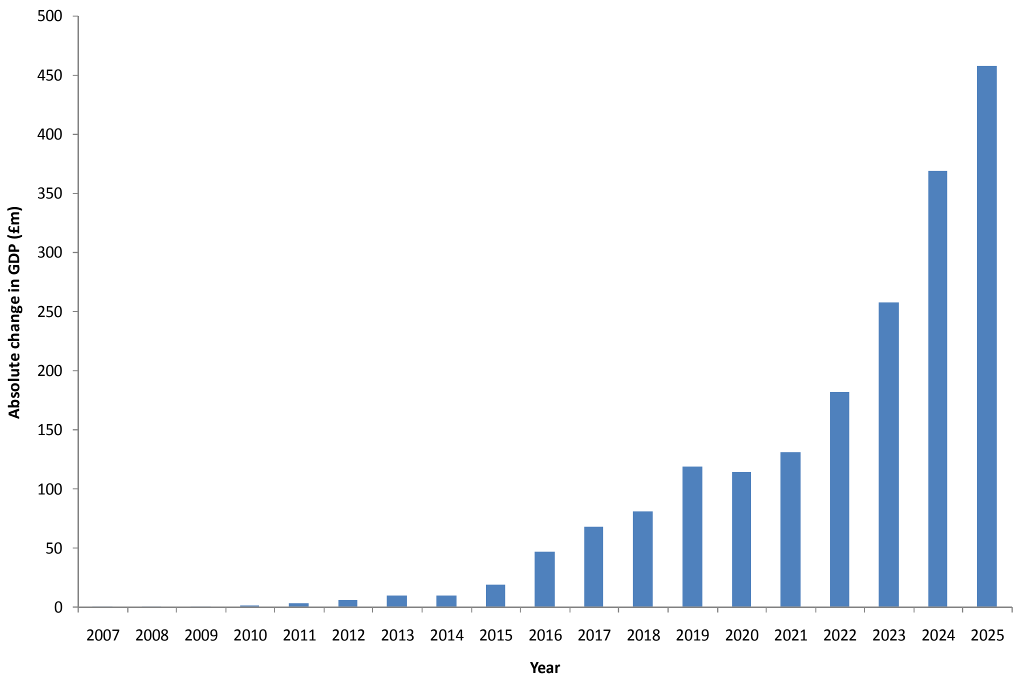
Table 1 shows the aggregate impact of the domestic and export demand stimulus on the UK economy for the central case scenario. The simulation results show that increased activity in the tidal turbine industry leads to an increase in GDP over the period (an increase of £457.1m by 2025 (Fig. 3), or 0.06% of GDP). In line with the increase in demand for UK output, there is a rise in aggregate employment, consumption and consumer prices, though the percentage increases are fairly small. According to the Bargaining relationship, real wages also rise as the unemployment rate falls, though by a modest amount: the real take-home consumption wage is 0.15% higher than base by 2025. Figure 6.9 illustrates the GDP trajectory over the simulation period, and highlights that output rises gradually relative to base over the period 2008 to 2015, and thereafter increases to a greater extent, reflecting the introduction of significant export demands, and therefore a much greater aggregate demand stimulus, from around 2016 onwards.

The increase in GDP relative to base, however, falls far short of the annual aggregate domestic and export stimulus. This occurs for two key reasons. Firstly, although the entire demand stimulus is directed towards domestically-produced tidal turbine commodities, only a part of it contributes towards UK GDP. Some of the intermediate component parts required for turbine manufacture are imported, thus diverting a share of the expenditure out of the domestic economy. Therefore, the more developed are the backward linkages for the industry, the greater the share of the stimulus that remains in the UK, and the higher the aggregate impact of a demand shock to the tidal energy sector.

Table 1. Central scenario: change in key economic variables from base

	2010	2015	2020	2025
GDP (%)	0.000	0.002	0.014	0.056
Consumption (%)	0.003	0.019	0.126	0.345
Investment (%)	0.000	-0.007	-0.019	-0.016
Nominal before-Tax wage (%)	0.000	0.033	0.247	0.676
Real T-H consumption wage (%)	0.000	0.007	0.050	0.150
Consumer price index (%)	0.000	0.000	0.200	0.500
Total employment (%)	0.000	0.005	0.036	0.107
Unemployment rate (%)	0.000	-0.070	-0.453	-1.341
Exports (%)	0.003	0.055	0.373	1.002
Imports (%)	0.004	0.077	0.542	1.436
Total change in employment	8	1,413	13,075	28,449
GDP (£million)	1.118	18.454	114.078	457.061

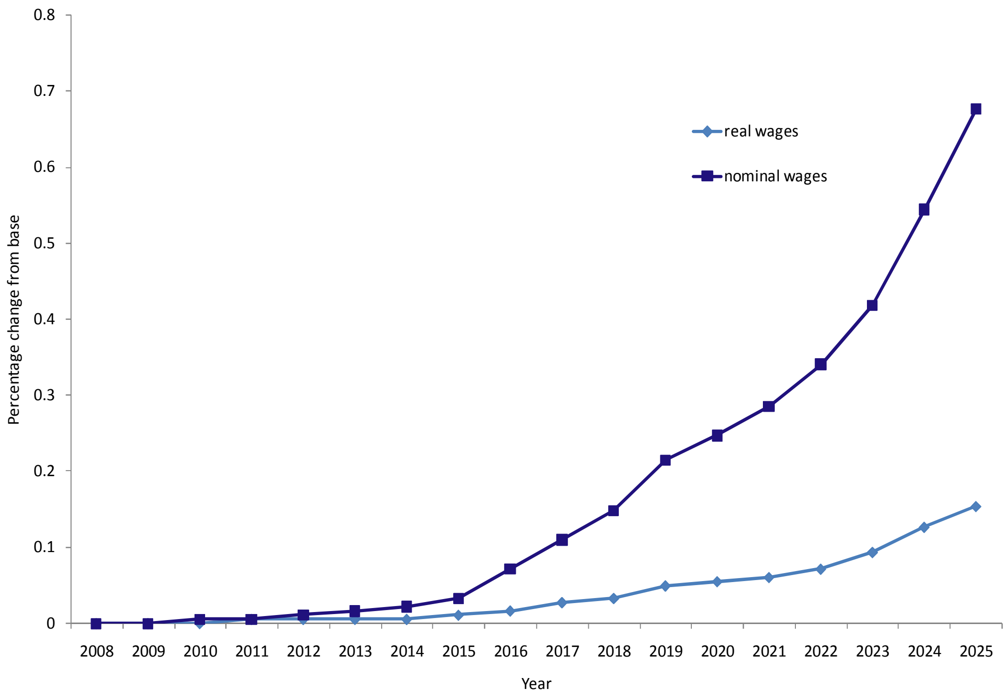
Figure 3. GDP impact of the domestic expenditure and export stimulus



Secondly, the increase in wages and the price of intermediate inputs for some sectors that accompanies the demand expansion crowds out activity in other sectors. This leads to a fall in competitiveness and a reduction in GDP in those other sectors, which contributes to a less-than-proportionate increase in aggregate activity. The real and nominal aggregate wage rate changes are shown in Fig. 4. In those years where the larger export demand stimuli are introduced (i.e. from 2016 onwards), nominal wages rise sharply, which means that some exports are crowded out to facilitate the increase in activity in the tidal industry sector.

The aggregate effect on employment is qualitatively similar to the effect on GDP: a similar gradual increase in employment is observed until around 2015, after which time there are larger increases in employment relative to base, corresponding to the larger size of the export stimuli which are imposed after this period. Within this aggregate employment result, however, there are clear differences in the sectoral employment impacts. These differences reflect, amongst other factors, the degree to which each of the sectors experience a direct demand stimulus, and the extent of crowding out across the sectors. In general, employment in those sectors that are directly influenced by the increase in demand is positively affected. The sectors which are affected by both the domestic and the larger export component of the shock experience an increase in activity and employment. This, however, crowds out activity from most of the other sectors which are not directly affected by the demand stimulus. Moreover, as for the GDP results, even two of those sectors which are directly affected by the increase in domestic expenditures - though crucially not by the export stimulus - experience a fall in employment as activity is directed away from these sectors (the 'communications, finance and business' and 'public administration' sectors, as before).

Figure 4. Percentage change in real and nominal wages



For the non-stimulated sectors, although there are positive indirect and induced effects that derive from the expansion in activity in the sectors affected by the total demand shock, the crowding out effects are sufficient to result in an overall reduction in activity in most of these sectors. In general, as commodity prices rise in these sectors, capital stocks and output falls, and this is associated with a fall in employment across the non-stimulated sectors. The fall in capital stocks in these sectors is significant enough to lead to a reduction in aggregate investment in the economy relative to base during the simulation period, despite the increase in capital stocks in the stimulated sectors. However, there are exceptions to this pattern of falling sectoral outputs, employment and capital stocks for two non-stimulated sectors: the 'other manufacturing' and the 'water' sectors. Following the demand shock, in the stimulated sectors there is an increase in demand for intermediate components which are intrinsic to tidal turbine installations. For the 'other manufacturing' and 'water' sectors, this indirect demand stimulus is sufficient to outweigh the negative effects of higher-priced inputs, so as to generate positive long-run effects on sectoral output, employment and capital stocks. This reflects the close intersectoral linkages between these two sectors and the stimulated sectors.

7. Policy issues and further discussion

In addition to the assumptions made regarding the resource capacity, turbine cost estimates and export demand and so forth, this analysis also relies on a number of additional, implicit, assumptions. These include, for example, the availability of a skilled labour supply, sufficient capacity and connectivity of the UK National Grid, and a competitive and viable price for electricity generated by tidal energy technologies. In practice, however, there are a number of systemic barriers to growth for the tidal energy sector, which could constrain the size of the economic impact associated with development of the sector. For the domestic industry, past surveys of investor attitudes signalled that emerging technologies such as tidal stream have struggled to attract investment from key commercial organisations due to their being considered as high-risk investments (House of Lords Select Committee on Economic Affairs 2004, 2008) and as a result of the perceived insufficient and inconsistent energy sector policy of the UK government relative to other countries (House of Commons Select Committee on Science and Technology, 2007). This deficiency of investment funds is an effect that is likely to have been further exacerbated by the recent financial crisis. Planning restrictions are also of significant concern (House Of Lords Select Committee on Economic Affairs, 2008), as are the capacity constraints of the UK National Grid at areas where tidal electricity generation would be most concentrated (British Wind Energy Association, 2006).

With regards to the international market for UK tidal commodities, the implicit assumption embodied in this analysis is that the domestic industry is able to replicate at least some aspects of the Danish model of the wind turbine industry, in order to achieve a competitive advantage in the production of tidal turbines and a significant share of worldwide revenues. This assumption, in particular, is non-trivial. The successful development of the Danish wind turbine industry since 1980 rests on a wide range of factors, encompassing progressive energy policy objectives, compatible political and social principles, as well as industry compliance within the Danish economy. The policy mechanisms in place included consistent price signals: high energy taxation on fossil fuels; wind investment subsidies that were adjusted downwards as the wind industry grew; and long-term feed-in tariffs which provided investors with the certainty required to expend large amounts of investment capital. These feed-in tariffs were set at fairly high levels relative to market rates for non-renewable energy sources, making it highly profitable for both individual households and private companies to invest in wind turbines (Morthorst, 1999, 2000). In addition, there was open and guaranteed access to the Danish grid: transmission operators were obliged to connect wind power generators, and to expand the grid where necessary. Crucially, there were also long term financial guarantees in place for large wind projects, which encouraged local manufacturing, and helped to establish a strong domestic market for wind power.

In the UK, there are clearly stated objectives for the reduction of greenhouse gases and the increase in renewable energy targets, with the Renewables Obligation policy being the main mechanism for achieving these targets. However, in comparison to the Danish model of the renewable energy industry, UK energy policies are so far less interventionist and social and industrial attitudes less progressive. The comprehensive nature of the Danish policies and circumstances suggest that a number of additional measures may be required for the UK tidal industry to follow a similar development path to that assumed in this analysis. However, this raises a number of issues regarding the nature and extent of appropriate government support, and consensus is still to be reached regarding the exact form any additional policy measures should take, or whether they should be pursued at all.

Moreover, the requirement for a consistent, comprehensive approach to renewable energy policy highlights some points of concern regarding the multi-level governance of the UK economy and the devolution of some limited aspects of Scottish energy policy to the Scottish Parliament. The devolution arrangements of the 1998 Scotland Act involve the division of powers between UK and Scottish governments for a range of policy areas. Energy policy, and the key policy instruments that can influence the energy industry (i.e. taxation and regulation) remain reserved powers for the UK government. Within energy policy, the Scottish government has responsibility only for the promotion of renewable energy and energy efficiency, and the Scottish Parliament currently has no power to vary taxes, other than the ability to vary the standard rate of income tax by up to 3p in each pound. This arrangement suggests that there is relatively little scope for significant policy-making with regards to renewable energy decisions in Scotland. In practice, however, the Scottish government and Parliament have interpreted the powers widely enough to develop a distinctive energy policy influence. This includes the setting of separate targets for renewable energy generation and pollution emissions that are more progressive than the UK government's objectives for energy policy. This is embodied in the Scottish government's target to reduce greenhouse gas emissions by 42% relative to 1990 levels by 2020, compared to the UK's target of 34% (Scottish Parliament (2009) and Committee on Climate Change (2008). The Scottish and UK governments have set equivalent targets for the reduction of greenhouse gas emissions by 2050, of 80% compared to 1990 levels). Similarly, the Scottish government is committed to sourcing 20% of its energy supply from renewable sources by 2020, compared to an equivalent pledge of 15% by the UK government.

These distinct policy priorities likely reflect, in part, the uneven distribution of renewable electricity-generating resources across Scotland and the UK. Scotland is a net exporter of electricity production, while the reverse is true for the RUK. Similarly, for renewable energy resources, a disproportionately large share of the UK's renewable capacity is located in Scotland (Department for Trade and Industry, 2006a). This is true for the tidal energy resource of the UK, with Scotland's share of the total resource ranging from an estimate of around 38% up to 68% (Sustainable Development Commission, 2007, and ABPmer, 2007). It is therefore likely that a disproportionately large share of the effects highlighted in this analysis could be concentrated in Scotland, relative to its contribution to UK GDP, and this would be especially true if clusters of marine energy sector activity congregate in areas near to the resource, and the existing established research and development clusters in Scotland. Thus the Scottish government's more ambitions energy targets possibly reflect the expectation that emissions reductions and increases in renewable energy uptake can be achieved at a lower cost in Scotland, and that the contributions to aggregate activity could be higher than in the RUK. In this study we highlight the overall UK impact of developments in the tidal turbine sector, but the unequal distribution of the resource across the UK, and the differing policy objectives outlined above, suggest that an interregional analysis of the issue would be beneficial.

8. Conclusions

The UK's portfolio of electricity generation techniques will undergo considerable changes over the coming years, with increased emphasis on local, renewable energy resources such as on and off-shore wind and wave and tidal technologies. The UK has considerable renewable energy resources, and in this chapter I attempt to quantify the economic impact of the development of the UK tidal energy sector. Substantial expenditures in a range of UK sectors would be associated with the production, installation and operation of tidal energy devices and, moreover, sizeable worldwide energy resources imply that there could be vast potential export revenues for the industry. The results of the analysis suggest that the demand stimulus could potentially deliver a significant economic benefit to the UK. There are likely to be crowding out effects associated with the shock, with the potential impact varying across the UK sectors.

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Acknowledgements

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