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Concurrent and legacy impacts from establishing a marine energy sector in Scotland: a computable general equilibrium analysis

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Section 1: Introduction and policy background

The recent UK Energy Review (DTI, 2006, p.15) concluded that:

> Over the next two decades, it is likely that we will need around 25GW of new electricity generation capacity, as power stations – principally, coal and nuclear plants – reach the end of their lives and close. This will require substantial new investment and is equivalent to around one third of today's generation capacity.

For both environmental and energy security reasons, there is a growing recognition that existing fossil fuel technology cannot continue to be as heavily used as in the past and there is a growing movement towards generation technologies which operate with low, or zero, carbon emissions. This includes renewable technologies, such as hydro, on- and off-shore wind, and marine (wave and tidal) devices. The use of wind technology to generate electricity has grown rapidly across the UK in the last decade. However, other renewable technologies, such as marine, have also received both financial support and political interest and the first generation of economically viable devices is now close to market[1].

The Energy Review has sought to increase UK investor confidence in renewable technologies by extending the Renewable Obligation to a maximum of 20% of electricity generation and also consulting on the possibility of "banding" the Obligation to "reflect the fact that some technologies are better-established and no longer need the full support of the Obligation, and so that it begins to provide more support to emerging technologies" (DTI, 2006, p16). The combination of these two developments means that a new target has been set that 20% of "our electricity" – presumably, one-fifth of the electricity generated in the UK – will come from renewable resources by 2020.

A parallel situation applies in Scotland (Allan *et al*, 2006a; Royal Society of Edinburgh, 2006). Until very recently, the nuclear and coal powered stations, which currently provide over 60% of Scottish electricity generation, were scheduled for

[1] Ocean Power Delivery (OPD)'s device – the Pelamis – has received an order from a Portuguese consortium to build the world's first commercial facility to generate electricity from ocean waves, which is due begin production in late 2006. As the Managing Director of OPD, Richard Yemm said, "The Portuguese government has put in place a feeder market that pays a premium price for electricity generated from waves compared to more mature technologies such as wind power." (OPD, 2006)

closure or decommissioning within the next twenty years. Subsequent announcements by British Energy on the Hunterston B nuclear power station and Scottish Power on coal-powered Longannet suggest that the loss of this capacity might be delayed. However, even with these adjustments, within twenty-five years all the existing major electricity generation facilities in Scotland could be closed (RSE, 2006).

The UK Energy Review make the important point that “much of our renewable resource, potential and planned projects are to be found in Scotland, where the promotion of renewable energy is the responsibility of Scottish Executive Ministers. We will work with them to deliver on our UK-wide targets” (DTI, 2006, p16). At this moment, considerable work has examined the possibility of using Scotland’s natural attributes for this purpose and, while energy supply decisions are strictly a matter reserved for the UK Parliament, the Scottish Executive has ambitious targets for renewable generation. These targets are to provide 18% of the electricity generated in Scotland by 2010 and 40% by 2020 from renewable sources (Scottish Executive, 2003). Expressed in absolute terms, the Scottish Executive (2005) has accepted the Forum for Renewable Energy Development in Scotland (FREDS, 2005) target of 6GW of installed renewables capacity, a substantial growth given current capacity of 2.8GW[2].

The extra capacity required to meet the Scottish Executive targets is intended to come from a range of sources, including on- and off-shore wind, biomass, landfill gas and wave and tidal. There are no specific targets for the amount of electricity to be generated by each of these technologies. However the Scottish Executive has recently launched a consultation on the ways in which the Renewable Obligations (Scotland) (ROS) could be amended to support increased generation of electricity from wave and tidal resources (Scottish Executive, 2006). Boehme *et al* (2006) argue that, after applying constraints concerning resource availability, economic viability and technological feasibility, wave power alone could contribute an installed renewables capacity in excess of 3GW.

[2] As of the end of April 2005.

In this paper, we examine the economic impacts that the installation and operation and maintenance of such a capacity of wave energy would have on Scotland. Essentially we treat the generated electricity either as being exported to the rest of the UK or acting as a substitute for imported electricity. We focus on a given type of wave energy device of an articulated wave energy converter. The investment characteristics of the device are outlined in Section 2, together with the details of the central case simulation used in the remainder of this paper. In Section 3 we describe the AMOSENVI Computable General Equilibrium model of Scotland and in Section 4 we report the simulation results for the central case. In Section 5 we perform extensive sensitivity analysis. Section 6 offers conclusions and outlines the implications of these results for energy policy in Scotland and the United Kingdom.

Section 2: The time profile of construction, installation and operating expenditures

The construction and installation of electricity generation technologies is often the largest cost outlay over the duration of the facilities lifetime. Fossil fuel plants, for instance, are expensive to design, commission and build. Once built though, these plants also have significant annual operating expenses, primarily for the fuel required to keep the facility in production. Renewable technologies, on the other hand, which use naturally occurring energy resources as their input, such as the waves, tides or wind, will have correspondingly low operating expenses. There might be high initial expenditures during the construction and installation phases, but once installed, the costs of running renewable technology facilities is typically a fraction of that of fossil fuel plants. In these renewable electricity generation technologies, especially marine and wind, installation costs therefore represent the bulk of the costs.

The illustrative marine device chosen in this exercise is of an articulated type (as described by Boehme *et al*. 2006), consisting of four thirty-metre cylindrical steel sections joined together by three independent hydraulic power conversion modules. Each device has a total steel weight of 380 tons, a rated power output of 750kW and an average power output of 263kW. As shown by Boehme *et al* (2006) the average power capture from a device varies with device location but the mean capacity factor of 35% used here may be observed for 3GW of wave power installed in Scottish waters. When deployed as part of a wave farm, multiple devices are installed in an array formation. In this section, we calculate the time profile of expenditures required to install 3GW wave energy capacity in Scotland by 2020, and the subsequent operating and refit expenditures over that capacity's lifetime. To attain a cumulative installed wave capacity of 3GW, four thousand devices must be installed by 2020. We assume that, in reaching 3GW of capacity by 2020, the installation of wave energy devices follows an exponential growth path similar to that displayed by the wind energy sector over the last decade.

[Figure 1]

The assumed absolute and cumulative total number of (750kW rated capacity) devices installed at the end of each year is shown in Figure 1 below. Initially around 30 devices are installed per year but this increases to seven hundred devices installed in the final year. Each of the wave devices installed has a lifetime of 20 years, with a refit scheduled to occur after the device has been installed for ten years. The time periods over which installation, operation and refit activities occur are illustrated in Figure 2. However, cost figures are required for the installation, operating and refit expenditures.

[Figure 2]

Installation expenditures

Figure 1 gives the time-exponential growth of annual physical investments needed to hit the 2020 target for the cumulative installed capacity. Subsequently, we calculate the total investment made each year as the product of the electrical output generated by the devices installed in that year (kWh) and the present value of each generated unit of electricity (£/kWh). Whilst it is recognised that power capture is dependent on numerous parameters, we employ a simple estimate of total electrical output for *N* devices operating for 20 years: *N* x average output (262kW) x 20 years. Following the carbon trust (2006) the cost of electricity is taken as 8.5p/kWh under the assumptions that renewable subsidies valuing 3.5p/kWh persist till 2020 and that the cost to generate electricity using fossil-fuel based generators will increase to around 5p/kWh. Having estimated a total investment per annum, we use published information (Previsic *et al*, 2004) for this type of wave energy device to calculate the total installation costs and the subdivision of these costs between different expenditure categories. Each of these expenditure categories is then allocated to an industrial sector as described in Table 1 below.

[Table 1]

The first column in Table 1 gives the installation expenditure category and column two the proportion of this expenditure that falls under that category. Columns three and four list the Standard Industrial Classification (SIC) designation and number. Column five gives the code for the corresponding sector in the AMOSENVI model.[3] Note that the direct impact is concentrated in two AMOSENVI sectors, 10 and 11, which receive 35% and 57% respectively of the expenditure. These are both manufacturing sectors: “Metal and Non-metal Goods” and “Transport and Other Machinery, Electrical and Instrument Engineering” respectively.

However, these installation expenditures will not all be made in Scotland, or on products produced in Scotland. The extent to which the component can be sourced from within Scotland will be important for the economic impact on the region. This decision as to the source of materials and components will, of course, be made by the device constructor, and it is reasonable to assume that the lowest cost source that satisfies the design requirements would be selected for each input.

Information on the imported content of these expenditures is uncertain, particularly given that we are considering future expenditures which might, at one extreme, lead to the creation of a strongly linked Scottish industry serving the production of components for marine energy devices, or, at the other, a situation where all the major components are imported to Scotland.[4] It is likely, for instance, that certain elements of the installation expenditures with high transport costs will be made close to where the devices are installed (such as the concrete structures or steel

[3] A detailed breakdown of the sectors in the AMOSENVI model is presented in Appendix 1.
[4] For example, with wind generated electricity the import content is extremely high, while for other generation technologies, there is a much more local input-sourcing (Allan *et al*, 2006a).

inputs). In the central case simulations we have made assumptions about the degree to which each component of capital expenditure is made within Scotland. These are given in column six of Table 1. We assume these proportions are fixed across all time periods of the simulation, so that, for example, the same percentage of total spend on undersea cables is made in Scotland in 2006 as in 2020.

Thus, in the central case scenario we assume that there is mixed success in establishing backward linkages for the marine energy sector. Concrete structures, construction facilities, installation and construction management are all assumed to have high Scottish content, given that they require standard industrial production techniques and high transport costs. The main element in terms of value is the power conversion module that contains a heave and sway joint, sets of hydraulic rams, smoothing accumulators, and a motor connected to an electrical generator. It is likely that companies able to provide components for these will be located outwith Scotland unless significant development in large-scale production of these specialised modules develops to serve the marine energy sector directly. Thus, we assume that only half of the total values of these expenditures are made directly in Scotland. Interestingly, the report by Previsic *et al* (2004, p. 23) notes that were this wave energy device to be deployed in California at the commercial scale envisioned, it would “make economic sense to establish local manufacturing facilities for the Power Conversion Modules. This will allow for a large amount of US content in the devices and bring benefits to the local economy”.

Once we take into account the imported elements of the installation expenditure, the local direct impacts will be reduced but the AMOSENVI sectors 10 and 11 still dominate.

Operating expenditures

Operating expenditures are small when compared to the initial costs for each device. However, these expenditures continue for the operating life of the device (here taken as 20 years) and so represent a potentially important continuing direct impact. The particular devices under consideration here are designed to minimise the amount of physical intervention required and are designed to be monitored remotely as much as possible (Previsic *et al*, 2004). Operating expenditures are difficult to predict as they include planned and unplanned maintenance, as well as monitoring costs.

The costs of maintenance trips will depend upon several factors, including the accessibility of the site by boat, the duration for which visits can be made over the year, the reliability of the devices installed and the extremes of sea-states that the devices encounter during their operation. We again assume that a certain portion of the value of the operating expenditures is made in Scotland. For the three elements of the operating expenditures, we assume the following percentage of Scottish sourced inputs: labour 95%, parts 75%, insurance 95%. For parts, the industrial sector chosen was SIC 29.1 as the largest portion of this expenditure is likely to be the power conversion module. Insurance expenditures were allocated to the "Communications, finance and business" sector in AMOSENVI (Sector 17). Operating expenditures made up 51.9% of total expenditures over the design lifetime of the devices.

Refit expenditures

Ten years after installation, the devices must be removed from their site at sea, for a complete overhaul and refit. This might include re-painting, but is also likely to include the exchange of some of the power take off elements – such as the hydraulic rams (Previsic *et al*, 2004). Expenses at this time are in two categories; operation costs (to de-ballast and remove the device to land before replacing back in the array) and parts. We assume that 90% of the operation expenditures are made in Scotland, while 50% of the parts for the refit are sourced in Scotland (since most of the replacement parts cost will be for the power conversion module). The refit operation costs were allocated to the Construction sector (SIC 45), while parts were again treated as coming from SIC 29.1. Total refit costs over the lifetime of the devices made up only 4.2% of all expenditures.

The timelines of these three Scottish expenditure elements: installation, operation and refit, are shown in Figure 3. This figure gives the expenditure streams that correspond to the activities charted in Figure 2 and includes all the judgements made above about the Scottish content of each expenditure component. In the absence of more detailed information, we assume that decommissioning costs incurred at the end of the devices expected lifespan are negligible.

The top line shows the total direct annual expenditures in Scotland. There are three distinct time intervals. The first is up to 2020 where the number of devices in operation is increasing at an exponential rate. Over this time interval, installation and operating expenditures occur from the start and in 2016 refit expenditures begin. Total expenditure increases to £1,545 million per annum in 2020. The second time period is between 2021 and 2029. In 2021 installation expenditures stop but operating and refit expenditures continue. As a result, total expenditure drops significantly between 2020 and 2021, to just over £400million, before rising slowly through to 2029. The increase in refit expenditure offsets the small reductions in operating expenditure that occurs from 2026 onwards as devices are decommissioned. The final period is between 2030 and 2041. During this period only operating expenditure occurs and this gradually falls in line with the number of devices.

[Figure 3]

Section 3: AMOSENVI model and simulation strategy

3.1 AMOSENVI model

The AMOSENVI model is explained in full in Hanley *et al* (2006).[5] This is a variant of the AMOS Computable General Equilibrium (CGE) model of Scotland (Harrigan *et al*, 1991), with an appropriate sectoral disaggregation and a set of linked pollution coefficients, developed specifically to allow the investigation of environmental impacts.[6] A condensed version of the model is given in Appendix 2. It is calibrated on a social accounting matrix (SAM) for Scotland for 1999.

AMOSENVI has 25 commodities and activities, five of which are energy commodities/supply (oil, gas, coal and renewable and non-renewable electricity). These sectors are listed in Table A1 in Appendix 1. The model has three transactor

[5] Allan *et al* (2006b) gives the UK national version of the model: UKENVI.
[6] AMOS is an acronym for a micro-macro model of Scotland.

groups, households, corporations and government; and two exogenous transactors (rest of the UK and rest of the world). Commodity markets are assumed to be competitive. We do not explicitly model financial flows, but make the assumption that Scotland is a price taken in competitive UK financial markets.

The AMOSENVI 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, generally of a constant elasticity of substitution (CES) form, so that there is input substitution in response to relative-price changes. Leontief specifications are imposed at two levels of the hierarchy in each sector – the production of the non-oil composite and the non-energy composite – because of the presence of zeros in the base year data on some inputs within these composites.

There are four major components of final demand: consumption, investment, government expenditure and exports. Of these, real government expenditure is taken to be exogenous. Consumption is a linear function of real disposable income. Exports (and imports) are generally determined via an Armington link (Armington, 1969), and are therefore relative-price sensitive. How investment is determined in each period of the model is discussed below.

We impose a single Scottish labour market characterised by perfect sectoral mobility. We also generally assume that wages are subject to a econometrically parameterised regional bargained real wage function (Layard *et al*, 1991). The regional real consumption wage is directly related to workers' bargaining power and therefore inversely related to the regional unemployment rate.

We run all the simulations below in a multi-period setting, given our interest in the period-by-period impacts of a series of transitory expenditure shocks. These periods are interpreted as years, in that we have used annual data where we econometrically parameterise relationships, especially those that update variables between periods. Within AMOSENVI, in each of these periods both the total capital stock and its sectoral composition is fixed, and commodity markets clear continuously. However, 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 in each sector. This process of capital accumulation is compatible with a simple theory of optimal firm behaviour given the assumption of quadratic adjustment costs. Desired capital stocks are determined on cost-minimisation criteria and actual capital stocks reflect last period's stocks, adjusted for depreciation and gross investment. The economy is assumed initially to be in long-run equilibrium, where desired and actual capital stocks are equal.

Similarly, in the multi-period simulations we report below, the net migration flows in any period are used to update the population stocks at the beginning of the next period, in an analogous way to the updating of capital stocks. We assume a migration specification based on the Harris and Todaro (1970) model, econometrically estimated on UK data by Layard *et al* (1991), in which net migration into Scotland is positively (negatively) related to the real wage (unemployment rate) differential between Scotland and the rest of the UK. The regional economy is assumed to have zero net migration in the base year and, ultimately, net migration flows re-establish this population equilibrium. We shall see that the specification of the relevant elasticities in this regional migration function is vital for the regional impact results of these simulations.

3.2 Simulation strategy

In each of the first thirty-five periods, the appropriate sectorally disaggregated installation, operation and refit expenditures are entered as exogenous shocks to final demand. The model is then run forward for a further 65 periods with no additional exogenous shocks. It is important to state that AMOSENVI is not a forecasting model. The economy is assumed to be initially in equilibrium so that if it runs forward with no exogenous shocks it simply replicates the base year values. The simulation results that we report here compare the simulation results with a constant base scenario in which there are no shocks to the model. All differences therefore, can be attributed solely to the direct or indirect effect of the positive demand disturbance.

Section 4: Central Case Scenario Results

Figure 4 gives the aggregate direct expenditure shocks, presented in Figure 3, together with the GDP results generated by the AMOSENVI model. In the period where the marine capacity built up is completed, 2020, the GDP increase is at its maximum value of £420.24 million. But note that the expansion in GDP is much lower than the increase in expenditure. This is primarily for two reasons. First, whilst all of the expenditure is on Scottish produced commodities, not all goes to Scottish GDP. Intermediate inputs produced outwith Scotland fail to contribute to Scottish GDP. Second, there will be crowding out in some sectors as the expansion in demand increases wages and the price of intermediate inputs. This leads to a loss of competitiveness and a fall in GDP in these sectors.

[Figure 4]

However, the steep drop in exogenous expenditure that occurs in 2021 is not accompanied by a correspondingly steep fall in GDP. GDP does decline, but by a relatively small amount, and it rises modestly in the second phase of activity up to 2029. After 2030, when refit expenditures cease and operational expenditures continue to decline, the GDP effects are actually greater than the direct expenditure impacts and these GDP effects continue after 2040 when the direct expenditures stop. Essentially these initial expenditures lead to an increase in factor supplies (of capital and labour) that have a subsequent “legacy” impact, an impact that remains even after the installation expenditures cease.

[Figure 5]

Figure 5 gives the simulation impacts on total employment generated by the introduction of the marine technology. The variation in total employment is qualitatively similar to the variation in GDP. We observe the same spike at 2020, where the employment increase equals fifteen and a half thousand jobs, prior to a gradual increase over the period 2021-2029 and the subsequent slow decline.

The change in working age population is also plotted in the same diagram.[7] It is important to be clear that this is a change in population brought about solely through increased net migration; we do not here model “natural” demographic changes. This positive net migration is a response to the tightening of the labour market. The absolute change in population is greater than the change in employment, though given the average participation rate, the unemployment rate falls until 2020. However, once the installation stage stops, the additional population (and work force) is a key factor in the subsequent legacy effects.

There are clear sectoral differences within this aggregate result which will reflect, among other things, the extent to which individual sectors are directly shocked by the demand injection, and the sectoral links to other sectors. There will be crowding out of activity, away from sectors not directly affected by the demand stimulus, while sectors experiencing the demand injections will experience increased output. Two key features of CGE models, such as AMOSENVI, are their generally high level of sectoral disaggregation and the active supply-side. Conventional macro-models have very limited sectoral disaggregation, whilst other sectorally disaggregated, but purely demand driven, modelling approaches, such as standard Input-Output (IO), cannot allow for crowding out effects.

Figures 6 and 7 give the evolution of output change in what we refer to as the “stimulated” and “non-stimulated” sectors respectively. The stimulated sectors are those that receive a direct exogenous demand stimulus as a result of the marine energy installation, operating and refit expenditures. Prices increase in these sectors, stimulating both output and also the return on capital and subsequent investment and therefore capital stock. The non-simulated sectors are subject to both positive and negative impacts that result from the expansion of the stimulated sectors. Whilst there are potential positive indirect and induced demand effects, there is also crowding out effects, especially in the labour market.

[Figure 6]

[7] The working age population is taken here to be all those between the age of 16 and 64.

[Figure 7]

It is clear that the three sectors primarily directly effected by the initial installation of the marine energy devices experience the biggest individual year output changes. These sectors are “Metal and Non-metal Goods”, “Transport and Other Machinery, Electrical and Instrument Engineering” and “Construction”. “Metal and Non-Metal Goods” record a 10% increase over base-year values in 2020 as a result of the creation of marine energy capacity.

For sectors that are not directly effected by the installation expenditure, the output effects are more muted and initially more varied. Figure 6 shows that by 2020, the impact on the majority of these sectors is small but negative. Again there is a spike in output at 2020 with a discontinuous adjustment for all sectors as the installation phase ends. However in the second phase of direct expenditures to 2030 the output of all non-directly stimulated sectors increases. After 2030 the output of some of these sectors begins to turn down but the majority are still increasing. By 2037 all non-directly stimulated sectors have an output greater than their base year value and this positive output relative to the base year remains the position for all these sectors, even when all the direct exogenous expenditures stop in 2040.

[Figure 8]

As we have argued already, a key factor driving the output results for the non-directly stimulated sectors is the changes in the wage. These real and nominal wage changes are charted for the central case scenario in Figure 8. Both the real and nominal aggregate wage rates increases in the first phase, between 2006 and 2020, as the marine energy capacity is installed. In the second phase, where operating and refitting remain, initially both the real and nominal wage fall, so that in 2021 the real wage is slightly below, and the nominal wage slightly above, the base year level. Up to 2030 both real and nominal wages are rising and both are above their base year levels at the end of this period. Between 2031 and 2040, as the operating expenditure gradually diminishes to zero, both nominal and real wage fall.

In those periods where there are significant exogenous expenditures (essentially up to 2030), there is generally upward pressure on wages and the increase in the nominal wage means that some exports are crowded out in order to facilitate the increase in installation and refit activity. However, once the direct expenditures stop in 2040, the lower nominal wage acts as a stimulus to the Scottish economy and it is primarily this that produces the large legacy effects.

Section 5: Sensitivity analysis

An advantage with using CGE models is that it is straightforward to test how sensitive the simulation results are to assumptions about functional form or key parameter values. This is especially useful when performing *ex ante* scenario analysis as we are here. In this section we investigate three aspects of the model in detail.

We have stressed in our central case scenario the importance of the legacy impacts that flow from the effect that the initial demand shock has on increasing the supply of labour and capital through the migration and investment functions. We measure the extent to which our results are changed if we vary the responsiveness of, firstly, migration and then investment to changes in Scottish economic activity. Finally, we consider the functional forms that have been adopted for the production structure. In particular, we remove the substitution possibilities and supply constraints from within the model and configure it as a standard demand driven dynamic Input-Output system. We compare the results from such a system and those derived from our central case scenario.

5.1 Varying migration sensitivity

One key characteristic of the central case scenario is the fact that increased wages and a lower unemployment rate generate positive net migration. The inflow of workers that occurs as a result of the demand stimulus associated with the marine energy exogenous expenditures ease supply constraints and act as a supply shock when these exogenous demand disturbances cease. The additions to the labour force are a major source of the legacy impacts that we have observed already. Here we quantify the impact of varying the strength of the migration effects.

The detailed specification of the migration equation used in the AMOS model is given in equation (1):

$$(1) \qquad \ln\left[\frac{m^S}{L^S}\right] = \varsigma - 0.08[\ln u^S - \ln u^R] + 0.06\left[\ln\left[\frac{w^S}{cpi^S}\right] - \ln\left[\frac{w^R}{cpi^R}\right]\right]$$

where m is net migration to Scotland, w is the nominal wage, u is the unemployment rate, cpi is the consumer price index, L is population, and ς is a constant, calibrated to ensure zero net migration (the equilibrium condition) for the base year data. The superscripts S and R indicate Scotland and the rest of the UK respectively.

The default coefficients on the relative real wage and unemployment terms are w=-0.08 and u=0.06 respectively and are taken from econometric work reported in Layard *et al*, (1991). We investigate the responsiveness of the results to the migration assumptions by varying these coefficients. We report three cases: a "medium scenario where we halve the coefficients in equation (1) to -0.04 and 0.03; a "low" scenario where the coefficients take the value –0.01 and 0.01 respectively; and a "migration off" scenario where the coefficients are reduced to zero. The reason for looking at lower values is that if the expenditures associated with the installation, operation and refit of the marine devices is seen as temporary, then the migration response might be more muted.

[Figure 9]

Figure 9 shows the change in population under the various migration scenarios. Remember that for the migration off case, there will be no change in population: this would be represented by a horizontal line along the x-axis. Note that the larger the wage and unemployment coefficients, the more sensitive migration is to these economic factors and so: the bigger the maximum impact on population change; the sooner that this maximum impact is attained; and the faster the population effects subside.

[Figure 10]

Figure 10 identifies the GDP changes under the various migration assumptions. The key point is the importance of migration for the size of the GDP effects. This is seen very clearly if we compare the figures from the central case and migration off simulations. A lack of positive net migration limits the GDP impacts of the first phase where marine capacity is being installed. However, the impact is relatively small because the build up of expenditure is rapid. The real differences in the GDP impacts occur in the period after 2020, where for the central case scenario population remains almost static, so that net migrants are retained, until 2030 and the additional labour force has important supply side impacts. In 2030, the GDP change over the base year value for the migration off simulation is just over a half the value for the central case scenario. Further from this point on, the ratio rapidly falls.

If we now match the central case simulation results with those for the medium and low migration coefficients, the comparison is less straightforward. As would be expected, for the period to 2020, lowering the migration coefficients results in smaller increases in population, and therefore also GDP and employment. This ranking of results for the main aggregate variables continues over the second and third periods, where direct operating and refit expenditures are still made. However, from period 2046 the population under the medium migration coefficients is greater than for the central case scenario and from 2049, GDP is higher too. A similar shift occurs in favour of the low migration coefficients around 2070. Within this range of parameter values we thus see a larger "legacy" impact when we make migration less responsive. This reflects the longer period over which population continues to increase, and the slower subsequent population decline, where the reaction of migration to changes in economic activity is more damped.

5.2 Varying investment sensitivity

We know from the zero net migration simulations reported in the last section that there are some legacy impacts, even where population is fixed. In the AMOSENVI model these additional effects operate through changes in the capital stock. However, the effect on GDP of any given proportionate change in capital stock will be less than an equal proportionate change in employment. This is because the share of labour in GDP is much greater than the share of capital. Also in the AMOSENVI model changes in capital stock are industry specific. Therefore the impact of a demand expansion focussed on specific industrial sectors will expand capacity in those sectors but the capital stock in other sectors might be little changed or might even fall if these sectors are adversely affected by crowding out effects in the labour or product markets.

[Figure 11]

As an example, Figure 11 shows the proportionate changes in capital stock, as against the base year values, for the AMOSENVI sectors in 2020. This is at the end of the period of accelerating installation activity. Note that the increase in capacity in the sectors directly receiving investment expenditures, and especially sector 10 “Metal and Non-metal Goods”, is sizeable. However, the impact on other sectors is small and in the majority of cases negative. Although the increase in the real wage would lead to some substitution of capital for labour, this is dominated by the fall in value added output in most sectors as a result of crowding out.

[Figure 12]

Figure 12 shows the sensitivity of the GDP figures to changes in the investment speed of adjustment parameter. This is the proportional adjustment to the difference between the actual and desired capital stock discussed in Section 3.1. The default value we use for the central case simulations is 0.3. In Figure 12 we compare the central case GDP results with those where the speed of adjustment parameter is increased to 0.5. As we expect, the GDP impacts in those periods where there are direct exogenous expenditures are greater for the more rapid capital adjustment. The economy responds more rapidly to reduce the capacity constraints generated by the demand injection. However, as with the migration results, the legacy impacts are increased where the adjustment speeds are lower.

5.3 Dynamic Input-Output

As we state in Section 3.1, in the AMOSENVI model, production in each sector is modelled as a multi-level production function, where at most junctures the relationship is of a constant elasticity of substitution (CES) form. This makes the choice of technique responsive to relative-price changes. We also impose a fixed capital stock in each time period in the production of the sector's value added, and a wage determined through bargaining at the aggregate level. In this section we compare the output under our central case scenario with that where we remove supply side flexibility and constraints. Essentially we configure the model as a dynamic extended Input-Output system.

This is done through imposing fixed coefficients at all levels of the production function, removing any capacity constraints in the production of value added and imposing a fixed real wage closure in the labour market. This means that demand in any sector can be met at the existing price. The model becomes completely demand driven. We have also retained the same investment function, so that, although output is not constrained by capacity in the short run, capital stock adjusts over time. We also retain the migration function, now solely driven by changes in the unemployment rate. It is useful to compare our central case model output with that of the dynamic Input-Output (IO) system, as it is such kinds of demand driven model that would typically be used in the UK to identify the aggregate impact of this type of exogenous expenditure injection.

[Figure 13]

Figure 13 gives the time path for the change in GDP under our central case scenario on the same diagram as the Input-Output results. Note that with the IO model, the initial change in GDP is much greater: in 2020, the GDP change for the extended dynamic IO system is three times that given by the central case scenario. No supply constraints operate to limit the expansion of the directly and indirectly stimulated sectors. Similarly there are no cost changes to generate crowding out effects. In 2020, the extended dynamic IO system gives an increase in GDP three times the value of that under the central case scenario.

However, by the same token, the IO model reacts strongly to the subsequent reductions in the exogenous expenditure associated with the introduction of the marine energy devices. For the period 2021 to 2030 the aggregate IO results are close (but a little above) the AMOSENVI figures. But after 2030 the IO model suggests a rapid decline in GDP, towards the base year value. After the operating expenditures finish in 2040 there is almost no activity change recorded by the IO model.[8] Contrast this with AMOSENVI's much more even path of GDP changes and extensive legacy effects that continue for another half century.

5.4 Present value of main aggregate impacts

In Table 2 we sum the GDP effects over time for the simulations that we have discussed in this section. We give the totals over the 100-year time period for which each simulation was run. We also break down that 100 years into 3 sub-periods: these are 2006-2020, the period where installation takes place; 2021-2040, when refitting and operational expenditures continue; and 2040+ where there are no remaining exogenous expenditure injections.

We give the figures undiscounted and discounted. Where we discount, we follow the discount rate suggested by the Green Book (HM Treasury, 2003) in using a real discount rate of 3.5% for the first 30 periods, falling to 3.0% for the next 45 periods and then 2.5% from periods 76 to 100. This discount rate is intended to reflect social time preference, in that society as a whole will "prefer to receive goods and services sooner rather than later, and to defer costs to future generations" (HM Treasury, 2003).

If we look initially at the totals, it is clear that the introduction of a marine energy sector in the Scottish economy would generate a significant stimulus to GDP over a long period of time. For the undiscounted central case scenario this is over £14 billion. Further this figure is not very sensitive to changes in migration and investment assumptions: the medium migration figure is less than 2% lower and the

[8] The small effects that there are come from residual capital and population adjustments impacting on investment demand and consumption demand through household income.

high investment total less than 1% higher. However, the impact is clearly affected by larger changes in migration and the migration off simulation generates a total increase in GDP that is less than a half of the central case figure. Finally the dynamic IO aggregate GDP result is close to the central case outcome.

When we look at the total figures discounted, the results change, not only in terms of the absolute size but also the qualitative relationship between the different simulations. Discounting gives greater weight to the results in the earlier years so that simulations that deliver GDP earlier are relatively favoured. This means that the present value of the GDP stream is maximised under the dynamic IO model. This is perhaps to be expected as in this model there are no supply constraints, the response to the initial installation expenditures is strong but the legacy effects are minimal. The GDP benefits are very much loaded here towards the early period. However, the high investment simulation also gives a relatively large effect and the difference between the alternative migration simulations is magnified.

If we compare the time sequence of effects across the different simulations, these observations are extended and reinforced. For all simulations, the undiscounted cumulative GDP impact over the twenty-year period 2021-2040 is greater than the impact over the fifteen-year period 2006-2020 when the installation expenditures occur. This is even the case with the dynamic IO simulation. Second, only for the migration off and the dynamic IO simulations are the undiscounted legacy effects, that is those that occur after 2040, lower than the impacts in the initial, installation period. Third, when we discount, the value of the legacy effects are reduced but they remain important in most cases. For example, in the central case scenario, discounted legacy effects make up just under 20% of the total discounted impacts.

Section 6: Conclusions and policy recommendations

Electricity generation in the UK will undergo considerable changes over the next twenty years. There will be increased generation from renewable sources, especially wind (both on and off-shore), but also wave and tidal technologies, as incentive schemes make these technologies economically viable. The installation of 3GW of wave energy capacity around the coast of Scotland is technically possible

(Boehme *et al*, 2006), but would require significant expenditures across a range of sectors involved in the construction, installation, operation and maintenance of the large numbers of wave energy devices required. In this paper we have sought to quantify the macroeconomic impact that these expenditures could have on Scotland over the operating lifetime of the introduction of 3GW capacity in this sector.

We find that these expenditures can potentially deliver a significant economic benefit to the region. The present value of GDP changes on the basis of the central case scenario is £5,466.2 million. This additional Scottish GDP is not only created over the lifetime of the investment, but continues for many years into the future, partly due to the positive net migration and additional investment into Scotland which accompanies the extra expenditures. This positive boost to GDP also has associated employment effects.

It should be mentioned that these results are based upon the assumption of an upper bound unit electricity value of 8.5p/kWh, which might not be realised. Further, the sub-division of investment between energy sectors is only indicative of the type of wave energy device considered here, and a different breakdown between sectors will be applicable for different types of devices.

These results are important for policy makers. If Scotland is able to use the potential that marine power has for electricity generation, this will not only be beneficial environmentally but also will give a positive boost to Scottish GDP, employment and population. This boost will be larger the more integrated the marine energy sector is into the local economy: i.e. the greater the proportion of locally sourced installation, operation and refit expenditures, the greater the positive impact on Scotland. Failure to establish a technical knowledge base in Scotland could result in the elements produced in Scotland consisting of the low-value generic engineering components only, and the importing of the high value elements requiring considerable engineering knowledge.

Also, it is apparent that in appraising the impact of a project in an open regional economy, one should consider not only the period over which the direct expenditures or activities related to that project are made, but also look beyond that horizon to the longer term. Essentially positive net migration and additional investments made directly or indirectly in response to the project produce supply-side effects that can be very long lasting. In a CGE context this has been investigated in the context of sporting events in Madden (2002). If we compare our central case scenario as against the dynamic IO model, the kind of model that would typically be used to identify the wider impacts of an exogenous demand injection, we observe a much smoother time path. Whilst the simulated initial impacts are much lower with the AMOSENVI model, the effects continue for much longer.

References

Allan, G.J., McGregor, P.G., Swales, J.K. and Turner, K.R. (2006a), “The impact of different electricity generation technologies on the Scottish economy: an illustrative input-output analysis”, Strathclyde Discussion Papers in Economics, No. 06-02, March 2006

Allan, G.J., Hanley, N., McGregor, P.G., Swales, J.K. and Turner, K.R. (2006b), The macroeconomic rebound effect and the UK economy, Final report to the Department of Environment Food and Rural Affairs, May 2006

Blanchflower, D.G. and Oswald, A.J. (1994), *The wage curve*, Cambridge, Massachusetts

Boehme, T., Taylor, J., Wallace, R. and Bialek, J. (2006), “Matching renewable electricity generation with demand”, academic study for the Scottish Executive by the University of Edinburgh, February 2006

The Carbon Trust (2006) “Future Marine Energy, Results of the Marine Energy Challenge: Cost competitiveness and growth of wave and tidal stream energy.” The Carbon Trust

Department of Trade and Industry (2006), “The energy challenge: Energy review report 2006”, Presented to Parliament by the Secretary of State for Trade and Industry, Cm 6887, July 2006

Ferguson, L., Learmonth, D., McGregor, P.G., McLellan, D., Swales, J.K. and Turner, K.R. (2004), “The national impact of regional policy: policy simulation with labour market constraints in a two-region computable general equilibrium model”, Strathclyde Discussion Papers in Economics, No. 04-20

Forum for Renewable Energy Development in Scotland (FREDS) (2005), “Scotland’s Renewable Energy Potential: realising the 2020 target”, Scottish Executive, online at http://www.scotland.gov.uk/Resource/Doc/69582/0017404.pdf

Garrad Hassan (2001), “Scotland’s renewable resource 2001”, Scottish Executive, Volume 1, online at http://www.scotland.gov.uk/Resource/Doc/47176/0014634.pdf

Hanley, N., McGregor, P.G., Swales, J.K. and Turner, K.R. (2006), “The impact of a stimulus to energy efficiency on the economy and the environment: a regional computable general equilibrium analysis”, Renewable Energy, Vol. 31, p161-171

Harrigan, F., McGregor, P.G., Dourmashkin, N., Perman, R., Swales, J.K. and Yin, Y.P. (1991), “AMOS: A micro-macro model of Scotland”, Economic Modelling, Vol. 8, p424-479

Harris, J.R. and Todaro, M. (1970), “Migration, unemployment and development: a two-sector analysis”, American Economic Review, Vol. 60, p126-142

HM Treasury (2003), *Green Book, Appraisal and Evaluation in Central Government*, online at http://greenbook.treasury.gov.uk/

Layard, R., Nickell, S. and Jackman, R. (1991), *Unemployment – Macroeconomic Performance and the Labour Market*, Oxford University Press, Oxford

Madden, J.R. (2002), “The economic consequences of the Sydney Olympics: the CREA/Arthur Andersen Study”, *Current Issues in Tourism*, Vol. 5, No. 1, p7-21

Ocean Power Delivery (2006), “World first wave farm – Shipping of first machine to Portugal”, Press release 14th March 2006, online at http://www.oceanpd.com/docs/OPD%20ships%20first%20machine%20to%20Portugal.pdf

Previsic, M., Bedard, R., Hagerman, G. and Siddiqui, O. (2004), “System level design, performance and costs for San Francisco Pelamis Offshore Wave Power Plant”, report by Global Energy Partners, Electricity Innovation Institute and EPRI

Royal Society of Edinburgh (2006), RSE Committee of Inquiry into Energy Issue for Scotland, Final report, June 2006, online at http://www.royalsoced.org.uk/enquiries/energy/full_report.pdf

Scottish Executive (2003), "Securing a Renewable Future: Scotland's Renewable Energy. 2003, online at http://www.scotland.gov.uk/Resource/Doc/47034/0014765.pdf

Scottish Executive (2005), "Future of renewable energy mapped out", Press release 22nd July 2005, online at http://www.scotland.gov.uk/News/Releases/2005/07/22150102

Scottish Executive (2006), "Consultation on Review of ROS (Support for Wave and Tidal Power) 2006", online at http://www.scotland.gov.uk/Resource/Doc/115084/0028289.pdf

Sustainable Development Commission (2006), "The Economics of Nuclear Power – Nuclear Paper 4", March 2006, online at http://www.sd-commission.org.uk/publications/downloads/Nuclear-paper4-Economics.pdf

Appendix 1: The sectoral breakdown in the AMOSENVI model

		Industrial Order Classification
1	Agriculture	1
2	Forestry planting and logging	2.1, 2.2
3	Fishing	3.1
4	Fish farming	3.2
5	Other mining and quarrying	6, 7
6	Oil and gas extraction	5
7	Manufacturing - Food, drink and tobacco	8 to 20
8	Manufacturing - Textiles and clothing	21 to 30
9	Manufacturing - Chemicals etc	36 to 45
10	Manufacturing - Metal and non-metal goods	46 to 61
11	Manufacturing - Transport and other machinery, electrical and instrument engineering	62 to 80
12	Other manufacturing	31 to 34, 81 to 84
13	Water	87
14	Construction	88
15	Distribution	89 to 92
16	Transport	93 to 97
17	Communications, finance and business	98 to 107, 109 to 114
18	Research and Development	108
19	Education	116
20	Public and other services	115, 117 to 123
	Energy	
21	Coal (extraction)	4
22	Oil (refining and distribution) and nuclear	35
23	Gas	86
	Electricity	85
24	Renewable (hydro and wind)	
25	Non-Renewable (coal, nuke and gas)	

Appendix 2: A condensed version of AMOSENVI

Equations	Short run
(1) Gross Output Price	$pq_i = pq_i(pv_i, pm_i)$
(2) Value Added Price	$pv_i = pv_i(w_n, w_{k,i})$
(3) Intermediate Composite Price	$pm_i = pm_i(pq)$
(4) Wage setting	$w_n = w_n\left(\frac{N}{L}, cpi, t_n\right)$
(5) Labour force	$L = \bar{L}$
(6) Consumer price index	$cpi = \sum_i \theta_i \; pq_i + \sum_i \theta_i^{RUK} \; \bar{pq}_i^{RUK} + \sum_i \theta_i^{ROW} \; \bar{pq}_i^{ROW}$
(7) Capital supply	$K_i^s = \bar{K}_i^s$
(8) Capital price index	$kpi = \sum_i \gamma_i \; pq_i + \sum_i \gamma_i^{RUK} \; \bar{pq}_i^{RUK} + \sum_i \gamma_i^{ROW} \; \bar{pq}_i^{ROW}$
(9) Labour demand	$N_i^d = N_i^d(V_i, w_n, w_{k,i})$
(10) Capital demand	$K_i^d = K_i^d(V_i, w_n, w_{k,i})$
(11) Labour market clearing	$N^s = \sum_i N_i^d = N$
(12) Capital market clearing	$K_i^s = K_i^d$
(13) Household income	$Y = \Psi_n N w_n (1 - t_n) + \Psi_k \sum_i w_{k,i}(1 - t_k) + \bar{T}$
(14) Commodity demand	$Q_i = C_i + I_i + G_i + X_i + R_i$

App. 1. (cont.) Equations	Short run
(15) Consumption Demand	$C_i = C_i\left(pq_i, \overline{pq}_i^{RUK}, \overline{pq}_i^{ROW}, Y, cpi\right)$
(16) Investment Demand	$I_i = I_i\left(pq_i, \overline{pq}_i^{RUK}, \overline{pq}_i^{ROW}, \sum_i b_{i,j} I_j^d\right)$ $I_j^d = h_j\left(K_j^d - K_j\right)$
(17) Government Demand	$G_i = \overline{G}_i$
(18) Export Demand	$X_i = X_i\left(p_i, \overline{p}_i^{RUK}, \overline{p}_i^{ROW}, \overline{D}^{RUK}, \overline{D}^{ROW}\right)$
(19) Intermediate Demand	$R_{i,j}^d = R_i^d\left(pq_i, pm_j, M_j\right)$ $R_i^d = \sum_j R_{i,j}^d$
(20) Intermediate Composite Demand	$M_i = M_i\left(pv_i, pm_i, Q_i\right)$
(21) Value Added Demand	$V_i = V_i\left(pv_i, pm_i, Q_i\right)$
(22) Pollutants (output-pollution coefficient)	$POL_k = \sum_i \phi_{i,k} Q_i$
(23) Pollutants (CO_2)	$POL_{CO2} = \sum_i \left[\sum_j (e_{i,f} \cdot f_{i,f}) + (g_i . \kappa_i) + h_i \right] Q_i$
Multi-period model	**Stock up-dating equations**
(24) Labour force	$L_t = L_{t-1} + nmg_{t-1}$
(25) Migration	$\frac{nmg}{L} = nmg\left(\frac{w_n(1-t_n)}{cpi}, \frac{w_n^{RUK}(1-t_n)}{cpi^{RUK}}, u, u^{RUK}\right)$
(26) Capital Stock	$K_{i,t} = (1-d_i)K_{i,t-1} + I_{i,t-1}^d$

NOTATION

Activity-Commodities

i, j are, respectively, the activity and commodity subscripts (There are twenty-five of each in AMOSENVI).

Transactors

RUK = Rest of the UK, ROW = Rest of World

Functions

pm (.), pq(.), pv(.)	CES cost function
k^S(.), w(.)	Factor supply or wage-setting equations
K^d(.), N^d(.), R^d(.)	CES input demand functions
C(.), I(.), X(.) functions,	Armington consumption, investment and export demand homogenous of degree zero in prices and one in quantities

Variables and parameters

C	consumption
D	exogenous export demand
G	government demand for local goods
I	investment demand for local goods
I^d	investment demand by activity
K^d, K^S, K	capital demand, capital supply and capital employment
L	labour force
M	intermediate composite output
N^d, N^S, N	labour demand, labour supply and labour employment
Q	commodity/activity output
R	intermediate demand
T	nominal transfers from outwith the region
V	value added
X	exports

Y	household nominal income
$\mathbf{b_{ij}}$	elements of capital matrix
cpi, kpi	consumer and capital price indices
d	physical depreciation
h	capital stock adjustment parameter
nmg	net migration
pm	price intermediate composite
pq	vector of commodity prices
pv	price of value added
$\mathbf{t_n, t_k}$	average direct tax on labour and capital income
u	unemployment rate
$\mathbf{W_n, W_k}$	price of labour to the firm, capital rental
Ψ	share of factor income retained in region
θ	consumption weights
γ	capital weights
$\mathbf{POL_k}$	quantity of pollutant k (output-pollution approach)
$\mathbf{POL_{CO2}}$	quantity of CO_2
ϕ_{ik}	output-pollution coefficients
$\mathbf{e_{ij}}$	fuel use emissions factors
$\mathbf{f_{ij}}$	fuel purchases
$\mathbf{g_i}$	import emissions factors
κ_i	import purchases
δ_i	process output-pollution coefficients

Figure 1: Cumulative total number of devices and annual number of devices installed, 2000 to 2020

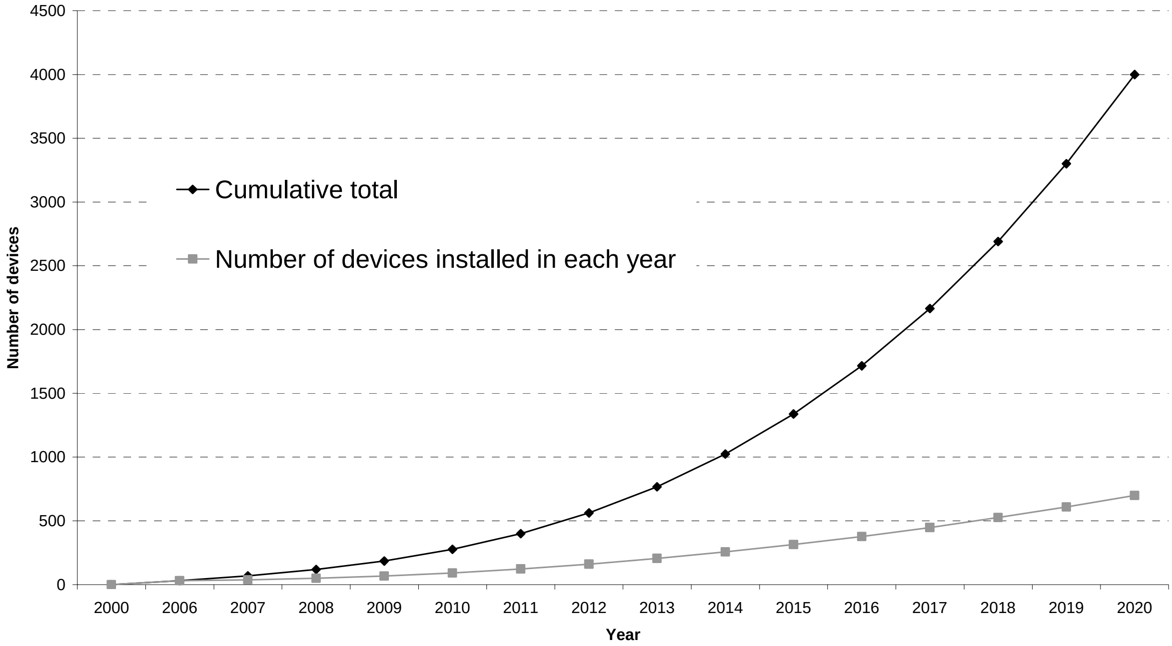

Figure 2: Timetable of planned expenditures

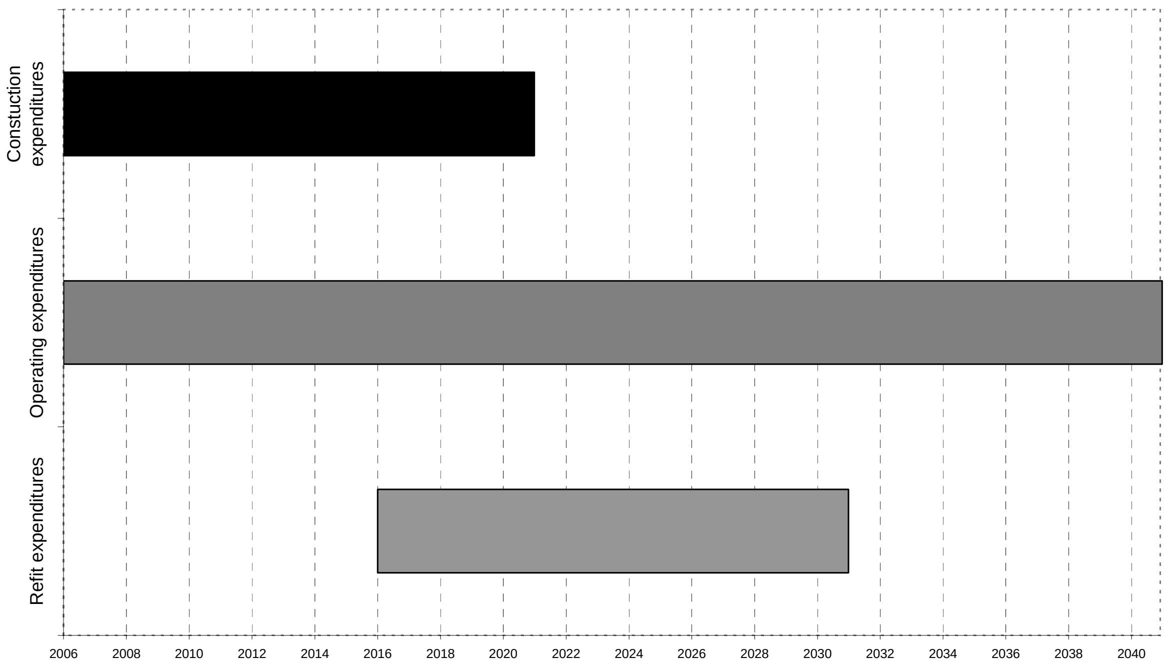

Figure 3: Total annual expenditures in Scotland under central case scenario, £millions

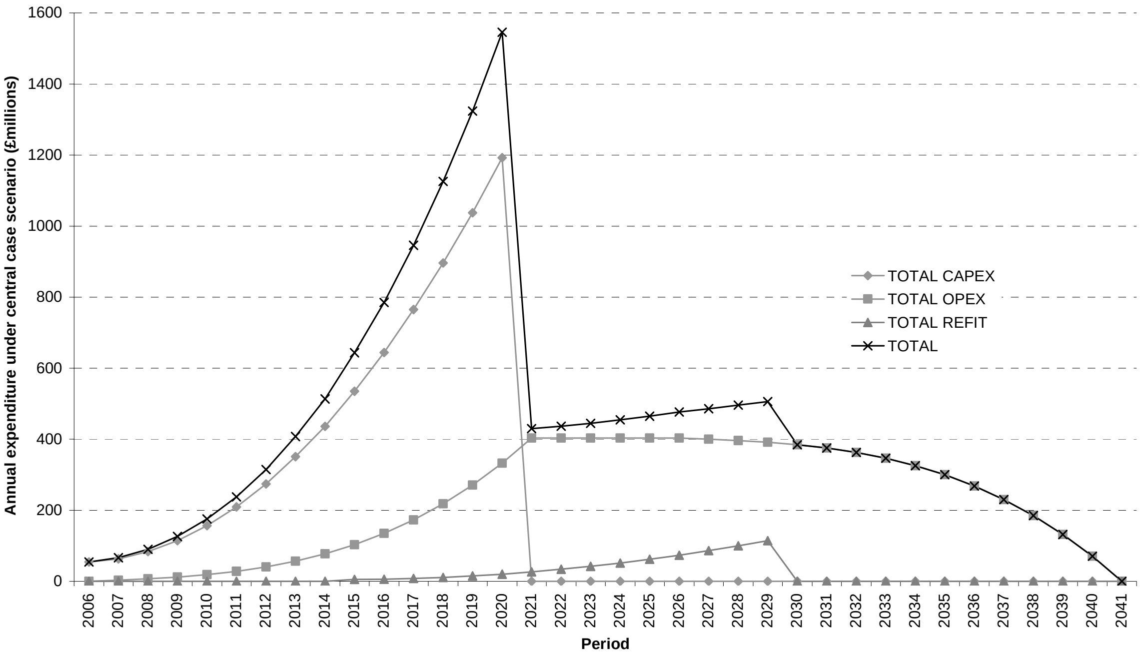

Table 1: Installation expenditure categories, shares and industrial sectors

Expenditure category	*Expenditure share*	*Industrial sector*	*SIC*	*AMOSENVI sector*	*Scottish share*
Onshore transmission and grid upgrade	1%	Electric motors and generators	31	11	75%
Undersea cables	5%	Electric motors and generators	31	11	75%
Spread mooring	10%	Structural metal products	28.1	10	75%
Power conversion module	51%	Mechanical power transmission equipment	29.1	11	50%
Concrete structures	20%	Articles of concrete	26.6	10	95%
Construction facilities	5%	Structural metal products	28.1	10	95%
Installation	4%	Construction	45	14	95%
Construction management	5%	Architectural activities	74.2	17	90%
Total	100%				

Figure 4: Absolute differences in GDP from base and expenditures, £millions

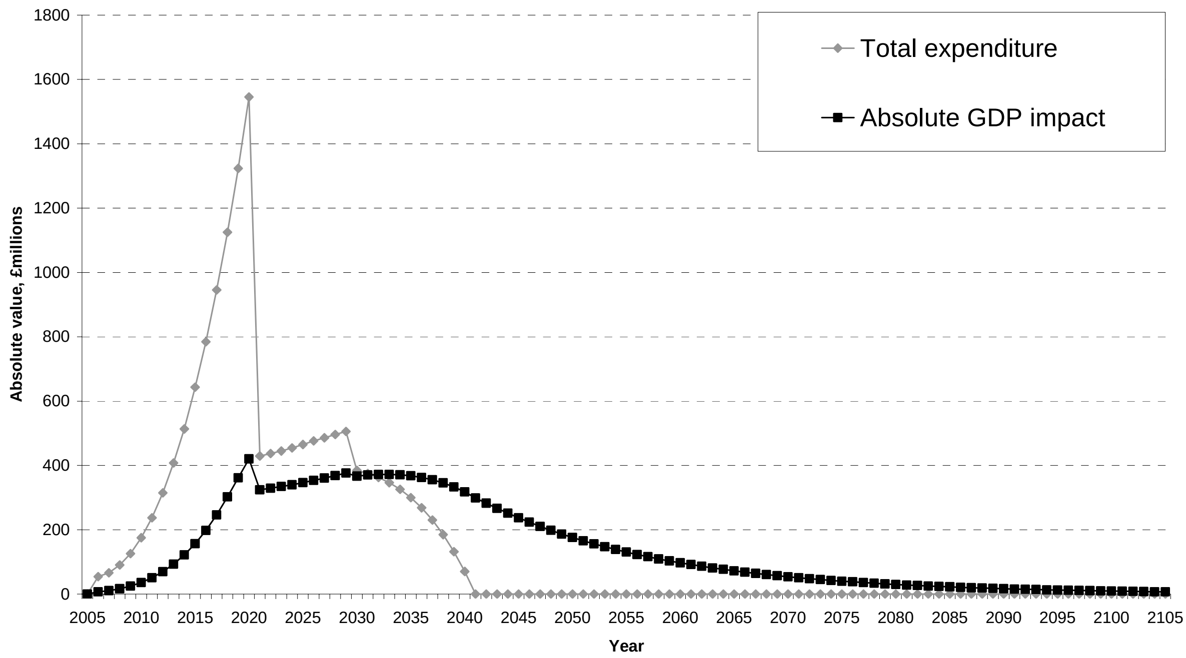

Figure 5: Absolute differences in employment and change in working age population

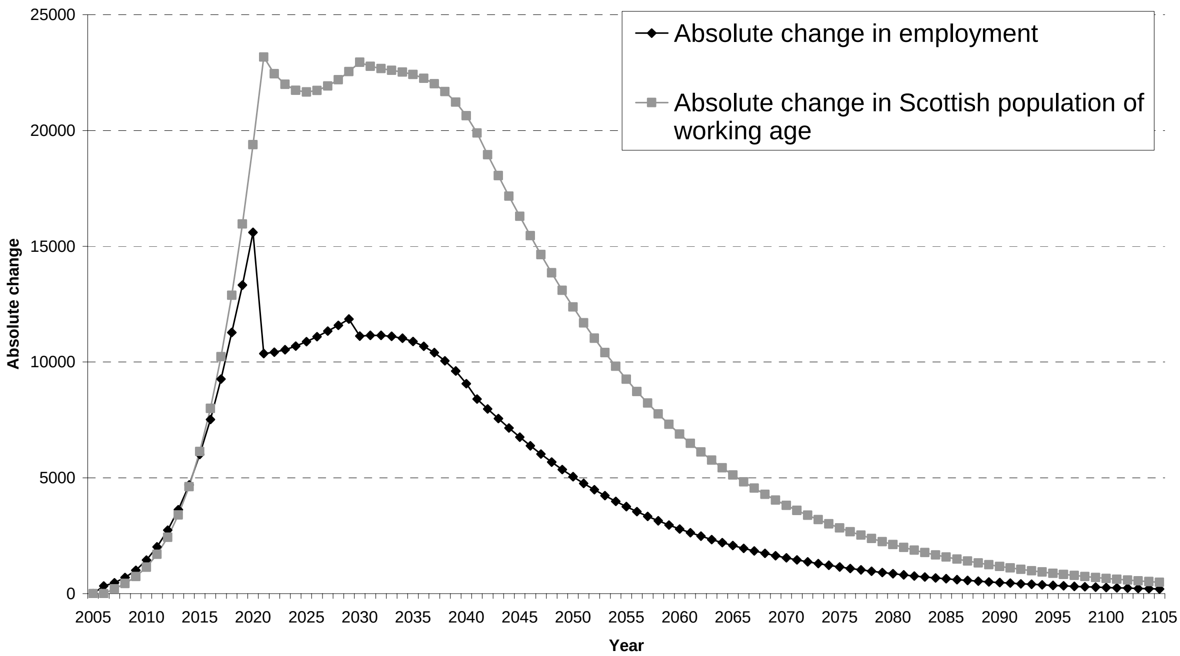

Figure 6: Sectoral changes in output in stimulated sectors, % differences from base

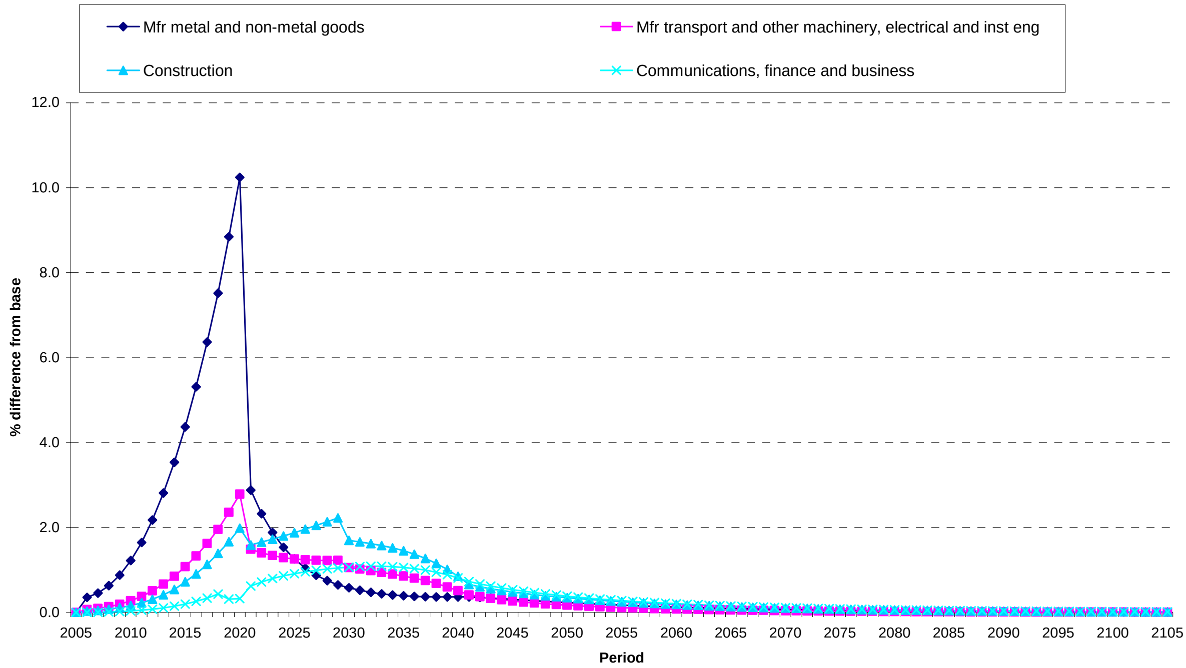

Figure 7: Sectoral changes in output in non-stimulated sectors

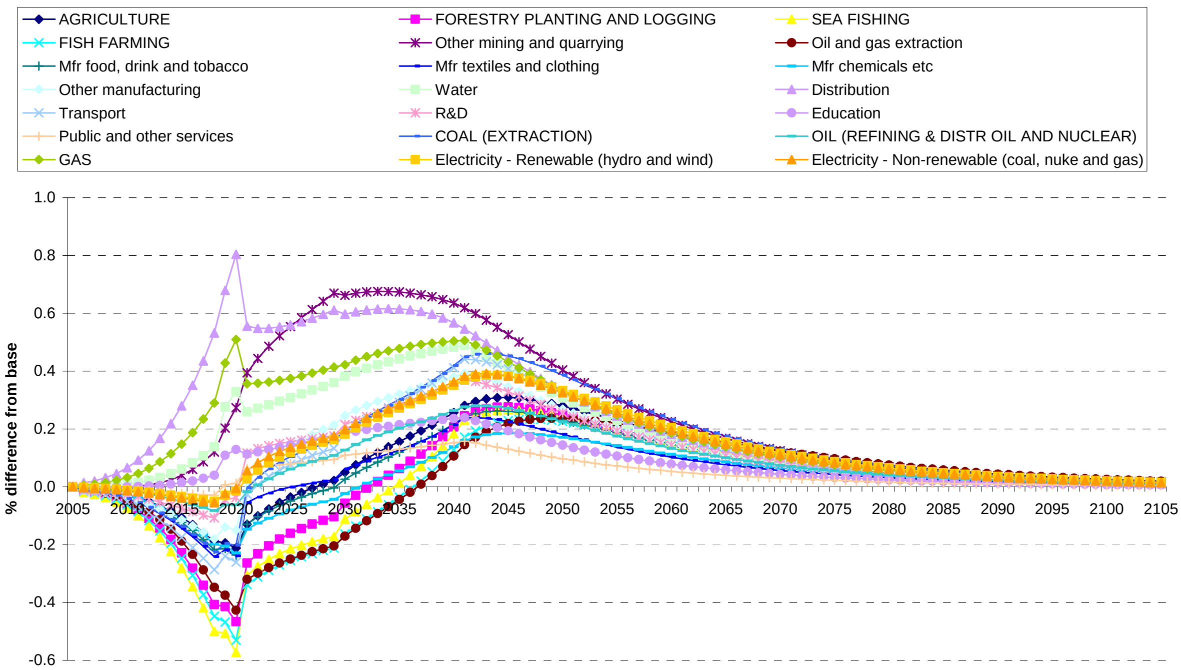

Figure 8: Real and nominal wage values in central case, % change from base

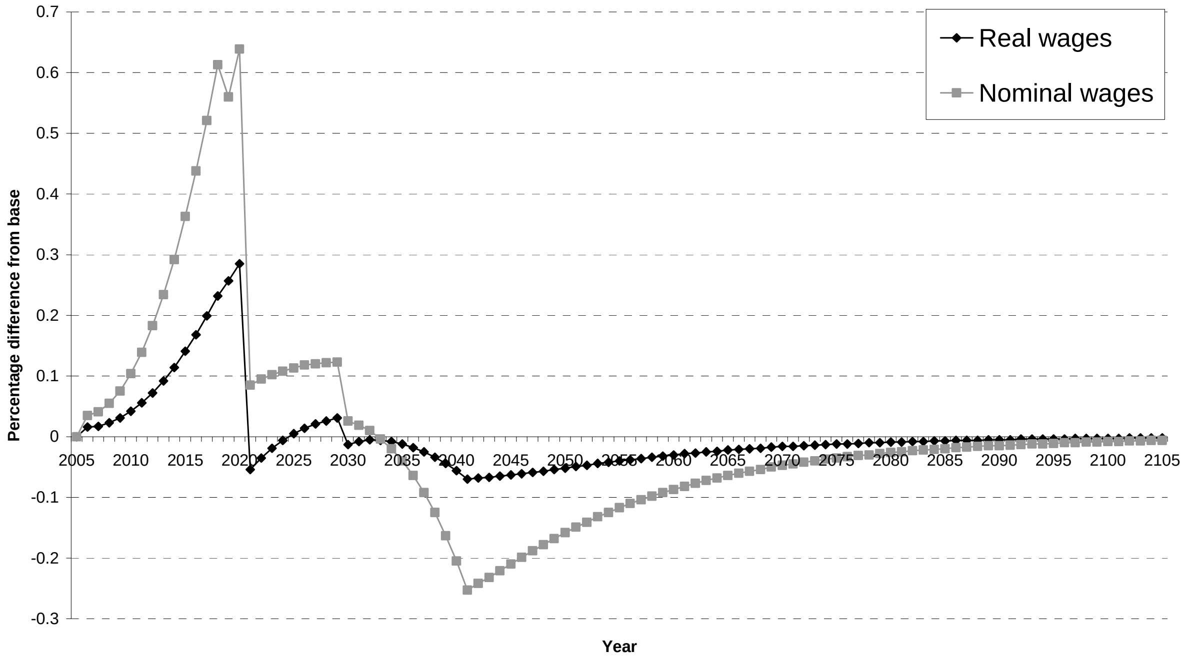

Figure 9: Population in Scotland in central case and with medium and low migration elasticities, percentage difference from base period

Figure 10: Absolute GDP impact for the central case against the medium, low and zero migration scenarios

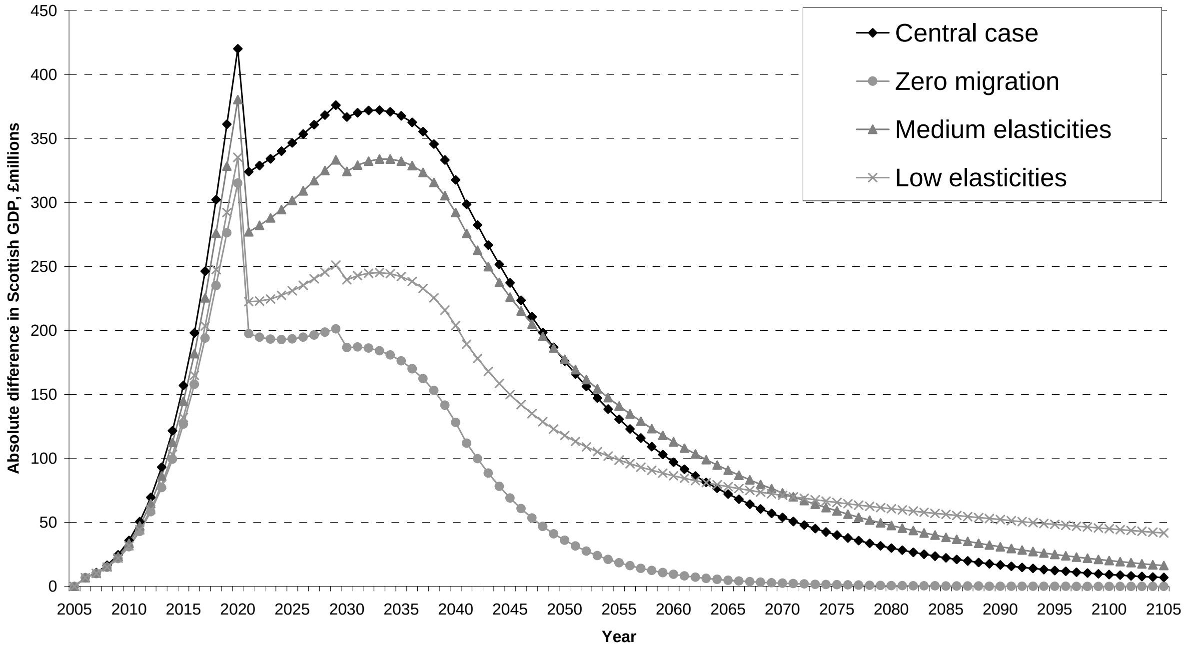

Figure 11: Percentage difference in sectoral capital stock in period 15 relative to base period

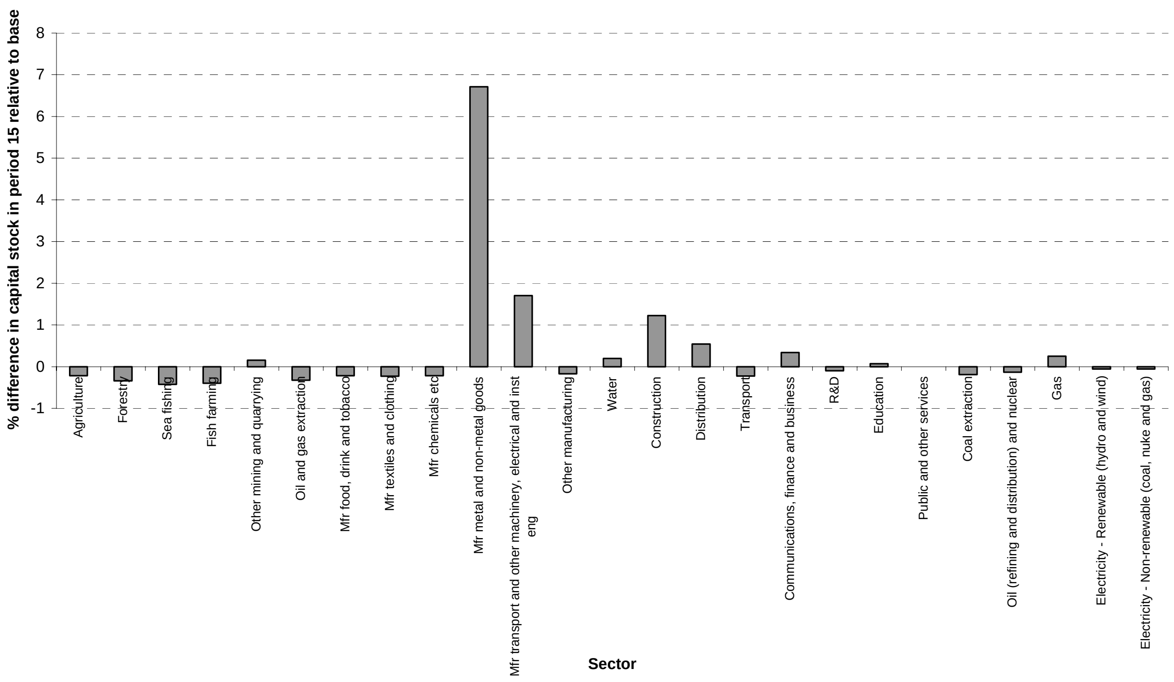

Figure 12: Absolute GDP effect, central case and with high speed of capital adjustment

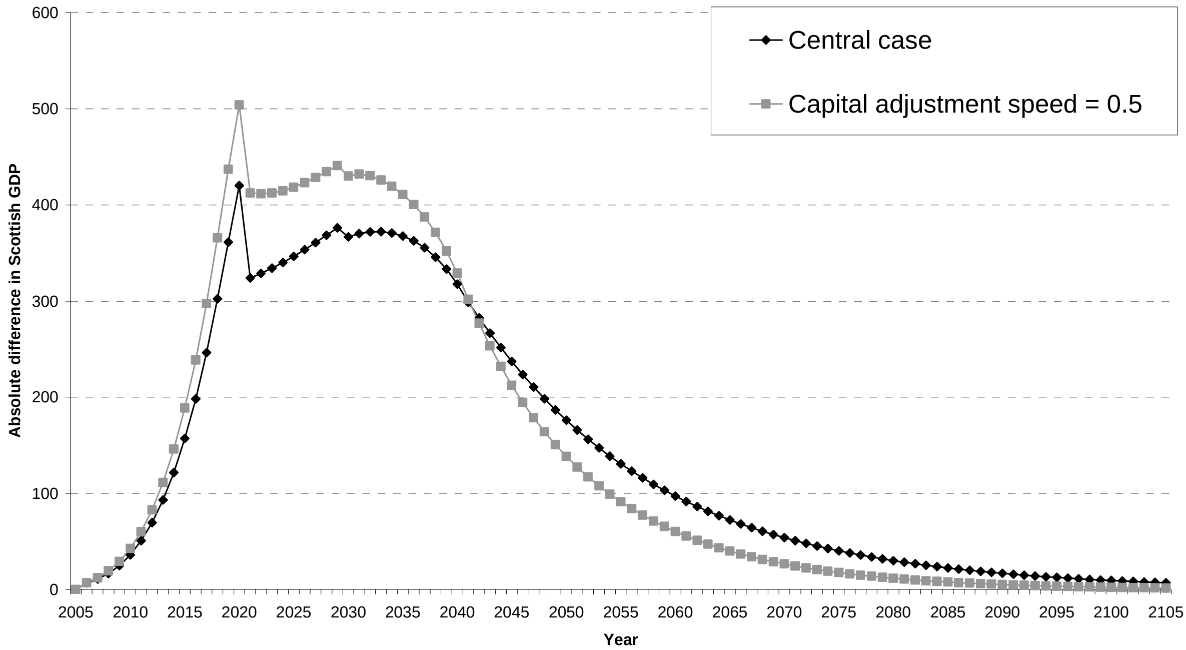

Figure 13: Absolute GDP effect, central case and with Dynamic Input-Output system

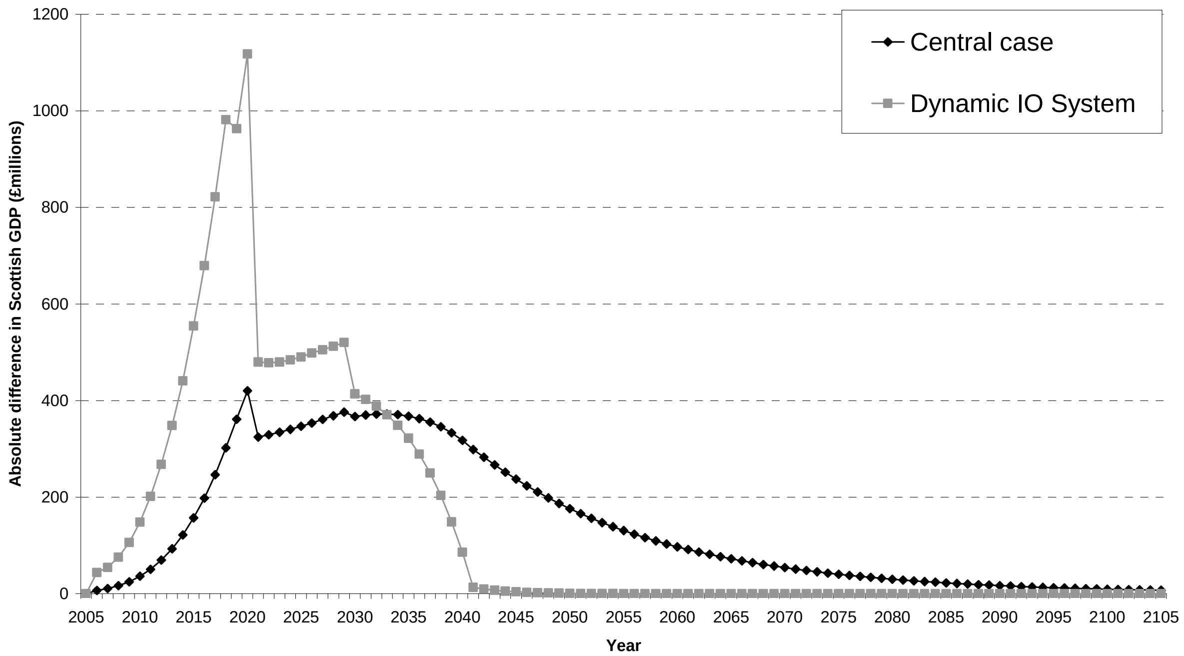

Table 2: Comparison of GDP impacts for central case plus sensitivity simulations

	GDP (£millions)				*Discounted GDP (£millions)*			
Period	*2006-20*	*2021-40*	*2041+*	*Total*	*2006-20*	*2020-40*	*2040+*	*Total*
Central case	2,115.3	7,067.1	5,110.1	14,292.6	1,416.8	2,997.8	1,051.6	5,466.2
Medium migration	1,938.2	6,280.5	5,816.8	14,035.4	1,299.8	2,653.2	1,113.9	5,067.0
Low migration	1,749.2	4,677.0	5,156.6	11,582.8	1,175.7	1,989.0	861.5	4,026.2
Migration off	1,667.7	3,620.2	938.0	6,225.9	1,122.4	1,565.5	231.7	2,919.7
High investment	2,542.6	8,186.2	3,689.5	14,418.3	1,701.6	3,506.5	828.6	6,036.7
Dynamic IO	6,805.4	7,670.0	49.6	14,525.0	4,633.5	3,439.7	13.7	8,086.9

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