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# The Importance of the Regional/Local Dimension of Sustainable Development: An Illustrative Computable General Equilibrium Analysis of the Jersey Economy[1]

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***Abstract:*** This paper uses a multi-period economic-environmental Computable General Equilibrium (CGE) modelling framework to analyse local sustainability policy issues. Our focus is the small, open, labour-constrained regional economy of Jersey. The case of Jersey is of particular interest for two main reasons. The first is the unusually low degree of geographical labour market integration for such a small regional economy. This motivates our treatment of labour as a region-specific factor of production. The second is the availability of high quality, Jersey-specific economic-enviromental data. We employ CGE model simulations to track the impact of changes in population on a number of energy-consumption and pollution indicators in a recursive dynamic framework under alternative hypotheses regarding economic conditions over the time period under consideration. In the case of Jersey, we find that household consumption is the key factor governing the environmental impact of economic disturbances. Therefore the analysis includes an examination of the sensitivity of the simulation results to different assumptions affecting the wage elasticities of labour demand and supply, and the speed of adjustment to equilibrium on the responsiveness of household income to shifts in labour supply.

**JEL classification:** D58, Q56, R13, R23

**Key words:** regional CGE modelling, population, environment

## 1. Introduction

The 'Rio Declaration' and Agenda 21 agreements of the 1992 Earth Summit (United Nations, 1992) stimulated considerable interest in modelling the impact of economic activity on indicators of sustainability and assessing the economic costs of reducing that impact.[2] While the problems of sustainability in general, and climate change in particular, are inherently global, a number of sub-global models have been developed to examine these issues. Many of these models have been constructed for national or regional economies that are small relative to the rest of the world, even though the impact on global sustainability of any change in activity in such target economies is likely to be trivial.

One of the reasons for modelling sustainability issues in a small economy context arises from commitments to international agreements such as the Kyoto Protocol on reducing $CO_2$ emissions. These commitments place constraints on economic activity at the national or regional level. Modelling the impacts of national policies to reduce $CO_2$ emissions has been tackled at the national level by Bergman (1990, 1991), Stephan *et al* (1992) and Böhringer and Rutherford (1997) and at the sub-national level by Conrad and Schröder (1991, 1993), Li and Rose (1995) and Kamat *et al* (1998).

A second reason is that, even if the concern is solely with global sustainability, in many countries, regional authorities have sufficient discretion over aspects of economic and environmental policy to ensure that national policies can only be delivered with their co-operation.

[2] For example, shortly after the Earth Summit, the OECD Model Comparisons Project examined the properties and predictions of GREEN, a multi-region global CGE model (Burniaux *et al*, 1992), and five other global models in assessing the economic and environmental costs and benefits of various programmes to reduce international $CO_2$ emissions (Dean and Hoeller, 1992).

In fact, one of the key elements of the Agenda 21 framework is the understanding that because many sustainability problems and solutions "have their roots in local activities, the participation and co-operation of local authorities will be a determining factor in fulfilling its [Agenda 21] objectives" (United Nations, 1992, p.233). In the case of the UK, a significant degree of responsibility for setting and achieving sustainability objectives has been devolved to the Scottish Parliament, the National Assembly for Wales and the English Regional Development Agencies.

Finally, for sub-national levels of government, sustainability objectives are likely also to reflect a wider concern for quality of life values that apply to the local economy, rather than indicators that feature in global sustainability debates. For example, there may be fears for the impact on local public health from pollution generation, even if the type or level of emissions does not conflict with any international agreements to which the nation or region is a party.

We use the Jersey economy to illustrate the importance of the local/regional dimension of sustainability. Jersey is the largest of the Channel Islands, situated about 100km south of the British mainland. It is a crown dependency of the United Kingdom and its economy is very closely integrated with that of the UK, sharing its language, currency and interest rates. The choice of Jersey is partly motivated by the availability of a comprehensive region-specific, economic-environmental database that is at present unique within the UK. However, there are also specific characteristics of the Jersey economy which make it of particular interest.

Jersey is an independent self-governing state. It therefore represents the limiting case of what is effectively a regional economy with full fiscal autonomy and considerable latitude to pursue its own local sustainability policies. Moreover, the current policy climate in Jersey exhibits the wider emphasis on the local, as opposed to global, perspective to sustainability that characterises most small economies. The Jersey economy is distinctive in that it has a labour market that is both very tight - with an unemployment rate of less than 1% - and also unusually weakly integrated with other regional labour markets. This, taken with a lack of diversity in the structure of the economy, means that the policy response to the issue of 'sustainability' is of particular interest.

## 2. Background – the Sustainability Policy Debate in Jersey

Jersey's main local sustainability policy concern is population. In 1998 its population was around 89,000. However, the optimal population level is a contentious policy issue. On the one hand, there is anxiety over the potential adverse economic effects that could accompany a static or declining labour force, particularly in the face of strong demand for the primary Finance export sectors.[3] It is feared that the resulting tightness of the labour market would stifle economic activity. Under this view, relaxing the population constraint through higher in-migration would have a sizeable impact on Jersey GDP. On the other hand, any growth in population is expected to have adverse environmental effects through increased congestion and pollution. For many Jersey residents, local environmental quality is a key concern. There is therefore considerable support within the island for stabilising the population at its present level. Moreover, in considering the population question, policymakers must also take into account the fact that Jersey is a party to several international agreements made by the UK on emissions of greenhouse gases.

In this paper, we use an economic-environmental Computable General Equilibrium (CGE) model for Jersey, JEMENVI, to identify the nature of the trade-offs involved in allowing population expansion through in-migration. The model quantifies the economic and environmental impacts of alternative population and labour-force projections over a policy-relevant 10-year period. These

[3] Similar concerns have also subsequently emerged in Scotland (Joshi and Wright, 2005; Wright, 2004).

demographic disturbances are modelled both with and without an expansion in demand to the Finance sectors. In the reported results, we focus on the changes occurring by the end of the period. These represent the culmination of a sequence of temporary equilibria as the economy adjusts to the sequence of demand- and supply-side shocks.

The remainder of the paper is structured in the following way. Section 3 outlines the JEMENVI model and its parameterisation and Section 4 identifies the simulation strategy. Section 5 presents a theoretical discussion of the impacts of the demographic changes. Section 6 reports the simulation results and Section 7 performs some sensitivity analysis. Section 8 is a brief conclusion.

## 3. The JEMENVI Model

### *Model Structure*

JEMENVI, a model parameterised on Jersey data, extends the AMOS single-region CGE modelling framework through the incorporation of environmental variables and is configured to capture key aspects of the Jersey labour market[4]. The model has 3 transactor groups - households, firms and government - and 2 exogenous external transactors - the UK and the rest of the world (ROW). Table A.1 in the Appendix lists the 25 activities/commodities, the degree of sectoral disaggregation being here limited by confidentiality requirements. In this paper, we use the period-by-period variant of the model, where, in contrast to previous applications of the AMOS framework

[4] AMOS is an acronym for *A Ma*cro-Micro Model *O*f *S*cotland. It is best regarded as a regional modelling framework "… because it encompasses a range of behavioural assumptions, reflected in equations which can be activated and configured in many different ways" (Harrigan *et al*, 1991, p. 424). Good descriptions of CGE modelling in general and regional CGE modelling in particular are given in Greenaway *et al* (1992) and Partridge and Rickman (1998) respectively.

(e.g. Ferguson *et al*, 2004) the sole endogenous dynamic element is the process of capital stock adjustment. A condensed version is presented in Table 1.[5]

In the version of JEMENVI used here, production takes place in perfectly competitive industries using multi-level production functions. Value-added is produced using capital and labour via standard production function formulations so that, in general, factor substitution occurs in response to relative factor-price changes. Typically, constant elasticity of substitution (CES) technology is adopted but Leontief and Cobb-Douglas (CD) options are available as special cases. Cost minimisation drives the industry cost functions (equation (1)) and the factor demand functions (equations (7) and (8)).[6]

The AMOS framework offers a wide choice of labour market closures (Harrigan *et al*, 1991; McGregor *et al*, 1996). The Jersey economy is characterised by a tight labour market with extremely low levels of unemployment. This we model by adopting a competitive labour market structure with a low labour supply elasticity. The nominal wage and employment in each time period is then derived through the interaction of the resulting labour supply and the general equilibrium labour demand curve (equation (9)). In the derivation of the general equilibrium labour demand curve, it is important to note that all prices and incomes are taken to be endogenous.

In the theoretical exposition in Section 5 and in the default simulations reported in Section 6 labour supply is taken to completely inelastic. However, in Section 7 sensitivity analysis is performed with a more elastic labour supply function. As is explained in greater detail in Section 4, alternative period-by-period evolutions of the Jersey labour force and population are exogenously

[5] In the simplified representation of the model given in Table 1, *inter alia* intermediate demand has been suppressed, income transfers not identified and taxes ignored.

imposed. These different projections represent the demographic outcomes associated with different migration scenarios. A final modelled characteristic of the labour market is that perfect labour mobility is assumed between sectors, generating a unified local labour market. Therefore, although wage rates vary between sectors in the base-year data set, in the simulations wages in all sectors change by the same proportionate amount in response to exogenous shocks.[7]

The four main components of commodity final demand (represented by equation (12)) are consumption, investment, government expenditure and exports. Household consumption is a linear homogenous function of real disposable income and relative prices (equations (2), (11) and (13)). Real government expenditure is taken to be proportionate to population, which is given exogenously (equation (17)). Exports are determined by exogenous external demand via an Armington link, making them relative price sensitive (equation (18)).

The modelling of investment demand is a little more complex. In the multi-period variant of the model, capital stock adjustment at the sectoral level, which ultimately determines aggregate investment demand, is dealt with in the following way. Within each time period, both the total capital stock and its sectoral composition are fixed. At the sectoral level, the interaction between this fixed capital supply and capital demand determines each sector's capital rental rate (equation (10)). The capital stock in each sector is then updated between periods via a simple capital stock adjustment procedure, whereby investment equals depreciation plus some fraction of the gap between the desired and actual level of the capital stock (equations (6), (14) and (15)).[8] Desired

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[6] In each industry intermediate purchases are modelled as the demand for a composite commodity with fixed (Leontief) coefficients. These are substitutable for imported commodities via an Armington link. The composite input then combines with value-added (capital and labour) in the production of each sector's gross output.

[7] In the model the labour market is not disaggregated by skill. The impact of in-migration is likely to alter if the skill composition of in-migrants differs markedly from that of the population as a whole. In the UK, inter-regional migrants are generally more skilled than the population as a whole (Minford *et al*, 1994). This observation is likely to apply to Jersey migration too.

[8] This process of capital accumulation is compatible with a simple theory of optimal firm behaviour given the assumption of quadratic adjustment costs. The whole process is analogous to Tobin's q.

capital stocks are determined on cost-minimisation criteria, using the user cost of capital as the relevant price of capital (equations (3) and (4)). In the base period the economy is assumed to be in long-run equilibrium, where desired and actual capital stocks are equal, with investment simply equal to depreciation. To calculate investment as a source of product demand, the sectoral requirements for additional capital stock are then run through the capital matrix (equation (16)).[9]

In the model, the labour market and product markets equilibriate within each time period. The labour force and capital stock adjust between periods, where the conceptual time periods of the model are interpreted as years, given that the data used for calibration and, where applicable, for parameter estimation are annual. Because the labour force adjustment is exogenous in the simulations reported here, the capital stock adjustment process is the sole endogenously dynamic element of the model. It may be argued that this treatment is rather simplistic. For example, it may be that other lagged adjustments in the labour market, or in product markets, could impact on the dynamic adjustment path of the economy. While such complexities can be accommodated within our general modelling framework, there is no evidence of such affects in Jersey. However, we do examine the sensitivity of our results to the specification of the capital stock speed of adjustment parameter, $\lambda_i$, in equation (15), since the default value is not obtained from econometric estimation using Jersey-specific data.

In the model, we do not impose macro-economic constraints, such as balance of payments or budget deficit limits or targets. However, we do track these deficits/ surpluses. Also, in these particular simulations, the primary disturbance to the model comes in the form of a projection of annual demographic changes.

[9] This treatment of capital adjustment implies that labour is the only regional-specific factor in the long run. In future research we wish to expand the model by the incorporation of land as a second fixed factor. Land use is a key environmental issue on Jersey and restrictions on house-building and home ownership are thought to be important mechanisms by means of which migration is controlled.

The environmental component of the JEMENVI model is a block of equations relating the physical energy use and the generation of pollutants to the production of sectoral outputs and the level of final demand expenditures in the base year (equations (19) and (20)). That is to say, a set of fixed output- and expenditure-pollution coefficients are used to calculate the physical amount of fuel used and pollutant generated in the production of each monetary unit of sectoral output and final demand expenditure. For the final demands, pollutant and direct energy use figures are available for household consumption and tourist expenditure. We model eight types of fuel, eight individual pollutants, and one composite pollutant, an index of global warming potential (the GWP Index).[10]

We should point out that the use of fixed output and expenditure coefficients for predicting environmental effects does not fully exploit the flexibility of CGE models (Beauséjour *et al*, 1994, 1995; Bergman, 1990, 1991). In particular, with fixed coefficients we cannot capture changes in pollution due to input and/or technology effects that would results from policies aimed at increasing energy efficiency or inducing substitution away from 'dirty' inputs through the use of energy or carbon taxes. This is not an important restriction in the current application, however, where the disturbances under consideration are unlikely to have a significant impact on the relative prices of energy inputs. If such price or efficiency effects are important elements of the disturbance being analysed, the fixed coefficient restriction would, of course, be inappropriate.[11]

***Parameterisation***

[10] The eight fuels modelled are aggregate automotive fuels (petrol and derv), sulphur grade kerosene (kerosene SGK), low-sulphur kerosene, gas oil, light fuel oil, heavy fuel oil, coal and gas. The eight individual pollutants are carbon dioxide ($CO_2$), methane ($CH_4$), sulphur dioxide ($SO_2$), nitrous oxides ($NO_X$), non-methane volatile organic compounds (NMVOC), carbon monoxide (CO), nitrogen dioxide ($N_2O$) and black smoke. The index of global warming potential (the GWP Index) is a weighted sum of $CO_2$, $CH_4$ and $N_2O$ emissions, which enter the index with weights ($CO_2$ equivalent conversion factors) 1, 21 and 310 respectively (Statistics Netherlands, 2002).

The structural characteristics of the JEMENVI model are parameterised on a Social Accounting Matrix (SAM) for Jersey for 1998 and the fuel-use and pollutant coefficients are similarly determined from a set of 1998 Jersey environmental satellite accounts (Turner, 2002, 2005). Key behavioural parameter values are imposed, as no adequate data are available for their econometric estimation for Jersey. In the first instance, default settings for the following key behavioural parameter values have been set through consultation with the States of Jersey and the States' economic advisors following a review of parameter values used in models of comparable economies.

In all sectors, the elasticity of substitution between capital and labour in the production of value added is 0.8. However, the elasticity of substitution between the individual components of the intermediate composites and between the intermediate composite and value added in the production of gross output is zero, implying fixed coefficients. The adoption of Leontief technology in the generation of the intermediate composite is required because of the large number of zero entries. The Armington trade elasticities for imports are 2.0 and for exports 5.0. The speed of adjustment parameter for the adjustment of actual to desired capital stock is 0.5. We investigate the sensitivity of our results to the value of the imposed parameters in Section 6.

## 4. Simulation Strategy

It should be stressed from the start that these simulations using the JEMENVI model are not forecasts for the Jersey economy. Rather they identify the impact of exogenous shocks on an initial base data set that is taken to represent a benchmark equilibrium. These simulations comprise

[11] See, for example our analysis of energy efficiency changes in Hanley *et al* (2005).

combinations of two alternative population scenarios with two alternative assumptions about external demand for the Finance sectors.[12]

The two population scenarios are associated with alternative migration assumptions.[13] The first is nil net migration. The second is limited net in-migration of 200 people *per annum* of working age over the period 2001 – 2011. The UK Government's Actuarial Department (UKAD) have quantified the demographic and labour force implications of these two options. Broadly, in the nil net migration scenario natural demographic forces determine population changes. In fact the population is increasing, but simultaneously ageing in a manner that causes the projected working population to fall. In the limited net in-migration scenario, the implications of annual net in-migration of 200 workers aged 25 or under are shown. Figures 1 and 2 illustrate the changes in total and working population predicted by the UKAD under these two scenarios, along with the resulting period-by-period change in total employment. These projections are measured in terms of percentage changes from the base year, 2001.

In the simulations, the in-migration simply relaxes the labour constraint and expands government expenditure (so as to maintain *per capita* public expenditure). In so far as in-migration might have other effects, such as increasing entrepreneurship (Ashcroft and Love, 1996), these are ignored here. As identified in Figures 1 and 2, the impact of the population change, which comes through changes in government expenditure, can be precisely captured in the model. However, the labour-

[12] This approach contrasts with that adopted by CGE modellers who first attempt a forecast simulation and then add the impacts of the policy shock. See, for example, Dixon *et al* (2002) and Giesecke and Madden (2002).

[13] We have imposed specific demographic and labour force projections made on the assumption of particular flows of in-migrants. Ideally the mechanism by which migration is regulated should be identified and used to generate the appropriate migration flow.

force changes are presently modelled by a linear trend that passes through the initial and final points of the 10-year series.[14]

We combine each of the two population scenarios in turn with two economic scenarios regarding demand conditions. In the first demand scenario there are no exogenous demand changes to the economy; in the second, there is a 50% increase in export demand for the output of the Finance sectors. In the first demand scenario, there are therefore no changes to the exogenous demand parameters, apart from adjustments to maintain a fixed level of government expenditure per head.[15] In the second scenario, there is a 50% permanent step increase in UK and ROW export demand for the Finance sectors that takes place in 2002. Finance covers the sectors 13-19 listed in Table A1 in the Appendix and accounts for 84% of Jersey exports. The combination of two possible demand scenarios with two population scenarios produces four (2x2) simulations in total.

In the first two simulations we model each of the migration scenarios in turn with no exogenous demand change: Simulation 1 with nil net migration and Simulation 2 with 200 net in-migrants *per annum*. In Simulations 3 and 4 we take the same two population scenarios but additionally apply a 50% export demand shock to the Finance sectors. The results for all the simulations are compared, in the first instance, as percentage changes from the corresponding base year values. However, we are particularly interested in the impact of relaxing the labour market constraint through in-migration. The results for Simulations 2 and 4 are therefore also sometimes presented as percentage point changes from Simulations 1 and 3 respectively. In this case these results are referred to as ΔSim2 and ΔSim4.

[14] Note that in Figures 1 and 2 the proportionate change in total employment resulting from the projected demographic changes is slightly larger than the change in total working population. This is because we assume all migrants enter the labour force which is a subset of the working population through the inclusion of non-participants

Our model is parameterised on data for 1998. However, we wish to identify the impacts of demographic changes projected to apply over the period 2001-2011. In reporting the results we assume the initial (base) data are appropriate for modelling the changes over this later period. That is to say, no attempt is made to bridge the period from 1998 to 2001. The proportional projected population and demand changes over the 11-year period 2001-2011 are therefore applied to the actual (1998) base year data.

The simulation base year, 2001, is the period where the first population (demographic and/or migration) changes occur but the economic impact does not begin until 2002, when the labour force is updated. Thereafter population and labour force changes occur in every period (year) up to and including 2011. Note that the results we report here only cover the time period 2001 to 2011 (inclusive). However, in all scenarios there will be further adjustments beyond 2011 before the economy returns to long-run equilibrium. While we do not do it here, the JEMENVI framework can be used to compute long-run results where capital, labour and population have fully adjusted to any exogenous shock (with period-by-period results describing the adjustment process).

## 5. Theory

### *Simulations*

In this section we provide some analytical insight into the factors underlying the simulation results that we report in Section 6. We focus on the labour market and very simple supply and demand analysis. This is a natural approach given the nature of the disturbances and the concerns of Jersey legislators over the tightness of the labour market. The analysis is implicitly long run so that

[15] Neither are any supply-side disturbances, such as improvements in technical progress, imposed. As argued in the text,

the identified equilibrium wage and employment levels are those towards which the economy is being attracted over time. However, note that the figures reported in Section 6 are for a time period over which such long-run adjustment is not yet complete.

Figure 3 represents the interaction of the general equilibrium labour demand and supply curves in the unified Jersey labour market. The analysis is comparative static in that it identifies the impact on the equilibrium nominal wage and employment of exogenous disturbances to the Jersey economy. In this exposition, and in the default simulations, we impose a completely inelastic (vertical) aggregate labour supply curve with a constant unemployment rate. This implies a fixed proportional relationship between employment and the working population. Given that the working population is determined exogenously in these simulations, this results in the vertical labour supply curve shifting in line with changes in the working population.

The labour demand curve represents the relationship between the demand for labour and the nominal wage in long-run equilibrium, with incomes, prices and, where appropriate, government expenditure endogenous.[16] Endogenising government expenditure has the following straightforward implications. The additional labour demand associated with the government expenditures that accompany those changes in the population linked to changes in the labour force are implicitly incorporated in the construction of the curve.[17]

The initial equilibrium is represented by the base-period (2001) labour demand and supply curves $LD_B$ and $LS_B$, generating the initial equilibrium employment and nominal wage levels $w_B$,

we do not attempt to forecast the economic performance of the Jersey economy over this time period.

[16] The general-equilibrium labour demand curve is drawn as downward sloping and this is the case for the Jersey economy with default parameter values. However, for combinations of extreme product demand and factor substitution elasticities, the general equilibrium labour demand curve can be upward sloping (McGregor *et al*, 1995).

$N_B$.[18] Simulation 1 represents the nil net migration scenario accompanied by no exogenous change in export demand for the Finance sectors. As discussed in Section 4, the nil net migration scenario is here associated with a fall in the labour force accompanied by a rise in population. This generates an inward shift of the labour supply curve, from $LS_B$ to $LS_0$, and an outward shift in the general-equilibrium labour demand curve, from $LD_B$ to $LD_0$. The expansion in labour demand reflects the increase in public sector activity required to maintain the fixed *per capita* level of government expenditure. Thus the main direct impact of the population changes implied by the nil net migration scenario is a lower labour supply, with employment $N_0$, and a higher general wage level, $w_0$.

In Simulation 2, there is an expansion in the labour force and population through the net in-migration of 200 *per annum* over the 10-year period. This generates an outward shift of the labour supply curve to $LS_{200}$. In this case, although there is an increase in population we do not shift the labour demand curve as such linked changes in public expenditure have already been endogenised. The effect is therefore simply to move the labour-market equilibrium down the labour demand curve $LD_0$, so that employment rises to $N_{200}$, but the wage falls to $w_{200}$.

Simulation 3 introduces a 50% expansion in export demand in the Finance sectors, together with the nil net-migration scenario. An expansion in export demand shifts the labour demand function outwards to $LD_X$, as the value of the marginal product increases in these sectors. The appropriate equilibrium is therefore at the intersection of the demand curve $LD_X$ and the labour supply curve $LS_0$. The wage rate rises to $w_0^X$ at an employment level of $N_0$. In Simulation 4, the employment constraint is again relaxed through in-migration but this time accompanied by the export demand shock to the Finance sectors. The labour-market equilibrium is therefore at the intersection of

[17] There is pedagogic value in treating all public expenditure as exogenous in the general equilibrium labour demand and supply diagrams (Turner, 2002). However, the simultaneous adjustment of supply and demand makes the diagrams cluttered, so that this approach is not used here.
[18] Because there is no ambiguity, in this section we drop the subscript n on the wage term.

labour demand curve $LD_X$ and labour supply curve $LS_{200}$, generating a wage of $w^X_{200}$ together with an employment level of $N_{200}$.

The impact on other aggregate variables and the sectoral distribution of economic effects is discussed in more detail in Section 6. However, a number of general points can usefully be made here. First, an expansion in the wage, *ceteris paribus*, reduces the competitiveness of Jersey output in relation to commodities produced off-island. But the increase in the wage relative to those commodities' prices reflects an improvement in Jersey's terms of trade and a rise in the real incomes for Jersey workers. In these terms, any in-migration increases competitiveness, but only at the expense of reduced real wages.

Second, whilst the expansion in the Finance-sectors export demand generates no increase in aggregate employment, it is accompanied by large shifts in activity between sectors. This demand disturbance is focussed primarily on one composite sector and the subsequent increase in wage will hit other sectors producing export-orientated output particularly hard. On the other hand, the increase in overall employment and economic activity that is associated with the expansion in labour supply (through in-migration) will have an impact that is much more evenly spread across sectors. The general fall in wages and commodity prices drives the expansion in output and employment across all activities.

This shift between sectors can also have an important role in determining household income. As noted in Section 3, although we model the labour market as unified, this implies simply that the wage rates in all sectors change by the same proportionate amount in response to particular disturbances. However, the absolute level of the wage varies substantially across industries and is particularly high in the Finance sectors. Therefore a shift of labour into the Finance sectors, even without any change in the ruling wage rate, would increase household income.

### *Sensitivity Analysis*

As an extension to the standard (default) simulations we also undertake sensitivity analysis. One function of such analysis is to show how vulnerable the measured economic and environmental results are to changes in the imposed parameter values. This motivates the simulations performed in Secton 7 using alternative labour supply elasticities and speed of adjustment parameters. However, one element of the sensitivity analysis we perform here has a more specific aim. Within the Jersey economy, the production of many pollutants proves to be closely related to the level of household expenditure. We wish to test whether parameter values exist where an expansion in employment can actually reduce household income and thereby reduce such pollutants. This is likely to occur where the general equilibrium labour demand function is highly inelastic.

As with Figure 3, Figure 4 represents long-run relationships, though in this case in an economy with two alternative sets of behavioural parameters. These generate alternative initial (base) general equilibrium labour demand curves $LD_{L,B}$ and $LD_{H,B}$, where the subscripts L and H represent low and high elasticities respectively. Both sets of parameters replicate the base data set: this condition is imposed by construction in CGE modelling, Therefore in the initial equilibrium, both these curves intersect the labour supply curve $LS_B$, where the nominal wage and employment are $w_B$ and $N_B$.

We are keen to see how the wage, and particularly total wage income, varies with the elasticity of the labour demand curve when the economy is subject to the shocks corresponding to Simulations 3 and 4. These are the simulations where a 50% expansion in export demand for the Finance sectors is accompanied by the nil net migration scenario (Simulation 3) or in-migration of 200 *per annum* (Simulation 4).

In Figure 4, the increase in demand for Finance-sectors exports shifts the general equilibrium labour demand curves outwards from $LD_{.B}$ to $LD_{.X}$. Where the wage is fixed, both curves pass through the same point. This would be the extended Input-Output result (McGregor *et al*, 1996). In the long run, if wage rates are held constant, there will no changes in prices and therefore, with linear homogeneous production functions, no change in the cost-minimising production techniques. This implies that the export demand stimulus to the Finance sectors will have the same output effect in both the high and low labour-demand elasticity versions of the model. This serves as a convenient reference point.

For the I-O result to occur, the employment (and therefore labour supply) must rise to $N_{IO}$. However, the labour supply under the nil net migration scenario actually falls to $N_0$. The wage must therefore rise in order to bring labour demand and supply into equilibrium. The increase in the wage is higher, the more inelastic the labour demand curve. This is because the more inelastic the labour demand curve, the more difficult it is to switch to foreign products and other factor inputs as the wage rate rises. This means that $w^X_{L,0} > w^X_{H,0}$. Clearly, also total wage income, Nw, and therefore also household income, will be higher under the set of parameters that generate a lower labour demand elasticity: $N_0w^X_{L,0} > N_0w^X_{H,0}$.

In Simulation 4, the relaxation of the labour supply constraint will reduce the wage. This labour supply curve shifts outwards to $LS_{200}$. Employment will rise to $N_{200}$ and the wage rates for the low and high labour demand elasticities fall to $w^X_{L,200}$ and $w^X_{H,200}$ respectively. Note that the lower the elasticity of labour demand, the greater the decline in the wage. Also, where this elasticity is less than unity, total wage income will fall as employment rises. If this occurs, it implies that $w^{X}_{L,0}\ N_0 > w^{X}_{L,200}\ N_{200}$.

## 6. Simulation Results

### *Economic Impacts*

Table 2 gives the results for the key economic and environmental variables in the four basic simulations. These results are presented in the form of the percentage changes between the 2011 and base-year (2001) values. The figures for Simulation 1 are shown in the first column. This is where there are no exogenous changes in external demand conditions combined with nil net migration. The impact on economic activity is slightly negative: Gross Domestic Product (GDP) falls by 0.46% by 2011. This is primarily because of the reduction in labour supply as an input to production that accompanies the ageing of Jersey's population.

Note that the decline in GDP is less than the drop in employment (0.76% by 2011). This partly reflects the small stimulus to demand as government spending increases in line with population growth. Moreover, capital stocks do not fall by as much as employment. There are two reasons for this. First, the increase in real wages causes firms to substitute capital for labour. Second, the downward adjustment of capital is subject to frictions due to capital fixity, so that in the short to medium run it is easier for firms to reduce employment than capital. These factors combine to ensure GDP does not fall by as much as employment and, therefore, GDP *per employee* actually rises. However, because of the increasing population, GDP *per head* falls, and does so even more rapidly than GDP, although again by a relatively small amount: by the end of 2011, GDP per head is 1.68% lower than the 2001 (base year) level.

The tightening of the labour market causes an increase in both nominal and real-consumption wages across the economy and a rise in the consumer price index (cpi). However, the scale of these increases is small – all change by less than 0.6% by 2011. Two points are important concerning this cpi result. First, it only demonstrates a step change in Jersey prices and does not chart an inflationary process. Second, the limited impact on the cpi is due to the fact that only local prices, not import prices, are rising: we assume that all external prices remain constant.

The increase in local input prices negatively affects competitiveness across all sectors in the Jersey economy relative to goods produced off-island. This causes a contraction in output and employment in most sectors, as shown in Figure 5.[19] However, despite the fall in competitiveness, output and employment actually rise in the four government sectors – "Education", "Health, Social Work & Housing", "Public Services" and "Public Administration". This is because, with the exception of "Education, these sectors are sheltered from external competition. They only serve local demand and do not export their output. Consequently, the government sectors are less affected by the rise in the relative prices than other sectors of the economy. Further, these sectors experience a direct demand boost through the increase in government expenditure that is required to maintain the constant public spending per head. However all the other sectors exhibit negative output and employment effects.

The extent of the negative impact on a particular sector is determined by two factors. First, labour intensive sectors are hit hardest by the increased cost of labour. Secondly, sectors that are more

[19] Recall that there are seven Finance sectors: "Banks and Building Societies", "Insurance", "Investment Trusts"," Computer Services"," Legal Activities"," Accountancy", and" Other Business Services".

open to international trade feel the negative competitiveness effects more strongly. "Agriculture and Fishing" suffers the most, due to a combination of these two factors and "Hotels, Restaurants and Catering" is hit relatively hard for the same reasons. On the other hand, "Banks and Building Societies" suffers the least, partly because it is the least labour intensive sector in the economy and partly because it uses relatively few locally produced inputs. It therefore experiences the lowest competitiveness effect.

In Simulation 2, the labour-force constraint is relaxed by allowing 200 in-migrants *per annum*. The results are given in the second column of Table 2. The increase in working-age population reduces the tightness in the labour market leading to a subsequent expansion in the economy. There are positive impacts in terms of employment and GDP, which more than outweigh the negative effects observed when migration is suppressed. However, the proportionate increase in GDP is lower than the rise in population, so that GDP per head falls further than under nil net migration scenario. Note also that the expansion in activity is accompanied by a reduction in the real wage level in the economy, an outcome that is not necessarily in the interest of existing Jersey residents.

In Simulation 3 we introduce the 50% export-demand shock to the Finance sectors under the nil net migration scenario. By 2011, none of the Finance sectors actually experience a full 50% increase in exports. This is because increases in their output prices - that is, decreases in competitiveness - ensure that this amount is never actually achieved. However, as can be seen in column 3 of Table 2, there is a sizeable impact on GDP, which increases by 9.11% by 2011.[20] However, predictably, the shortage of labour and increase in export demand combine to push up both real wage and the cpi, which increase by 5.23% and 2.22% respectively. This compares with

[20] However, note that the impact on Jersey GNP is much smaller only rising by 2.65% to 2011. This is due to the high degree of foreign ownership in the Jersey Finance sectors, which means that a significant proportion of the additional income from the export demand boost in Simulation 3 accrues to non-Jersey residents.

the increases of only 0.42% and 0.13% in Simulation 1, where there was no exogenous demand shock.

The expansion of output in the seven Finance sectors leads to increases in employment in those sectors, but a fall in employment in other sectors, as shown in Figure 6.[21] As would be expected, the biggest losers are non-Finance sectors that are highly export- and/or labour-intensive, such as Agriculture & Fishing, Wholesale & Retail Trade, Hotels, Restaurants & Catering, Land Transport, and Sea & Air Transport sectors.

Simulation 4 combines the Finance export demand shock with a 200 *per annum* net in-migration. The figures are given in column 4 of Table 2. This expansion in the labour force improves competitiveness and partly mitigates the negative effects felt by some sectors as a result of the export demand shock. GDP rises in association with the expansion in the labour force, though the real wage falls. However, one key observation can be made. In Simulation 2, the additional impacts that accompany the 200 person net in-migration *per annum* are enough to outweigh all the negative effects on activity and prices of the demographic changes in the nil net migration scenario reported in Simulation 1. This is no longer true in the presence of a 50% increase in Finance sectors export demand.

The impacts generated solely by relaxing the labour constraint through allowing 200 net in-migrants per annum are labelled ΔSim2 and ΔSim4 respectively. ΔSim2 is calculated by subtracting the results for Simulation 1 from the results for Simulation 2. Similarly, ΔSim4 is produced by subtracting the results for Simulation 3 from the results for Simulation 4. The effect on output and

[21] The Finance sectors, as defined here (following the States of Jersey's policy requirements) are a rather heterogeneous group of sectors (see footnote 19). Not all experience an increase in employment: "Other Business Services" is an example.

employment across all sectors from ΔSim4 are illustrated in Figure 7. Note that the benefits from expanding the labour supply are relatively evenly spread across sectors. However, for a number of sectors this stimulus is not enough to outweigh the negative impact on activity generated by Simulation 3 which is illustrated in Figure 6. Similarly the downward pressure on the real wage level and cpi from allowing 200 in-migrants *per annum* is not enough here to combat the upward pressure on both these variables in nil net migration case where the export demand shock is present. In other words, while allowing 200 net in-migrants *per annum* does ease economic conditions, the economy is still sufficiently labour constrained to cause crowding out in some sectors and a general upward pressure on prices.

An interesting comparison can be made between the results generated by relaxing the labour-force constraint both with and without the expansion in the export demand in the Finance sectors. This implies comparing ΔSim2 with ΔSim4. Specifically, the changes in GDP are surprisingly similar in the two cases. For ΔSim2, GDP increases by an additional 2.041% by 2011 (1.58% – (-0.46%)) and for ΔSim4 by 2.197% (11.31% - 9.11%).[22] Intuitively one might have thought that increasing the export demand for Finance would have had a much more dramatic impact on the effectiveness of expanding the labour supply. Why does adding the export shock make so little difference?

At the margin, all firms bid for workers on a level playing field and the additional workers are distributed across sectors broadly according to their existing demand for labour. This is quite different to the situation reported in Simulation 3 (in comparison to Simulation 1) where hundreds of employees move into the Finance sectors, away from other sectors, with a corresponding increase in GDP of 9.11% by 2011. Rather, as demonstrated in Figure 7, the extra employees in ΔSim4 are spread across sectors in a relatively even fashion. The slightly higher additional impact on GDP of the expansion in the labour force that is found in ΔSim4, relative to ΔSim2, can be attributed to the increase in the productivity of the Jersey economy as a whole as a result of the Finance export demand shock. In comparing Simulation 3 with Simulation 1, the effect of the demand stimulus is to increase GDP per head by 9.57%. In comparison the change in GDP reported in ΔSim4 (2.20%) is a similar 7.89% higher than that in ΔSim2 (2.04%).

### *Environmental Impacts*

The key factors determining the environmental impacts of all four simulations are the effects on the "Agriculture and Fishing" sector and on the level of real consumer expenditure in Jersey. "Agriculture and Fishing" is an important energy user. However, more importantly, in 1998 it directly generated 82.7% of total Jersey methane emissions (Turner, 2002, 2005). The States of Jersey's Environmental Charter, endorsed in 1996, includes a commitment to the principles agreed at the Earth Summit in Rio de Janeiro in 1992 regarding greenhouse gas emissions (States of Jersey, 1998). Methane is a major component of the Global Warming Potential (GWP) Index, which is widely accepted as an indicator of the impact of individual economies on the climate change problem. On the other hand, household consumption is central in determining the level of emissions of most of the other major pollutants identified in the JEMENVI model. This particularly applies to traffic-related emissions because in 1998 local households directly accounted for 70.5% of total automotive fuel use in Jersey. Indeed, in the absence of a heavy industrial sector, households are directly responsible for most types of emissions generation.[23]

[22] The change in the real wage and cpi are very similar too, but it is the GDP change that is given prime policy significance in Jersey.
[23] See McGregor *et al* (2001) and Turner (2002) for a full analysis of emissions generation in Jersey in 1998.

One local environmental problem that particularly concerns policymakers is the impact of traffic-related emissions generation and congestion in the main urban area of St. Helier. As explained in Section 3, JEMENVI has been developed to model the generation of a number of individual air pollutants, including emissions of CO, $N_20$, NMVOC, $CO_2$ and $NO_X$ from the combustion of automotive fuels (petrol and derv) in different types of vehicle. However, in the results reported in Table 2 we limit our attention to the simulation results for two environmental indicators. These are automotive fuel use - as the source of traffic-related emissions and an indicator of total vehicle use or congestion - and the composite Global Warming Potential (GWP) Index.[24]

Under the nil net migration scenario captured in Simulation 1, all traffic-related emissions fall (in fact emissions of all pollutants fall) as activity across the whole economy contracts. Note from the first column of Table 2 that automotive fuel use in the government sectors increases, though only by 0.48%. This is as a result of the increase in total government expenditure required to maintain a fixed level of spending *per capita* as total population rises. Indeed there is a general increase in energy use and pollution generation in the government sectors, but this is insufficient to offset the negative effects of reduced activity elsewhere in the economy.

The addition of either the demand shock or positive migration generates an increase in automotive fuel-use and traffic-related emissions as against the 2001 base level. The 50% increase in the export demand in the Finance sectors produces the biggest impact on automotive fuel-use. This is because there is a substantial increase in activity in the high-wage Finance sectors, thus increasing the level of real income and expenditure per household. Generally when the population constraint is relaxed (with or without the export demand shock), all types of energy use, water use and pollution generation increase as the level of activity in all sectors increases. However, we have

[24] A fuller account of the environmental impacts of the four simulations discussed here is given in Turner (2002).

seen that the demand shock does crowd out a number of activities. This generates the 3.54% decline in automotive fuel-use in the non-government production sectors and the 22.25% reduction in tourist use reported for Simulation 3. Agriculture & Fishing is the production sector that suffers the greatest proportionate decline in activity following its reduced competitiveness as the real wage and local input prices rise.

The increase in the GWP Index in the presence of the demand shock is less substantial than the increase in traffic-related emissions. In Simulation 3, the GWP Index increases by only 1.82% compared to an increase in total automotive fuel use of 5.96%. The GWP Index is influenced by traffic-related emissions $CO_2$ and $N_2O$, which increase by 2.78% and 4.56% respectively. However the weight attached to methane, and the absolute reduction in the emissions of this pollutant due to the crowding out of agricultural activity, serve to limit the size of the increase.

Note, however, that when in-migration occurs, there is a marked increase in GWP emissions due to the general increase in activity, both agricultural and non-agricultural, in the economy, with an additional 2.61% increase in emissions in ΔSim4 on top of the 1.82% reported for Simulation 3. However, in Simulation 4 the total percentage change in the GWP Index remains lower than the change in either $CO_2$ or $N_2O$, reflecting the overall fall in methane emissions, even with migration.

In terms of the policy debate in Jersey regarding the costs and benefits of population expansion, one approach is to focus on the trade-off between increased energy use/pollutant generation and GDP associated with the demand and population disturbances analysed here. The increase in export demand for the Finance sectors generates a relatively large increase in GDP (9.11%) but a much smaller change in both the total automotive fuel use (5.96%) and GWP index (1.82%). For the Jersey economy at least, this suggests a relatively environmental friendly expansion in GDP. On the other hand, increasing population through in-migration generates a greater increase in energy use and GWP index than GDP. Figure 8 tracks the change in the GWP to GDP ratio over time resulting from the additional impact of 200 in-migrants *per annum*. Note that this ratio increases over time with in-migration and that the size of the increase is smaller in the presence of the demand shock to the Finance sectors because of the change in the composition of the economy, particularly the continued crowding out of agricultural activities.

## *7.* Sensitivity Analysis

Given the absence of econometrically estimated values for many of the key parameters in the JEMENVI model, it is prudent to undertake sensitivity analyses. However, as we explain in Section 5, a part of our sensitivity analysis is a little more directed here than is usual. In the first instance, we focus on two of the key parameter values in the model, the Armington trade elasticities and the elasticity of substitution between capital and labour in the CES production functions. The Armington trade elasticities determine the sensitivity of export demand to changes in local output prices, and the production substitution elasticities establish the composition of the primary input aggregate (value-added) in each sector. We limit the sensitivity analysis to the two scenarios where the most significant environmental impacts are observed. These are Simulation 3, where a 50% export demand shock to the Finance sectors is introduced under the assumption of nil net migration, and Simulation 4, where the labour supply constraint is partially relaxed under these demand conditions, by allowing 200 in-migrants *per annum*.

We re-run these two simulations with the default (5.0) and four alternative values for the Armington elasticity of export demand ($\eta$). These are 0.5, 1.0 (Cobb-Douglas), 2.0 and 3.0. Similarly we use the default (0.8) and six alternative values for the constant elasticity of substitution between capital and labour ($\sigma$), namely 0.1, 0.3, 0.5, 1.0 (Cobb Douglas), 1.2 and 1.5.[25] All other model specifications are unchanged. Tables 3a, b, c and d show the proportionate changes in Real Household Income and Expenditure and Total Automobile Fuel Use for Simulation 3 and the additional impact of Simulation 4 ($\Delta$Sim4) for these combinations of parameter values. The default parameter values and simulation results are shown in bold.

As outlined in Section 5, we would expect that in the case of the export demand shock in Simulation 3, the more wage inelastic labour demand – that is, the smaller the values of $\sigma$ and $\eta$ - the bigger the positive impact on real wages. While not reported here, the sensitivity results for the impact on the real wage level in Simulation 3 broadly follow this pattern.[26] In Table 3a we report the percentage change in household income and expenditure under the range of values for these two parameters. But the consequent impact on household income and expenditure does not only depend on changes in the general wage level. It is also affected by the composition of employment across different sectors, given the initial variation in wage rates across these sectors.

In Simulation 3, where a large export demand shock directed at the Finance sectors causes labour to shift into relatively high wage activities, *ceteris paribus*, we would expect to observe a significant positive impact on real household income. This sectoral shift reinforces the general increase in wages. However, both the elasticity of general equilibrium labour demand and the extent of the shift of employment into the Finance sectors is sensitive to the values of $\sigma$ and $\eta$. Where we hold the elasticity of substitution in production, $\sigma$, constant, reducing the price elasticity of export demand, $\eta$, increases both the real wage and the shift of employment towards the Finance sectors.

[25] Note that the model will not solve for 5 combinations in both cases (indicated by asterixes in Table 3). These are scenarios where labour demand becomes so wage-inelastic that the model cannot adjust to a new equilibrium.

[26] Where $\eta$ = 5.0, there are some disequilibrium effects, with the expected negative relationship between the size of the change in the wage and elasticity of substitution between capital and labour not being observed until some time after 2011.

Therefore, for each value of $\sigma$ reported in Table 3a, as $\eta$, falls, household income rises. However, if the price elasticity of export demand is held constant, reducing the elasticity of substitution in production will increase the wage, but not necessarily boost employment in the Finance sectors and therefore the size of this sectoral shift. Thus Table 3a shows that where the elasticity of export demand is low (values of unity or under), household income rises as the elasticity of substitution falls. However, where the export demand elasticity is high (values of 3 and over), household income falls as the elasticity of substitution falls. For the case of $\eta = 2$, household income initially rises, then falls as $\sigma$ falls. [27]

The sensitivity results for the impact on total automotive fuel use (Table 3b) are in line with the findings for total real household income and expenditure. The impact on automotive fuel use is in all cases smaller in proportionate terms than the impact on household income and expenditure because of the downward pressure from reduced activity elsewhere in the economy, but its magnitude is just as sensitive to what we assume about the values of $\sigma$ and $\eta$.

However, the most interesting results are found in the Tables 3c and 3d, which report the sensitivity analysis of the household income and expenditure and automotive fuel use impacts in ΔSim4, where the effects of relaxing the labour force constraint are identified. In the simulations using default parameter values reported earlier in this section, we find that the additional impacts of allowing 200 in-migrants *per annum* are detrimental as measured on all environmental indicators. This is mainly because of the upward pressure on the level of total household consumption, which is the main source of most types of pollution, particularly traffic-related emissions, in the Jersey economy. However, we have speculated that if labour demand is sufficiently wage inelastic, the

[27] Also at lower values of $\eta$ some disequilibrium effects are again clearly present. Recall that the sensitivity analysis, as with all the simulation reported here, relates to the end of time period studied, 2011, which is not a long-run

reduction in real wages from relaxing the labour supply constraint may be enough to offset the increase in employment, with the implication that total household income and expenditure must fall. This in turn may lead to some types of pollution generation in the economy falling as the aggregate level of activity increases.

In the default ΔSim4, where $\sigma = 0.8$ and $\eta = 5.0$, total household income and expenditure increases by an additional 1.98% by 2011 when 200 net in-migrants *per annum* are allowed in the presence of the 50% increase to the Finance sectors export demand. However, Table 3c reveals that this figure is subject to considerable fluctuation as $\sigma$ and $\eta$ are varied. In Table 3c we do not observe the impacts of large sectoral shifts that is evident in Table 3a. The impact on household income of relaxing the labour market constraint uniformly increases as the export demand and production substitution elasticities are increased. A key finding is that the *direction* of this effect *is* sensitive to what we assume about the elasticity of substitution between capital and labour. Specifically, if the value of $\sigma$ is assumed to be 0.1 (in all sectors), total household income and expenditure fall as output and employment rise in all sectors of the economy. This is independent of the value of $\eta$. Further, if the elasticity of export demand, $\eta$, is reduced to 0.5 the net impact on total household income and expenditure is almost zero where $\sigma = 0.5$, and negative where $\sigma = 0.3$.

In terms of actual policy analysis, one would have to question the plausibility of labour demand in Jersey actually being as highly inelastic as is required to bring about this decline in total household income and expenditure. Moreover, note from Table 3d that the decline in household consumption is only sufficient to bring about a net decline in *total* automotive fuel use in the case where $\sigma = 0.1$ and $\eta = 1.0$ (Cobb Douglas). In this one case the net impact on emissions of the main traffic-related pollutants, NMVOC, CO and $N_2O$, is also negative. However, we find that the

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equilibrium. Disequilibrium effects are clearly present in the case of $\eta = 0.5$, the lowest value we consider for the additional impact on all other types of pollution is uniformly positive, regardless of what we assume about the substitutability of labour for capital or the price elasticity of export demand. This is due to the increase in productive activity across the economy when the labour supply constraint is partially relaxed.

We also conduct sensitivity analysis on two other key parameters.[28] These are the speed of adjustment parameter in the investment equation ( $\lambda_i$, equation 15); and the elasticity of the local labour supply with respect to the real wage (ε, equation 5). We have previously the labour supply to have a wage elasticity equal zero. We re-run all four simulations with the default (0.5) and two alternative values for the capital stock adjustment parameter $\lambda_i$. These values are selected to reflect a smaller (0.3) and larger (0.7) adjustment between actual and desired capital stock in each period. Similarly we use the default parameter of zero for the response of the local labour force to changes in the real wage and an alternative small but positive elasticity of 0.2.[29] All other model specifications are unchanged. In particular, the parameters σ and η take their default values of 0.8 and 5.0 respectively.

Table 4 gives the results of this sensitivity analysis for each of the four basic simulations outlined in Section 4. The endogenous variables shown are identical to the set reported in Table 2 for the default simulations. In Table 4, for each basic simulation, the default results are shown in column 2 and are given in bold. Deviations from the default results reflect the sensitivity of the reported endogenous variables to these parameter changes.

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Armington elasticity of export demand.

[28] We are grateful to an anonymous referee for suggesting this analysis.

[29] In this model run we actually use a wage-curve labour market closure but the parameter is chosen to replicate an elasticity of supply of 0.2.

Increases in the speed of adjustment parameter generally imply that the period 2011 result will be closer to the long-run equilibrium adjustments to the exogenous population and final demand changes. In Simulation 1, in which working population falls but there is no exogenous change in the export demand in the Finance sectors, the default simulation shows a fall in activity with capital stock falling. Increasing the capital stock adjustment speed means that this fall, in both capital stock and aggregate activity, occurs more rapidly. And whilst the reduction in the labour supply generates an increase in the real wage, the more rapid the reduction of the capital stock, the more this real wage increase is moderated.

For the other three base simulations, there is an expansion in economic activity and an increase in capital stock. For these simulations, increasing the speed of adjustment always increases the impact on real variables: GDP, GDP per head, the real wage and, where relevant, employment. That is to say, where the default results for these variables are positive, this is increased, and where negative, the absolute value is reduced. However, this having been said, the size of the adjustments made through changing the value of $\lambda_i$ in this range is relatively small and the relevant values never change sign.

Where the assumption of a completely inelastic labour supply is relaxed, the impact can be seen in the labour market. The introduction of a low labour supply elasticity (0.2) reduces the absolute size of any change in the real wage and increases (reduces) employment where the real wage is above (below) its base year value. The impact of varying the elasticity of labour supply on other aggregate variables, such as GDP, GDP per head and real household income, is in the same direction as the employment change. However, relaxing the labour supply elasticity by this relatively small amount has a correspondingly small impact on these economic variables.

The impact of the sensitivity analysis on the automobile fuel use and GWP Index reflects the corresponding changes in economic activity. The sensitivity of these environmental variables to changes in the capital speed of adjustment and the labour supply elasticity is again relatively low.

## 8. Conclusion

In this paper we explore the local/regional dimensions of sustainability in the Jersey economy. We illustrate these local/regional issues by focussing on the impact of relaxing the labour force constraint through increased in-migration. The main findings are that whilst this generates a positive stimulus to activity in the economy, this stimulus is relatively small and is accompanied by falling real wages and productivity, and rising congestion and pollution. However, the in-migration modelled here might have one important positive characteristic from a policy perspective. An expansion in export demand in the Finance sectors leads to sectoral disruption as employment is pulled into the expanding sectors. In-migration, which eases the labour shortage over all sectors, could play a key role in easing these sectoral tensions.

Overall, we believe that our analysis demonstrates the potential value from using local/regional economic-environmental CGEs. When calibrated to capture the key characteristics of the local economy (in terms of both model data and specification), these models can explore the local/regional contributions to local, national and global sustainability objectives. This approach is likely to find fruitful application elsewhere. In the UK the local/regional dimension of sustainability *per se* is becoming increasingly important, as is the role of sub-national governments in delivering national commitments to international sustainability agreements.

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# APPENDIX

**Table A.1 Sectors (Activities/Commodities) Identified in JEMENVI**

| No | Sector | Jersey/UK Standard Industrial Classification (JSIC 1995, UK SIC 1992) |
|---|---|---|
| 1 | Agriculture & Fishing | 01, 05 |
| 2 | Quarrying & Construction | 14, 45 |
| 3 | Manufacturing | 15 – 18, 20, 22, 25-26, 28-31, 33,35, 37 |
| 4 | Electricity | 40.1 |
| 5 | Water | 41 |
| 6 | Gas, Oil & Fuel Distribution | 40.2,50.50,52.48 |
| 7 | Telecommunications | 64.2 |
| 8 | Wholesale & Retail Distribution | 50 – 52 |
| 9 | Hotels & Restaurants | 55 |
| 10 | Land Transport | 60.2, 60.3 |
| 11 | Sea & Air Transport and Transport Support | 61, 62, 63 |
| 12 | Post | 64.1 |
| 13 | Banks & Building Societies | 65.121, 65.121, 65.21, 65.22, 65.233, 65.234, 65.235 & 65.236 |
| 14 | Insurance Companies | 66 |
| 15 | Investment Trusts & Fund Managers | 65.231, 65.232, 67 |
| 16 | Computer Services | 72 |
| 17 | Legal Activities | 74.11 |
| 18 | Accountancy | 74.12 |
| 19 | Other Business Activities | 70, 71, 73, 74.13 - 74.8 |
| 20 | Other Service Activities | 91, 93 |
| 21 | Recreation, Culture & Sport | 92 |
| 22 | Education | 80 |
| 23 | Health, Social Work & Housing | 85 |
| 24 | Public Services (Sewage & Refuge Disposal) | 90 |
| 25 | Public Admin. & Defence | 75 |

## Tables

## Table 1: A Condensed Version of the JEMENVI CGE Model

| | |
|---|---|
| (1) Commodity Price | $p_i = p_i(w_n, w_{ki})$ |
| (2) Consumer Price Index | $cpi = \sum_i \theta_i p_i + \sum_i \theta_i^{UK} \overline{p}_i^{UK} + \sum_i \theta_i^{ROW} \overline{p}_i^{ROW}$ |
| (3) Capital Price Index | $kpi = \sum_i \gamma_i p_i + \sum_i \gamma_i^{UK} \overline{p}_i^{UK} + \sum_i \gamma_i^{ROW} \overline{p}_i^{ROW}$ |
| (4) User Cost of Capital | $uck = uck(kpi)$ |
| (5) Labour Supply | $N^S = N^S(\overline{L}, w_n, cpi)$ |
| (6) Capital Sock | $K_{i,t}^S = (1-d_i)K_{i,t-1}^S + \Delta K_{i,t-1}$ |
| (7) Labour Demand | $N_i^D = N_i^D(Q_i, w_n, w_{k,i})$ |
| (8) Capital Demand | $K_i^D = K_i^D(Q_i, w_n, w_{k,i})$ |
| (9) Labour Market Clearing | $\sum_i N_i^D = N^S = N$ |
| (10) Capital Market Clearing | $K_i^S = K_i^D$ |
| (11) Household Income | $Y = \Psi_n N w_n + \Psi_k \sum_i K_i w_{k,i}$ |
| (12) Commodity Demand | $Q_i = C_i + I_i + G_i + X_i$ |
| (13) Consumption Demand | $C_i = C_i(p_i, \overline{p}_i^{UK}, \overline{p}_i^{ROW}, Y, cpi)$ |
| (14) Desired Capital Stock | $K_i^* = K_i^D(Q_i, w_n, uck)$ |
| (15) Capital Stock Adjustment | $\Delta K_i = \lambda_i(K_i^* - K_i)$ |
| (16) Investment Demand | $I_i = I_i(p_i, \overline{p}_i^{UK}, \overline{p}_i^{ROW}, \sum_i b_{i,j}\Delta K_j)$ |
| (17) Government Demand | $G_i = g_i P\overline{O}P$ |
| (18) Export Demand | $X_i = X_i(p_i, \overline{p}_i^{UK}, \overline{p}_i^{ROW}, \overline{D}^{UK}, \overline{D}^{ROW})$ |
| (19) Pollutants | $POL_k = \sum_i m_{i,k} Q_i + \sum_z m_{z,k} C_z$ |
| (20) Physical Energy Use | $FUEL_l = \sum_i \varepsilon_{i,l} Q_i + \sum_z \varepsilon_{z,l} C_z$ |

## NOTATION

### Subscripts

| | |
|---|---|
| i, j | activity or commodity |
| k | pollutant type |
| l | fuel type |
| t | time period |
| z | final demand type |

### Transactors

| | |
|---|---|
| UK | United Kingdom |
| ROW | Rest of World |

### Functions

| | |
|---|---|
| p (.) | cost function |
| uck(.) | user cost of capital formulation |
| $K^D(.)$, $N^D(.)$ | factor demand functions |
| C(.), I(.), X(.) | Armington consumption, investment and export demand functions, homogenous of degree zero in prices and one in quantities |
| N(.) | labour supply function |

### Variables

| | |
|---|---|
| C | consumption |
| D | exogenous export demand |
| $FUEL_l$ | quantity of energy/fuel type l |
| G | government demand for local goods |
| I | investment demand for local goods |
| $\Delta K$ | investment demand by activity |
| $K^D$, $K^S$, $K^*$, K | capital demand, capital supply, desired and actual capital stock |
| L | labour force |
| $N^D$, $N^S$, N | labour demand, labour supply and total employment |
| $POL_k$ | quantity of pollutant k |
| POP | population |
| Q | commodity/activity output |
| X | exports |
| Y | household nominal income |
| b | elements of capital matrix |
| cpi, kpi | consumer and capital price indices |
| d | physical depreciation |
| g | government real expenditure coefficient |
| p | price of commodity/activity output |
| uck | user cost of capital |
| $w_n$, $w_k$ | wage, capital rental |
| $\Psi$ | share of factor income retained in region |
| $\theta$ | cpi weights |
| $\gamma$ | kpi weights |

| | |
|---|---|
| $\lambda$ | capital stock adjustment parameter |
| $m_{i,k}$ | output-pollution coefficients |
| $m_{z,k}$ | (final demand) expenditure-pollution coefficients |
| $\varepsilon_{I,l}$ | output-energy use coefficients |
| $\varepsilon_{z,l}$ | (final demand) expenditure-energy use coefficients |

***Notes*:**

Variables with a bar are exogenous

A number of simplifications are made in this condensed presentation of JEMENVI

1. Intermediate demand is suppressed throughout e.g. only primary factor demands are noted in price determination in equation (1) and final demands in the determination of commodity demand in equation (12).
2. Income transfers are generally suppressed.
3. Taxes are ignored.
4. There are implicit time subscripts on all variables. These are only stated explicitly in the capital updating equation (6).

**Table 2. Summary Simulation Results: Percentage Change by 2011 from Base Year (2001) Values**

| | **Simulation** | | | |
|---|---|---|---|---|
| | No finance demand shock | | Finance demand shock | |
| | **1** | **2** | **3** | **4** |
| | Nil net migration | 200 net in-migation p.a | Nil net migration | 200 net in-migation p.a |
| **GDP** | -0.46 | 1.58 | 9.11 | 11.31 |
| **GDP per head** | -1.68 | -2.27 | 7.89 | 7.46 |
| **Real Wage** | 0.42 | -1.04 | 5.23 | 3.66 |
| **Real HH Income & Expend.** | -0.33 | 1.52 | 11.73 | 13.71 |
| **Total Employment** | -0.76 | 2.82 | -0.76 | 2.82 |
| **CPI** | 0.13 | -0.23 | 2.22 | 1.86 |
| **Total automotive fuel use** | -0.52 | 1.89 | 5.96 | 8.36 |
| **Government sector** | 0.48 | 3.07 | 3.55 | 6.18 |
| **Other production** | -0.76 | 2.39 | -3.54 | -0.48 |
| **Households** | -0.33 | 1.52 | 11.73 | 13.71 |
| **Tourists** | -1.77 | 3.95 | -22.25 | -17.60 |
| **GWP Index** | -0.50 | 2.17 | 1.82 | 4.43 |

**Table 3. Summary Sensitivity Analysis Results: Sim3 and ΔSim4**

**Percentage Change in Household Income and Expenditure and Total Automotive Fuel Use by 2011**

## Simulation 3

**(a) Real Household Income and Expenditure**

**Nil net migration: % change from base year (2001) values**

| CES substitution elasticity K/L (σ) | Armington elasticity of export demand (η) | | | | |
|---|---|---|---|---|---|
| | 0.5 | CD (1) | 2 | 3 | **5** |
| 1.5 | * | * | 17.16 | 15.35 | 12.95 |
| 1.2 | * | 20.50 | 17.30 | 15.20 | 12.55 |
| CD (1) | 24.17 | 21.08 | 17.37 | 15.04 | 12.20 |
| **0.8** | 25.56 | 21.78 | 17.40 | 14.77 | **11.73** |
| 0.5 | 28.63 | 23.08 | 17.17 | 14.00 | 10.70 |
| 0.3 | 32.02 | * | 16.48 | 12.96 | 9.69 |
| 0.1 | * | 24.02 | 14.69 | 11.35 | 8.59 |

**(b)Total Automotive Fuel Use**

**Nil net migration: % change from base year (2001) values**

| CES substitution elasticity K/L (σ) | Armington elasticity of export demand (η) | | | | |
|---|---|---|---|---|---|
| | 0.5 | CD (1) | 2 | 3 | **5** |
| 1.5 | * | * | 11.21 | 9.41 | 7.18 |
| 1.2 | * | 14.01 | 10.94 | 9.00 | 6.72 |
| CD (1) | 16.94 | 14.11 | 10.71 | 8.67 | 6.36 |
| **0.8** | 17.53 | 14.22 | 10.44 | 8.29 | **5.96** |
| 0.5 | 18.91 | 14.45 | 9.87 | 7.53 | 5.22 |
| 0.3 | 20.61 | * | 9.24 | 6.81 | 4.60 |
| 0.1 | * | 14.62 | 8.22 | 5.91 | 3.96 |

## ΔSim4

**(c)Real household income and expenditure**

**Additional % change from base year (2001) values**

**From 200 net in-migration p.a.**

| CES substitution elasticity K/L (σ) | Armington elasticity of export demand (η) | | | | |
|---|---|---|---|---|---|
| | 0.5 | CD (1) | 2 | 3 | **5** |
| 1.5 | * | * | 2.02 | 2.17 | 2.29 |
| 1.2 | * | 1.57 | 1.93 | 2.08 | 2.20 |
| CD (1) | 0.98 | 1.45 | 1.84 | 2.00 | 2.11 |
| **0.8** | 0.72 | 1.27 | 1.70 | 1.87 | **1.98** |
| 0.5 | 0.01 | 0.79 | 1.31 | 1.49 | 1.62 |
| 0.3 | -1.08 | * | 0.66 | 0.88 | 1.07 |
| 0.1 | * | -3.26 | -2.11 | -1.68 | -1.30 |

**(d)Total Automotive Fuel Use**

**Additional % change from base year (2001) values**

**from 200 net in-migration p.a.**

| CES substitution elasticity K/L (σ) | Armington elasticity of export demand (η) | | | | |
|---|---|---|---|---|---|
| | 0.5 | CD (1) | 2 | 3 | **5** |
| 1.5 | * | * | 2.14 | 2.31 | 2.48 |
| 1.2 | * | 1.77 | 2.12 | 2.29 | 2.46 |
| CD (1) | 1.30 | 1.71 | 2.09 | 2.26 | 2.44 |
| **0.8** | 1.16 | 1.63 | 2.03 | 2.21 | **2.41** |
| 0.5 | 0.74 | 1.37 | 1.84 | 2.06 | 2.30 |
| 0.3 | 0.05 | * | 1.50 | 1.78 | 2.12 |
| 0.1 | * | -1.10 | 0.03 | 0.61 | 1.39 |

Table 4. Summary Sensitivity Results: Sim1-4

Percentage Change By 2011 From Base Year (2001) Values

**SIMULATION 1 - NIL NET MIGRATION, NO FINANCE DEMAND SHOCK - SENSITIVITY ANALYSIS**

| | EXOGENOUS LABOUR SUPPLY | | | BRW - LR elasticity LS wrt real wage 0.2 | | |
|---|---|---|---|---|---|---|
| | SPEED ADJUSTMENT CAPITAL STOCK PARAMETER | | | SPEED ADJUSTMENT CAPITAL STOCK PARAMETER | | |
| | 0.3 | 0.5 | 0.7 | 0.3 | 0.5 | 0.7 |
| GDP | -0.41 | **-0.46** | -0.50 | -0.38 | -0.43 | -0.47 |
| GDP per head | -1.63 | **-1.68** | -1.72 | -1.60 | -1.65 | -1.69 |
| Real Wage | 0.48 | **0.42** | 0.39 | 0.45 | 0.40 | 0.37 |
| Real HH Income & Expend. | -0.28 | **-0.33** | -0.36 | -0.26 | -0.31 | -0.33 |
| Total Employment | -0.76 | **-0.76** | -0.76 | -0.71 | -0.71 | -0.72 |
| CPI | 0.13 | **0.13** | 0.13 | 0.13 | 0.12 | 0.12 |
| Total automotive fuel use | -0.49 | **-0.52** | -0.54 | -0.46 | -0.49 | -0.51 |
| Government sector | 0.50 | **0.48** | 0.47 | 0.51 | 0.50 | 0.49 |
| Other production | -0.72 | **-0.76** | -0.80 | -0.68 | -0.72 | -0.75 |
| Households | -0.28 | **-0.33** | -0.36 | -0.26 | -0.31 | -0.33 |
| Tourists | -1.96 | **-1.77** | -1.66 | -1.86 | -1.68 | -1.59 |
| GWP Index | -0.47 | **-0.50** | -0.52 | -0.43 | -0.46 | -0.48 |

**SIMULATION 2 - 200 IN-MIGRATION PER ANNUM, NO FINANCE DEMAND SHOCK - SENSITIVITY ANALYSIS**

| | EXOGENOUS LABOUR SUPPLY | | | BRW - LR elasticity LS wrt real wage 0.2 | | |
|---|---|---|---|---|---|---|
| | SPEED ADJUSTMENT CAPITAL STOCK PARAMETER | | | SPEED ADJUSTMENT CAPITAL STOCK PARAMETER | | |
| | 0.3 | 0.5 | 0.7 | 0.3 | 0.5 | 0.7 |
| GDP | 1.43 | **1.58** | 1.70 | 1.35 | 1.51 | 1.63 |
| GDP per head | -2.43 | **-2.27** | -2.15 | -2.50 | -2.34 | -2.22 |
| Real Wage | -1.23 | **-1.04** | -0.91 | -1.15 | -0.99 | -0.87 |
| Real HH Income & Expend. | 1.38 | **1.52** | 1.62 | 1.33 | 1.47 | 1.56 |
| Total Employment | 2.82 | **2.82** | 2.82 | 2.67 | 2.70 | 2.71 |
| CPI | -0.21 | **-0.23** | -0.23 | -0.20 | -0.21 | -0.22 |
| Total automotive fuel use | 1.77 | **1.89** | 1.96 | 1.69 | 1.81 | 1.89 |
| Government sector | 3.01 | **3.07** | 3.11 | 2.98 | 3.04 | 3.08 |
| Other production | 2.17 | **2.39** | 2.51 | 2.05 | 2.27 | 2.40 |
| Households | 1.38 | **1.52** | 1.62 | 1.33 | 1.47 | 1.56 |
| Tourists | 4.40 | **3.95** | 3.66 | 4.09 | 3.72 | 3.47 |
| GWP Index | 2.06 | **2.17** | 2.24 | 1.96 | 2.08 | 2.16 |

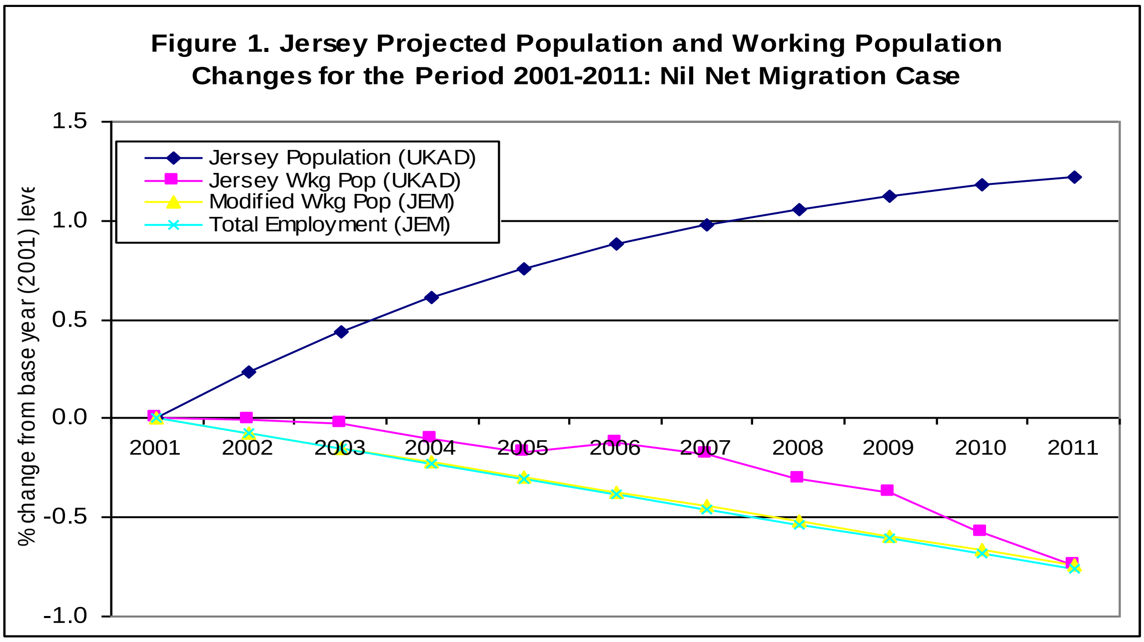
**SIMULATION 3 - NIL NET MIGRATION, 50% FINANCE DEMAND SHOCK - SENSITIVITY ANALYSIS**

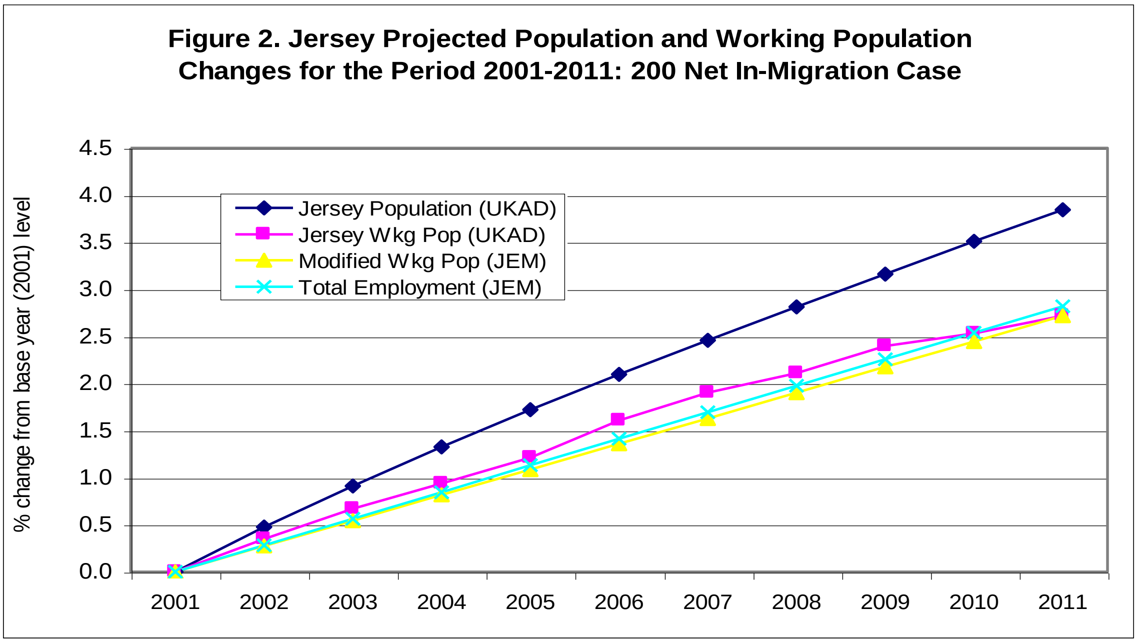
| | EXOGENOUS LABOUR SUPPLY | | | BRW - LR elasticity LS wrt real wage 0.2 | | |
|---|---|---|---|---|---|---|
| | SPEED ADJUSTMENT CAPITAL STOCK PARAMETER | | | SPEED ADJUSTMENT CAPITAL STOCK PARAMETER | | |
| | 0.3 | 0.5 | 0.7 | 0.3 | 0.5 | 0.7 |
| GDP | 6.65 | **9.11** | 10.66 | 6.91 | 9.45 | 11.05 |
| GDP per head | 5.43 | **7.89** | 9.44 | 5.69 | 8.23 | 9.83 |
| Real Wage | 4.55 | **5.23** | 5.60 | 4.34 | 5.03 | 5.41 |
| Real HH Income & Expend. | 10.41 | **11.73** | 12.52 | 10.60 | 11.97 | 12.80 |
| Total Employment | -0.76 | **-0.76** | -0.76 | -0.35 | -0.30 | -0.27 |
| CPI | 2.05 | **2.22** | 2.32 | 2.00 | 2.16 | 2.26 |
| Total automotive fuel use | 5.27 | **5.96** | 6.36 | 5.53 | 6.27 | 6.71 |
| Government sector | 3.18 | **3.55** | 3.77 | 3.30 | 3.70 | 3.93 |
| Other production | -3.05 | **-3.54** | -3.90 | -2.68 | -3.10 | -3.42 |
| Households | 10.41 | **11.73** | 12.52 | 10.60 | 11.97 | 12.80 |
| Tourists | -20.33 | **-22.25** | -23.33 | -19.68 | -21.61 | -22.71 |
| GWP Index | 1.74 | **1.82** | 1.87 | 2.02 | 2.16 | 2.24 |

**SIMULATION 4 - 200 IN-MIGRATION PER ANNUM, 50% FINANCE DEMAND SHOCK - SENSITIVITY ANALYSIS**

| | EXOGENOUS LABOUR SUPPLY | | | BRW - LR elasticity LS wrt real wage 0.2 | | |
|---|---|---|---|---|---|---|
| | SPEED ADJUSTMENT CAPITAL STOCK PARAMETER | | | SPEED ADJUSTMENT CAPITAL STOCK PARAMETER | | |
| | 0.3 | 0.5 | 0.7 | 0.3 | 0.5 | 0.7 |
| GDP | 8.59 | **11.31** | 13.05 | 8.77 | 11.57 | 13.38 |
| GDP per head | 4.74 | **7.46** | 9.20 | 4.92 | 7.72 | 9.37 |
| Real Wage | 2.74 | **3.66** | 4.19 | 2.61 | 3.51 | 4.04 |
| Real HH Income & Expend. | 12.18 | **13.71** | 14.65 | 12.31 | 13.90 | 14.88 |
| Total Employment | 2.82 | **2.82** | 2.82 | 3.10 | 3.18 | 3.23 |
| CPI | 1.70 | **1.86** | 1.96 | 1.66 | 1.81 | 1.90 |
| Total automotive fuel use | 7.52 | **8.36** | 8.88 | 7.69 | 8.61 | 9.16 |
| Government sector | 5.74 | **6.18** | 6.46 | 5.82 | 6.30 | 6.60 |
| Other production | -0.23 | **-0.48** | -0.70 | 0.01 | -0.14 | -0.31 |
| Households | 12.18 | **13.71** | 14.65 | 12.31 | 13.90 | 14.88 |
| Tourists | -15.04 | **-17.60** | -19.07 | -14.60 | -17.10 | -18.56 |
| GWP Index | 4.22 | **4.43** | 4.57 | 4.41 | 4.69 | 4.88 |

## Figures




***Note:*** In Figures 1 and 2, the lines marked UKAD are projections by the UK Government Actuarial Department, while those marked JEM are the actual trends inputted to the Jersey Economic Model

**Figure 3. General Equilibrium Labour Supply and Demand under the Population and Demand Shock Scenarios Simulated**

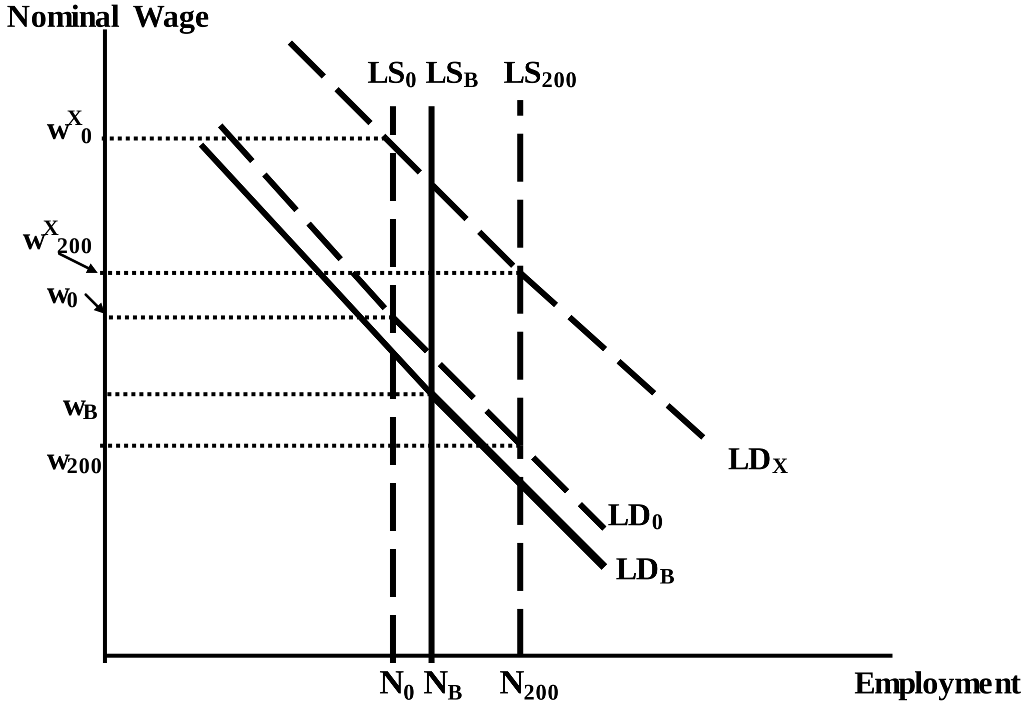



**Figure 4. General Equilibrium Labour Supply and Demand under Different Assumptions About the Elasticity of Labour Demand**

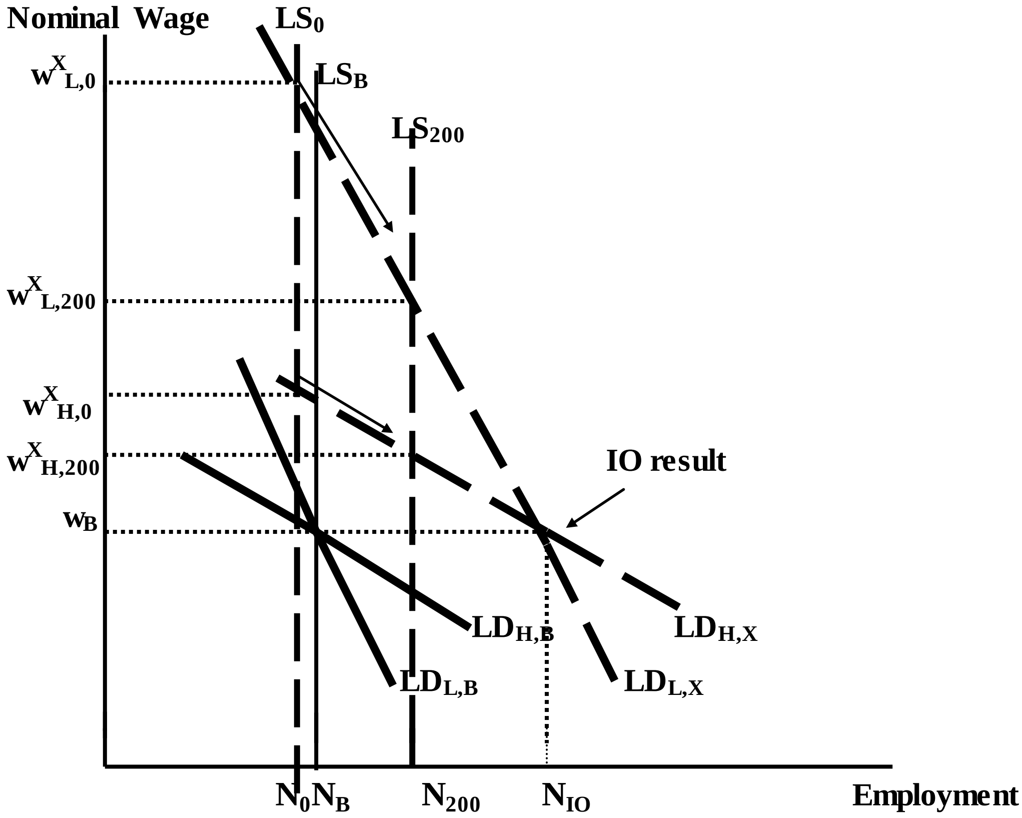


**Figure 5. Impact By 2011 of Nil Net Migration (Simulation 1) on Sectoral Employment and Output In Jersey**

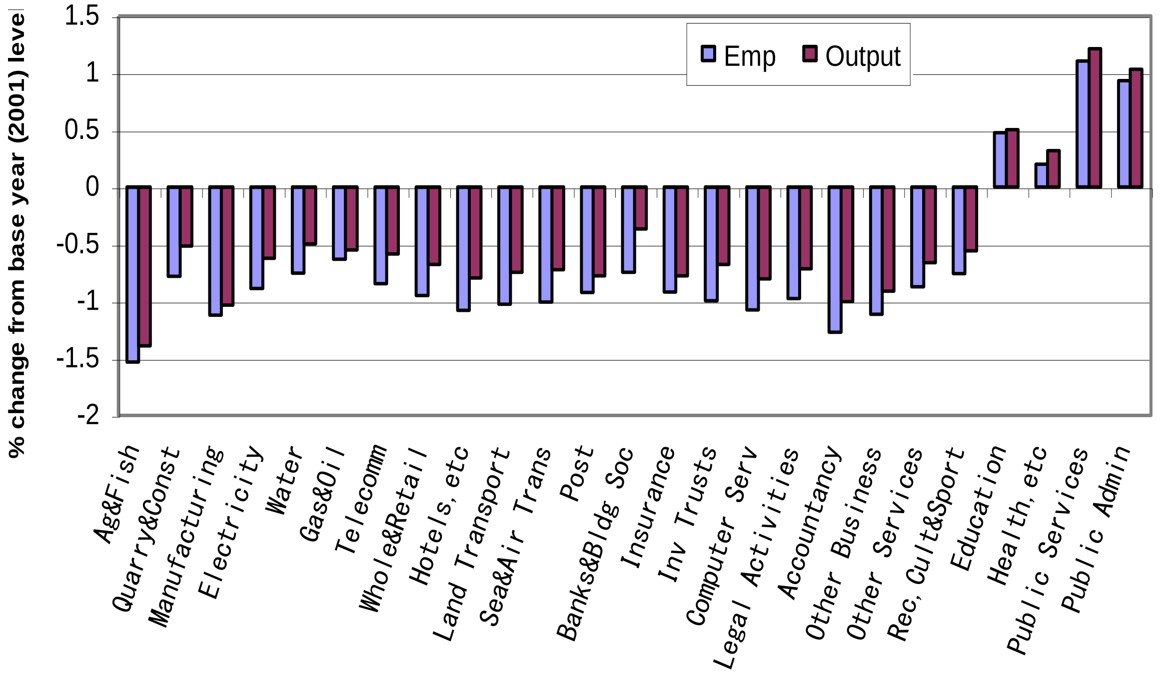
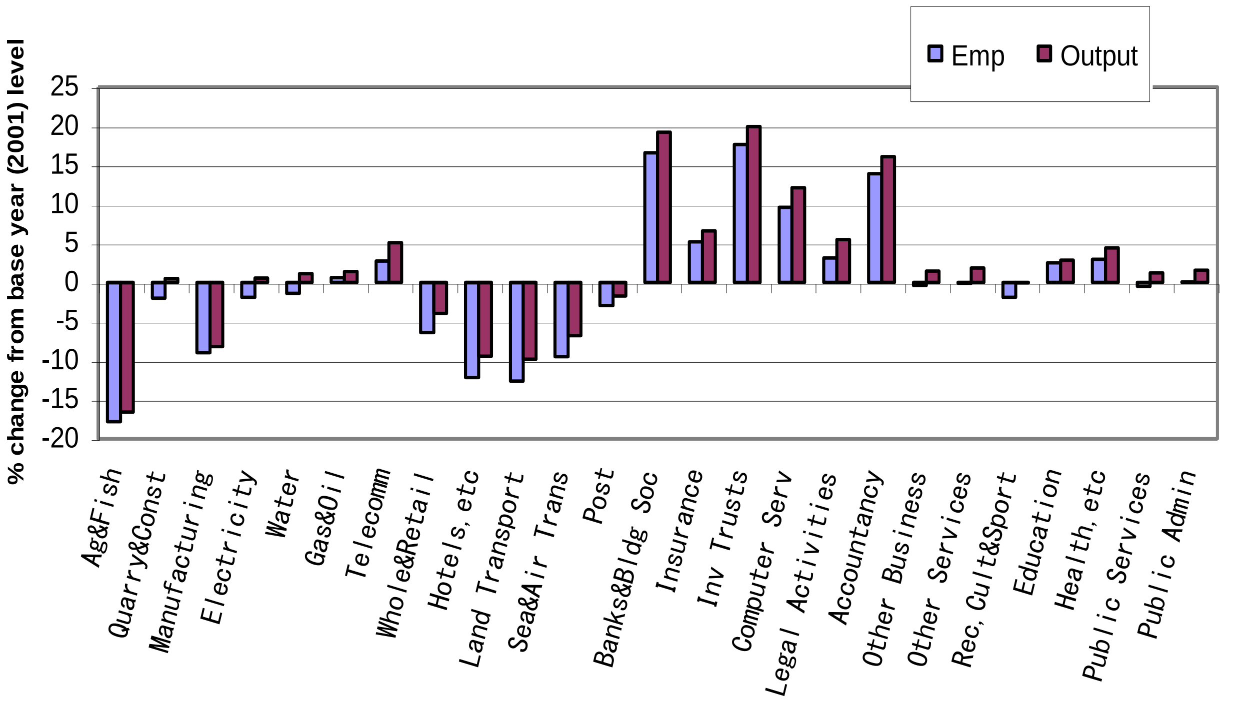



**Figure 6. Impact By 2011 of Nil Net Migration with a 50% Export Demand Shock to the Finance Sector (Simulation 2) on Sectoral Output and Employment in Jersey**



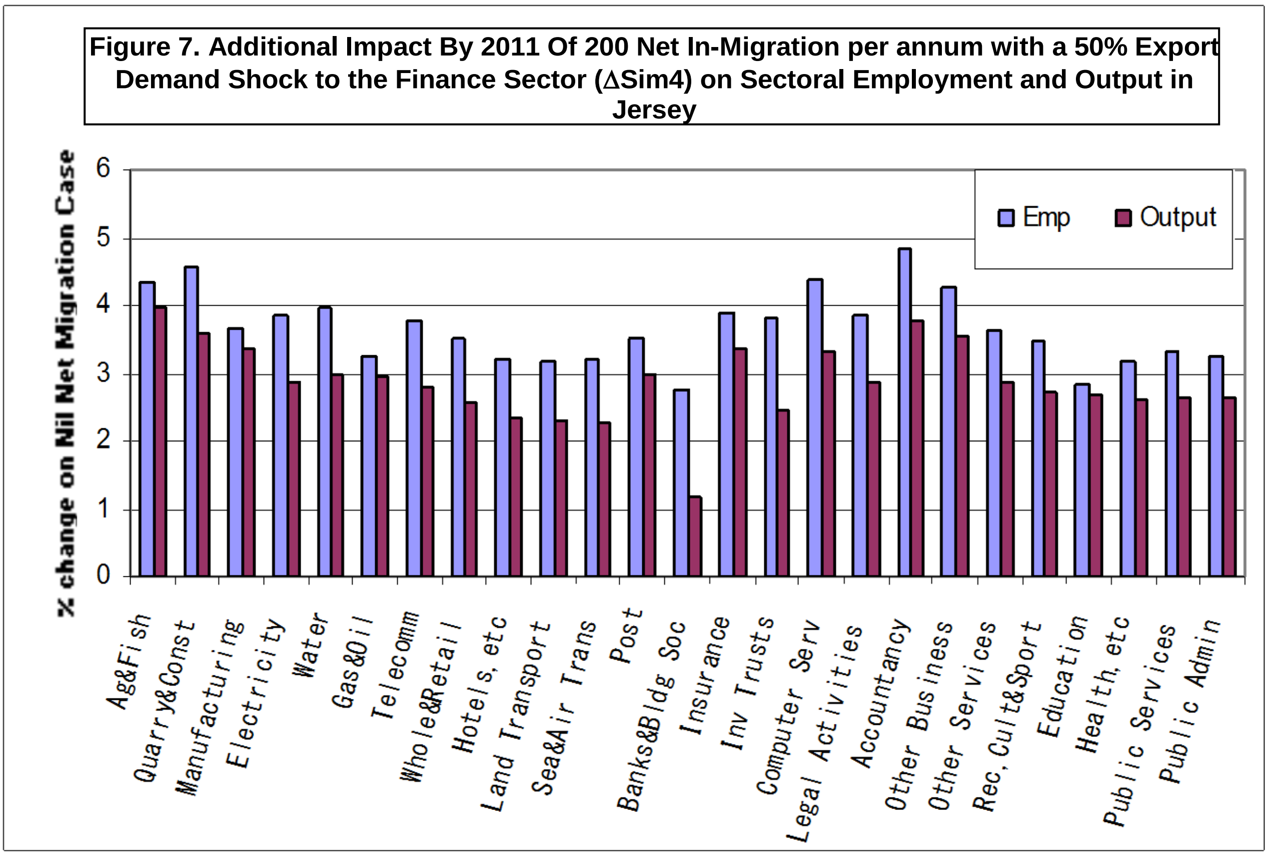


Figure 7. Additional Impact By 2011 Of 200 Net In-Migration per annum with a 50% Export Demand Shock to the Finance Sector (ΔSim4) on Sectoral Employment and Output in Jersey
% change on Nil Net Migration Case
Emp
Output
Ag&Fish
Quarry&Const
Manufacturing
Electricity
Water
Gas&Oil
Telecomm
Whole&Retail
Hotels, etc
Land Transport
Sea&Air Trans
Post
Banks&Bldg Soc
Insurance
Inv Trusts
Computer Serv
Legal Activities
Accountancy
Other Business
Other Services
Rec, Cult&Sport
Education
Health, etc
Public Services
Public Admin

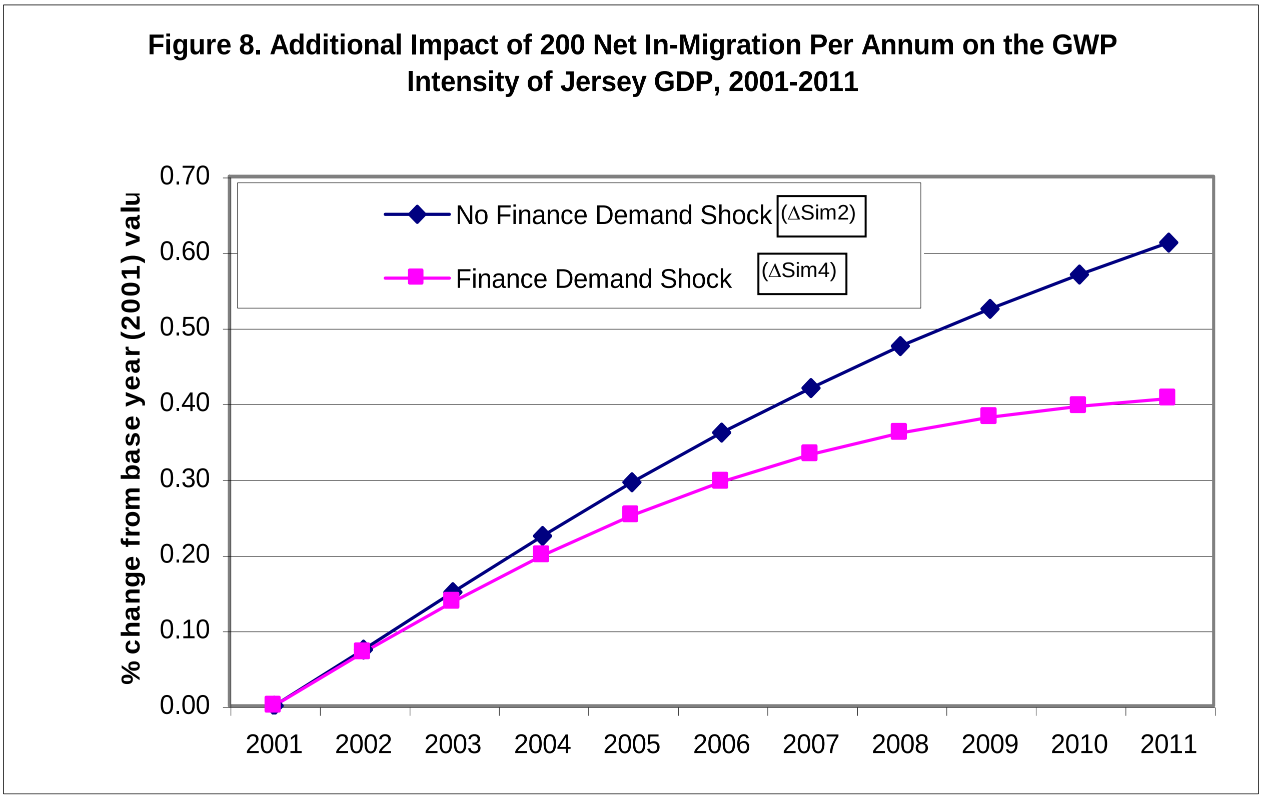



Figure 8. Additional Impact of 200 Net In-Migration Per Annum on the GWP Intensity of Jersey GDP, 2001-2011
% change from base year (2001) valu
No Finance Demand Shock (ΔSim2)
Finance Demand Shock (ΔSim4)
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011