Resilience in a Behavioural/Keynesian Regional Computable General Equilibrium Model *

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Abstract

This paper constructs a regional dynamic macroeconomic model with an eclectic, broadly Keynesian and behavioural flavour. The model, which is parameterised on Scottish data, is used to identify the impact of expectations and business confidence on regional resilience. Simulations compare the evolution of the regional economy after a temporary negative export shock under a range of investment functions. The mainstream neo-classical perfect-foresight form generates a reduction in activity which is small and is limited to the duration of the shock. The heuristic-based, imperfect-information investment models produce more negative, longer-lasting and unstable adjustment paths.

1. Introduction

Economists have faced strong and widespread criticism because of their inability to: predict the onset of the financial crisis; question the institutions which created that crisis; and more especially, provide subsequent appropriate policy advice (Earle et al., 2017; Kwak, 2017; Wren-Lewis 2015). A key aspect of this critique is the perceived malign influence of abstract theory and, in particular, general equilibrium analysis. However, there is an obvious attraction to adopting a method that models the economy as a whole, simultaneously incorporating both micro- and macro-economic perspectives in an internally consistent and flexible manner. Moreover, it is a misconception that general equilibrium analysis is constrained by the conventional neo-classical straightjacket. General equilibrium models do not automatically require markets to clear or choices to be made optimally. In the aftermath of the financial crisis there has been much discussion of the influence of behavioural aspects of decision making.

The present paper has three primary aims. The first is to outline a Computable General Equilibrium (CGE) modelling framework that can encompass a wide range of conceptions conceptions as to the operation of a (regional) economy. The second is to illustrate this flexibility by developing a CGE model for Scotland which exhibits a number of key behavioural characteristics. This model has an eclectic, broadly Keynesian, flavour and is underpinned by the work of Joan Robinson and the psychologist Daniel Kahneman.[1] The paper's third aim is to use this model to investigate the role that firm agency and decision making play in determining regional resilience (Martin, 2012; Martin and Sunley, 2015). Specifically we investigate the effect of different expectation-formation processes on the level of investment and the impact that this has on the response of overall regional economic activity to a temporary exogenous demand disturbance. We use the CGE framework as a test bed so as to study the impact of varying a key determinant of resilience in a controlled theoretical and empirical setting.

Section 2 introduces the background to the behavioural approach and the link with Keynesian economics. Section 3 outlines the specific way in which the AMOS CGE regional model has been adapted to incorporate behavioural concepts. Section 4 details alternative investment

[1] For accounts of Joan Robinson's and Daniel Kahneman's life and work see Harcourt (1995) and Lewis (2017) respectively.

behaviour. Section 5 discusses the calibration and parameterisation of the model and the simulation strategy. Section 6 reports the simulation results. Section 7 compares the regional resilience to demand side shocks implied by the different characterisations of investment behaviour. Section 8 is a short conclusion.

2. Background

The basic characteristics of the neo-classical research programme are summarised by Becker (1976, p.5) : "The combined assumptions of maximizing behaviour, market equilibrium, and stable preferences, used relentlessly and unflinchingly, form the heart of the economic approach as I see it." Both Arrow and Debreu received the Nobel Prize in Economics, at least in part for their separate work on the existence and uniqueness of general equilibria under these neo-classical assumptions, even though this analysis has almost no practical application.[2] However, important welfare results apply under such equilibria; for example Rodrik (2016) claims that the First Theorem of Welfare Economics – essentially that universal perfect competition in an economy in general equilibrium ensures a Pareto Optimal outcome – is one of the crown jewels of economics. In this way standard neo-classical theory is an interweaving of normative and positive elements, purporting not only to account for how the economy actually operates but also how it ought to operate, if desirable consumer welfare ends are to be achieved (Weimann et al. 2015).

But whilst the neo-classical research programme is presented as being theoretically progressive, its empirical success is much less certain. In the "Anomolies" section of the Journal of Economic Perspectives, Thaler teased other economists with instances of their own behaviour that seemed irrational and therefore inconsistent with traditional microeconomic theory (Thaler, 2015). Similarly, through the development of game theory, rational strategic behaviour under perfect and imperfect information has been extensively studied. But classroom experiments with many simple games failed to replicate the outcomes predicted by theory. This raises difficulties for the conventional instrumentalist defence of the use of unrealistic assumptions in economics which rests on the supposed predictive power of standard theory (Friedman, 1953). Moreover, the imposition of the efficient markets hypothesis and rational expectations led to the hegemony in the academic macroeconomic modelling literature that failed to forsee the financial crash. But much more importantly,

[2] McKenzie independently published key results marginally earlier than the other two but missed out (Duppe and Weintraub, 2014).

these macroeconomic models also proved of little use in dealing with the subsequent aftermath (Vines and Wills, 2018; Wren-Lewis, 2015; 2018).

Computable General Equilibrium analysis initially had a strong development stream with a non-neoclassical basis (Taylor, 2011). However, this eclectic approach seems to have been swamped by off-the-shelf conventional variants populated with rationally maximising agents. The standard applied general equilibrium model has a consistent neo-classical base. It assumes perfectly competitive markets for goods and factors, well-behaved production and consumption functions and, where the models are dynamic, perfect foresight is typically imposed and balanced budget fiscal rules applied. A central notion is that all decisions are rational and not subject to systematic error. It is important to stress that such models are not just theoretical tools but actually used to inform policy debate.[3]

Economics is therefore typically presented as comprising a single dominant model, fundamentally based on universal and consistent rational behaviour. As a matter of principle, Joan Robinson fought against such a one-size-fits-all approach, recognising that appropriate economic analysis should reflect the social and administrative conditions under which it is applied. Further, changing key assumptions is a useful form of thought experiment (Robinson, 1960).[4] She was particularly interested in alternative conceptions of the economy and how these varied across different schools of economic thought, often carrying a clear ideological charge (Robinson, 1962). As Amos Tversky, co-author of Nobel-cited work with Kahneman, states: “Reality is a cloud of possibilities, not a point” (Lewis, 2017, p.312).

In this respect, is it reasonable to assume that economic agents are rational and fully informed? Kahneman (2012) makes the distinction between Type 1 and Type 2 thinking. Type 1 thought processes cover automatic responses to stimuli, associative thinking and heuristics (or rules of thumb). It is “low-cost” mental activity. Humans find it easy to do and adopt Type 1 thinking as a default. Type 2 mental activity involves simultaneously considering or comparing previously stored information. These are “high-cost” thought processes that humans typically avoid through the use of mental short-cuts, gut feelings or intuition. So whilst neoclassical general equilibrium theory implies that all decisions are

[3] A typical example is the use by HM Treasury of such a CGE model in assessing the economic impact of fiscal changes (HM Revenue and Customs, 2013; HM Treasury and HM Revenue and Customs, 2014).

[4] Rodrik (2016) takes a similar viewpoint in stressing the use of *a* model, rather than *the* model.

made using Type 2 processes, there is extensive evidence that much behaviour by economic agents is driven by Type I thinking.[5]

It is often argued that there has been a behavioural revolution in economics. However, such a revolution seems to be only skin deep; behavioural economics essentially appears to have been accommodated within the conventional neo-classical framework. As Angner (2012, p. xv) states; “while behavioural economists reject the standard theory as a descriptive theory, they typically accept it as normative theory”. Further, “much of behavioural economics is a modification or extension of neo-classical theory.” Therefore whilst a behaviouralist approach would seem to imply a rather radical questioning of standard neo-classical theory, its actual impact has been much more muted. In this paper we wish to identify some of the ways in which behavioural concepts could be more firmly anchored in general equilibrium models. It is clear that such a model would have a strong Keynesian flavour. We also wish to illustrate how taking such a behavioural/Keynesian approach to investment behaviour would affect the modelling of regional resilience.

3. A Behavioural Regional CGE

In this paper we demonstrate the potential flexibility of CGE modelling and take the first step in developing a variant of the AMOS model for Scotland that incorporates behavioural assumptions in a fundamental way (Harrigan et al. 1991).[6] The primary focus is to provide alternative specifications of the investment function, some of which incorporate behavioural characteristics. However, we also discuss behavioural interpretations of other elements of the model, such as household consumption and the labour market.

A key characteristic of Computable General Equilibrium models is their potential flexibility. In the present case we retain a standard supply side through imposing a competitive market structure where firms are assumed to maximise profit. Essentially this means that in the long run production occurs at minimum cost with a constant profit rate across all sectors. This

[5] The standard claim is that for prediction it is irrelevant whether or not agents consciously maximise as long as they act “as if” they maximise (Friedman, 1953). However, this implies that errors are random. The strength of the behavioural critique is that at least some errors are systematic. Of course whether in principle Friedman’s “as if” theories give adequate explanations is a different story (McLachlan and Swales, 1990).

[6] AMOS is an acronym for *A M*acro-micro model *O*f *S*cotland

condition is imposed by Keynesian, Marxian, neo-Ricardian and standard neo-classical models. Also in many sectors computerisation, together with improved communications and connectivity, has allowed more effective cost minimisation. The behavioural elements are introduced in the consumption, labour market and investment decisions.

Behavioural research points to a degree of irrationality in individual decision making. Some inconsistent behaviour is systematic, such as loss aversion, distorted time preference and difficulty in dealing with uncertainty and probability. Other inconsistencies are more idiosyncratic. For example, an individual's response to specific choices might depend crucially on how these choices are framed. Further, firms are aware of such consumer informational asymmetries and irrationality and use these in their own interests through target advertising, political lobbying and other types of promotion.

In the present model we take consumption to be consistent with standard theory. However, we do not consider these choices necessarily optimal in any normative sense. Therefore whilst we model household expenditure using deterministic consumption functions which are price and income sensitive, we do not assume that these represent welfare maximising under constraints. Nor do we have a measure of welfare that can be used to compare alternative equilibria. Consumption behaviour is simply a constraint on the firm's profit maximising behaviour.[7]

In the standard CGE neo-classical approach to the labour market, the worker simply trades off leisure for wage income. The wage and other employment conditions are not determined by negotiation between the firm and the worker (or their representative) and unemployment is treated as voluntary leisure. Behavioural economists have taken a different view, stressing mechanisms such as nominal wage stickiness and the importance of the worker's reference point in determining the wage bargain (Kahneman, 2012, p. 290; Thaler, 2015, p. 131-132). Similarly, empirical work identifies unemployment as being a particularly potent and persistent cause of self-reported reductions in well-being (Weimann et al, 2015). Clearly there is a strong argument for considering the labour market, from both a practical and policy perspective, in a bargaining or imperfectly competitive manner.

[7] There are many examples of firms and industries acting against their own customers' interests, typically through the manipulation of asymmetric information or the encouragement of addictive behaviour. See, for example Cappuccio et al., 2014; Eyal and Hoover, 2014; Harford, 2017; House of Commons Committee of Public Accounts, 2016; Keefe, 2017; and Lewis, 2016.

In the AMOS CGE model we have a number of alternative labour market options, which include closures exhibiting nominal and real wage rigidity. In the simulations reported in this paper, labour supply is not treated in the conventional neo-classical manner. Rather we consider wage determination to be governed by social and legal institutions and constraints. We therefore characterise the labour market as operating through a wage curve, where the real wage is a function of the unemployment rate. This is given as:

$$(1) \qquad \ln\left[\frac{w_t}{CPI_t}\right] = \theta - \varepsilon \ln(u_t)$$

In equation (1), w represents the nominal take-home wage, *CPI* is the consumer price index, u is the unemployment rate and the t subscript stands for the time period. The parameter ε is the elasticity of the real wage with respect to the unemployment rate and θ is calibrated so as to reproduce the base year data. There is extensive evidence for such a labour market specification, which can be motivated through a bargaining or efficiency wage interpretation (Blanchflower and Oswald, 2005; Galvez, 2014). In each there is involuntary unemployment so that workers cannot freely choose whether to work or not; that is to say, in each case there would be unemployed workers prepared to work at the existing real wage.

In a conventional CGE model, the firm plays a totally passive role. The representative household is characterised as both the supplier of productive inputs and the consumer of commodities. Technology transforms inputs into outputs; there are markets, but no other intervening institutions. This has the implication that both saving and investing are undertaken by the household, becoming essentially the same activity driven by the need to optimise consumption over time. This runs counter to a key element of Keynesian analysis, which is that savings and investment are actions taken by two quite separate groups of people.

Moreover, behavioural approaches have strongly questioned the notion that savings are determined in a rational, optimal manner, as a trade-off between present and future consumption (Akerlof and Shiller, 2009). In the present model we adopt a Keynesian saving function where savings are a fixed share of disposable income, with the interest rate determined in extra-regional (national and international) financial markets. Saving and investment are therefore not equilibrated through movements in the interest rate, which is governed by liquidity preference. They therefore have to be analysed separately.

4. Alternative Investment Behaviour

Investment necessarily commits the firm to costs in advance of future revenues. In making an investment decision, the firm has to predict the time path of relevant exogenous disturbances and the endogenous reaction of the rest of the economic system to these shocks. The part played by expectations is clearly important, with Keynes stressing the role of uncertainty, framed in terms of animal spirits and liquidity preference. This aspect of his work is emphasised by Robinson (1962) and these ideas are strongly supported by behavioural economists, such as Akerlof and Shiller (2009). Certainly in terms of financial investment, as Thaler (2015, p. 209) states: "Keynes … was a true forerunner of behavioural finance". Although authors have previously explicitly linked Keynesian and behavioural approaches, the discussion of animal spirits in behavioural economics is extremely limited (Pech and Milan, 2009). That is to say, there seems a dearth of literature as to how individuals predict the future, and how this affects investment decisions.[8]

The core neo-classical model is characterised by perfect foresight and, in a stochastic context, rational expectations. All economic actors are assumed correctly to foresee the future and act optimally, given that all others are similarly optimising using a correct (neo-classical) model of how the economy operates. Whilst this is a market economy, many futures markets do not exist so that individuals have to be able to correctly model the response of markets in the future to prior exogenous shocks. Essentially, mainstream economists are routinely working on models that assume that economic actors can already solve such models. Behavioural and Keynesian economists disagree and argue that individuals simply do not operate in this way.

There are many experimental studies of choices under risk, where the odds of particular outcomes occurring are known (Kahneman, 2012). Investigating risk in such a restricted and controlled setting sharpens the behavioural results and makes their existence absolutely clear. This work shows that such choices are often inconsistent, failing the very lowest form of rationality, which is clearly problematic for conventional economic theory.

[8] For a discussion of systematic errors made in predicting the impact of present events and decisions on future well-being see Loewenstein and Schkade (1999).

However, the actual decisions that economic agents have to make are typically much more complex. First they involve consistent, exponential discounting of future costs and benefits. But there is clear evidence of the extensive use of hyperbolic discounting which generates time-inconsistency and self-control problems (Ainslie, 1992; Laibson, 1996; Loewenstein and Prelec, 1992). Second, in the perfect foresight model, individuals need to be able to predict and optimally act upon the behaviour of others. But evidence from experiments with the centipede game suggests that in practice individuals find this difficult to do, even in a relatively straightforward situation (Angner, 2012). Where individuals have differing levels of skill, experience or information the optimal decision for any one player depends not on the actual optimum but what they think others believe to be the optimum (Keynes, 1936, Cartwright, 2011, Ch.6). Further, with investment even if agents could calculate what the optimal future capital levels should be for individual sectors, for example, there would still be an issue in practice about co-ordinating the actual investment decisions by individual firms. In this situation there seems no obvious focal point.

In the simulations whose results are reported in Section 6, we introduce an exogenous temporary 5% reduction in export demand that lasts for five periods. We assume that this demand shock is unanticipated. We use three alternative investment functions to determine the subsequent evolution of industrial capital stocks: perfect foresight; partial adjustment with myopic expectations; and partial adjustment with imperfect foresight. Each of these investment models is motivated by a different expectations-formation process.

4.1 Perfect foresight

In this case, although the disturbance is unanticipated, its subsequent size and duration is known, as are the subsequent market reactions. Within the AMOS model, this represents the standard, state-of-the-art neoclassical approach. In this case, in each sector the path of private investment is obtained by maximizing the present value of the representative firm's cash flow:

$$(2)\text{Max } \sum_{t=0}^{\infty} \frac{1}{\left(1+r\right)^{t}} \left[\pi_{i,t} - I_{i,t}\left(1+g\left(\omega_{t}\right)\right) \right]$$

$$\text{subject to } K_{i,t+1} = K_{i,t} \cdot (1-\delta_{i}) + I_{i,t}$$

The cash flow is given by profit, $\pi_{i,t}$, less private investment expenditure, $I_{i,t}$, subject to the presence of adjustment cost $g(\omega_{i,t})$ where $\omega_{i,t} = \frac{I_{i,t}}{K_{i,t}}$ and δ is the rate of physical depreciation.

4.2 Partial adjustment, myopic expectations

In the partial adjustment models, firms attempt to adjust their capital stock to the desired level determined by present input prices and projected output conditions although, because of adjustment costs, this process is not instantaneous. This implies that in these models, gross investment in time period t is equal to depreciation plus some proportion, v, of the difference between the desired capital stock in the next time period, $K^*_{i,t+1}$, and the actual present capital stock, $K_{i.t}$. This implies:

(3) $$I_{i,t} = v\left[K^*_{i,t+1} - K_{i.t}\right] + \delta K_{i,t}$$

The desired capital stock in period t+1 is determined by the output price and cost of capital in time period t, and the expected output in period t+1, $Q^e_{i,t+1}$, so that:

(4) $$K^*_{i,t+1} = K_i(Q^e_{i,t+1}, p_{i,t}, r_{i,t})$$

In the myopic case, the firm takes the existing industry output as the best estimate of output in the next period. Expressed formally, the myopic case implies:

(5) $$Q^e_{i,t+1} = Q_{i,t}$$

4.3 Partial adjustment, imperfect foresight

In the imperfect foresight model firms are forward looking but instead of basing their expectations on fully solving the general equilibrium model of the economy, they use a simple heuristic. This is that future output in their industrial sector will be a linear extension of the past trend in output. A similar phenomenon, in a micro setting, is the mistaken "hot hand" belief amongst basketball players (Gilovich, et al, 1985). This is the conviction that a player whose shooting accuracy has been particularly good in the immediate past will continue to exhibit this accuracy in the immediate future. Also Rosling (2018) notes the strong tendency to project present trends into the future along a linear track. He argues that being able to predict linear paths of projectiles would confer a survival advantage to human beings in the early stage of their evolution and that this remains as a prominent part of our mental toolkit. In the context of regional resilience, note also the linear predicted employment trajectories used by Martin and Sunley (2015, Figures 2 and 3).

We therefore operationalise the partial adjustment, imperfect foresight, model by adopting equations (3) and (4), but by determining the expected output in time t+1 as a linear projection of past output change over the last n periods, so that:

(6) $$Q_{i,t+1}^{e} = Q_{i,t} + \frac{Q_{i,t} - Q_{i,t-n}}{n} = \frac{(n+1)Q_{i,t} - Q_{i,t-n}}{n}$$

5. Model Calibration, Parameterisation and Simulation Strategy

The CGE model is parameterised on a Social Accounting Matrix for Scotland constructed with data for 2010. There are 30 industrial sectors. The real wage is determined by the operation of the wage curve together with a fixed labour force.[9] In all sectors the Armington trade elasticities are set to a value of 2 and the elasticities of substitution in production between labour and capital and between value-added and intermediates are 0.3. For the regional CGE model we impose no balance of payments constraint (Lecca et al., 2013). Also for the present simulations government expenditure is held constant in real terms and tax rates are fixed. This primarily reflects the system of devolved public finances operating in the UK at the time. The Scottish government had essentially no control over tax rates or total public expenditure in Scotland which was set by the UK government, independent of the taxes raised in Scotland.[10]

We simulate the impact of the temporary exogenous demand shock in the following way. The model is initially calibrated to be in long-run equilibrium. This means that if the model were run in period-by-period mode with no change in exogenous variables, the value of none of the

[9] This does not imply that employment is fixed, as participation/unemployment is allowed to vary. For simplicity we impose zero migration but a flow-equilibrium regional migration option is available in the AMOS model.

[10] For an account of Scotland's new fiscal powers subsequent to the recommendations of the Smith Commission see Audit Scotland (2016). A more detailed account of other aspects of the CGE model that we use is given in Lecca et al (2013).

endogenous variables would change. In period 1 we introduce a 5% step reduction in the demand for all Scottish exports. We maintain this reduction for a further four periods and then reverse the export demand change. This means that in period 6 the export demand function returns to its original level.[11] The model is then run forward for a further 40 periods. Each period is equal to a year which is consistent with the annual data used for parameterisation.

In the long run, which is the time interval over which capital stocks are fully adjusted, the economy moves to a new steady-state equilibrium. Because the model generates no hysteresis effects and the disturbance is transitory, in the reported simulations variables ultimately return to their original values. The long-run results exhibit zero change from the base year.[12] However, whilst the model is parameterised on a static equilibrium, the results can also be interpreted as fluctuations around a constant growth trajectory. We simulate with three versions of the model with the different expectation-formation characteristics informing the investment decision, as outlined in Section 4. In all the models the results for all the endogenous variables are reported as percentage changes from the corresponding base-year values.

6. Simulation Results

Table 1 reports the values that a set of key endogenous economic variables take for periods 1, 6, 11 and 16. Period 1 corresponds to the short run (SR) where the negative demand shock has been introduced but the capital stocks are still fixed. Subsequently, in each industry investment updates the capital stock between periods. Period 5 is the last period in which the negative demand shock operates, so that from period 6 the initial export demand parameter is reinstated. Detailed period-by-period impacts on investment, GDP, employment and household consumption are given in Figures 1, 2, 3 and 4. Note that by around period 40 all models have returned to long-run equilibrium but that their adjustment paths are very

[11] This does not mean that in period 6 the actual volume of exports goes back to its original value as this also depends on competitiveness which, as a result of endogenous changes to the capital stock, might differ from the initial value.

[12] If the negative 5% export demand shock were permanent, all the models would generate a long-run reduction in GDP and employment of 1.4% and 1.0% respectively.

different. We begin by discussing the simulation results where investment is determined through perfect foresight.

Figure 1. Period by period adjustment of investment

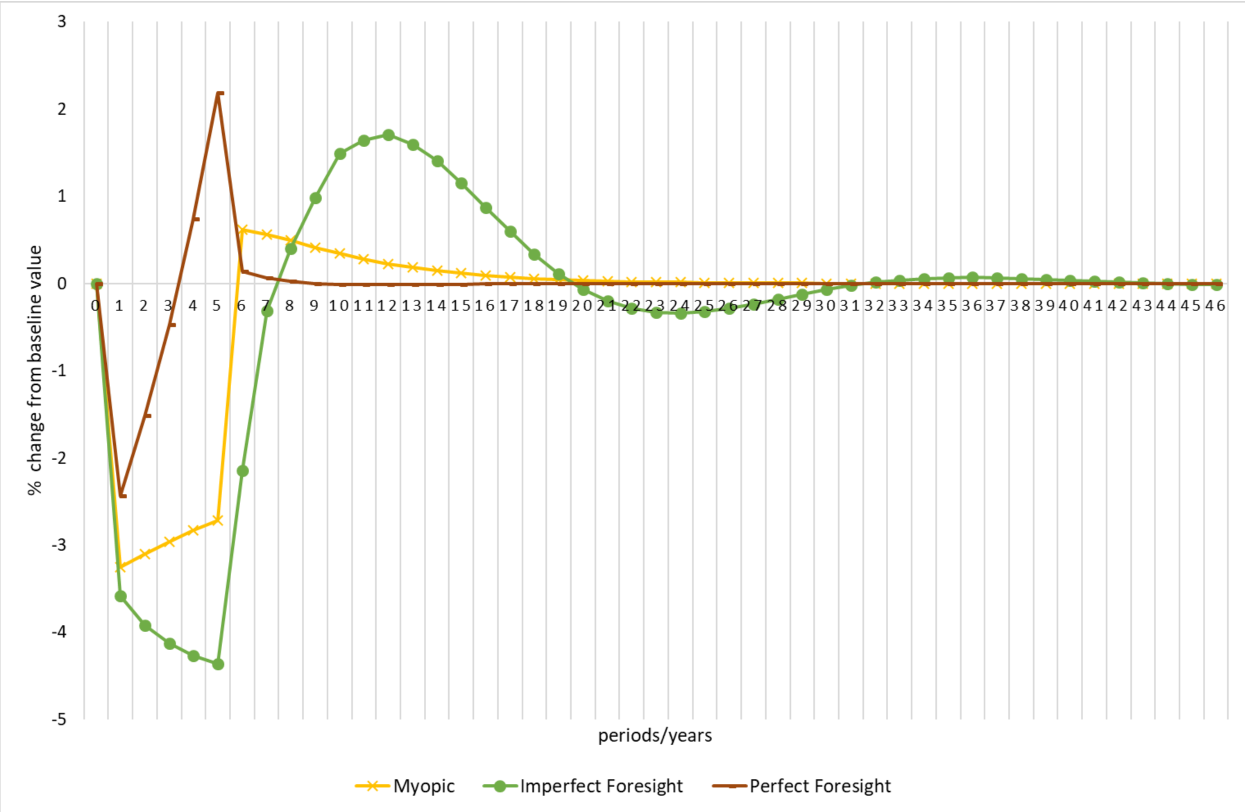

Figure 2. Period by period adjustment of GDP

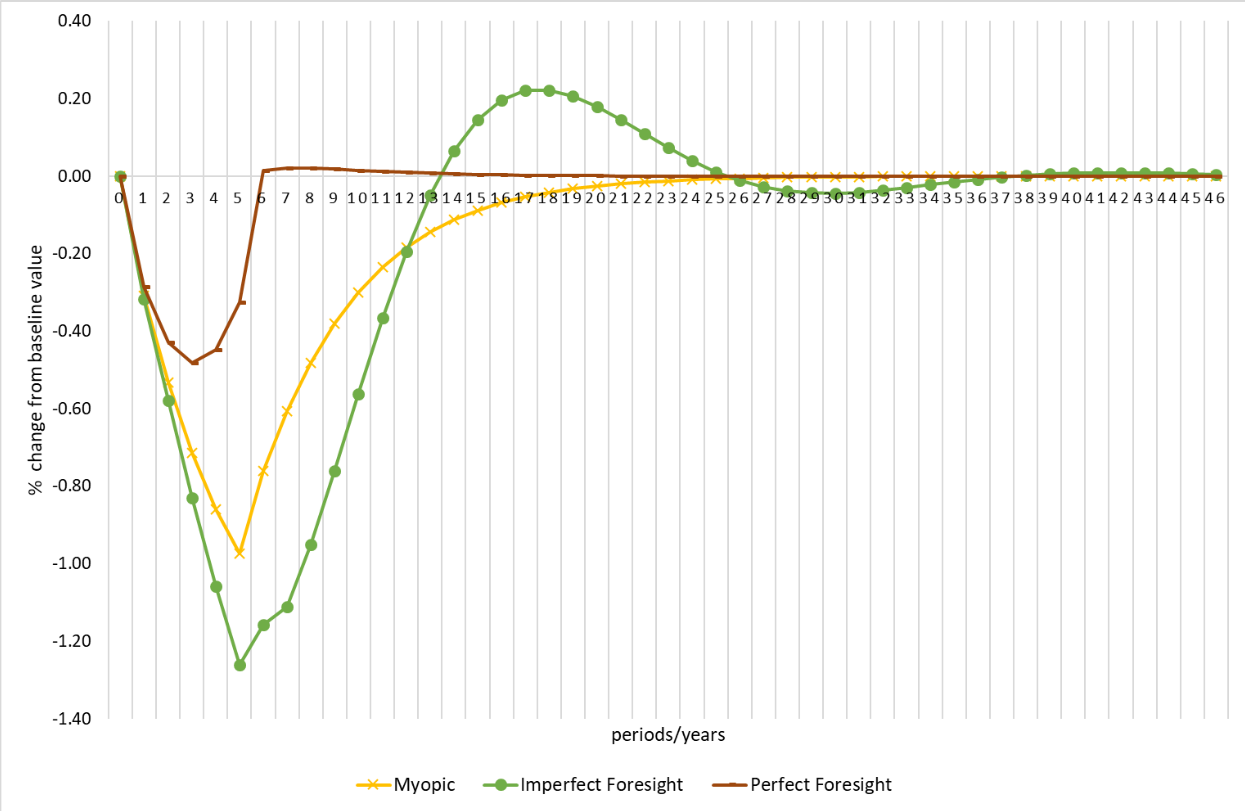

Figure 3. Period by period adjustment of employment

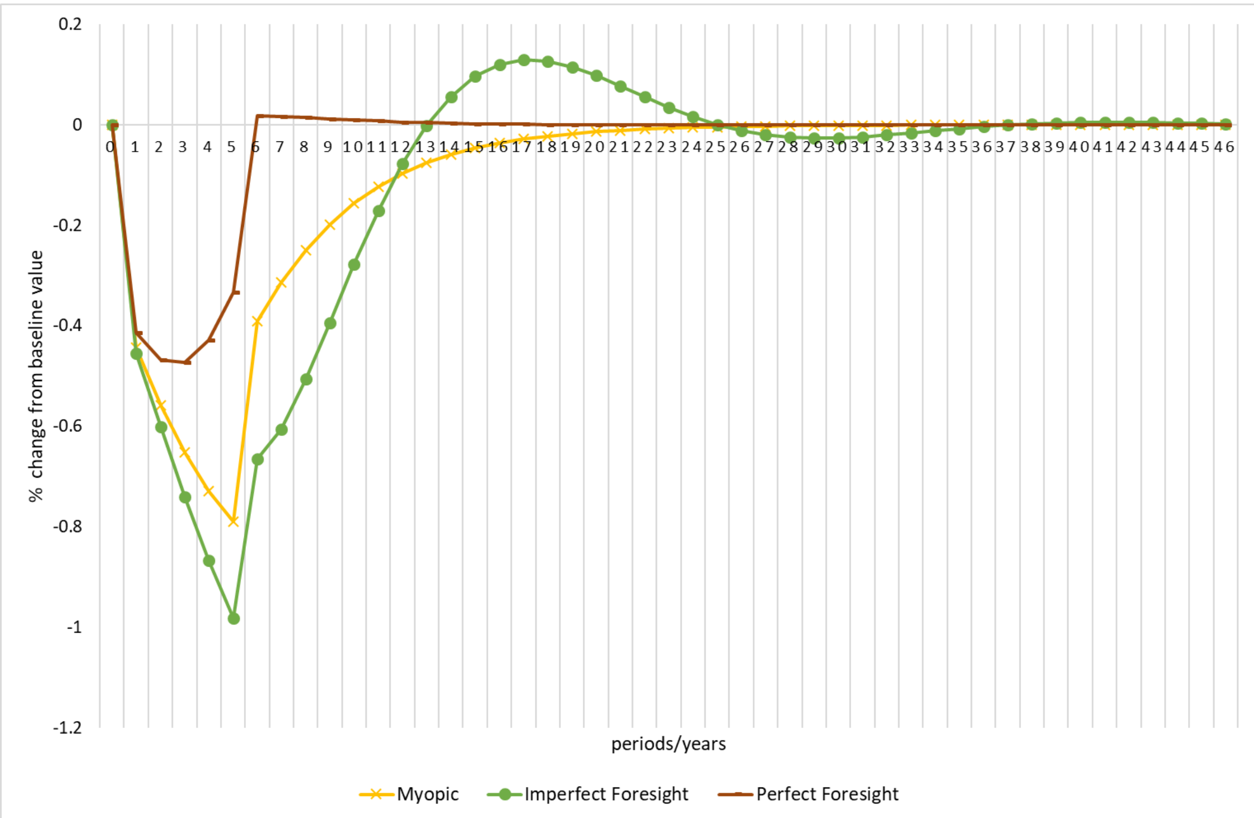

Figure 4. Period by period adjustment of household consumption

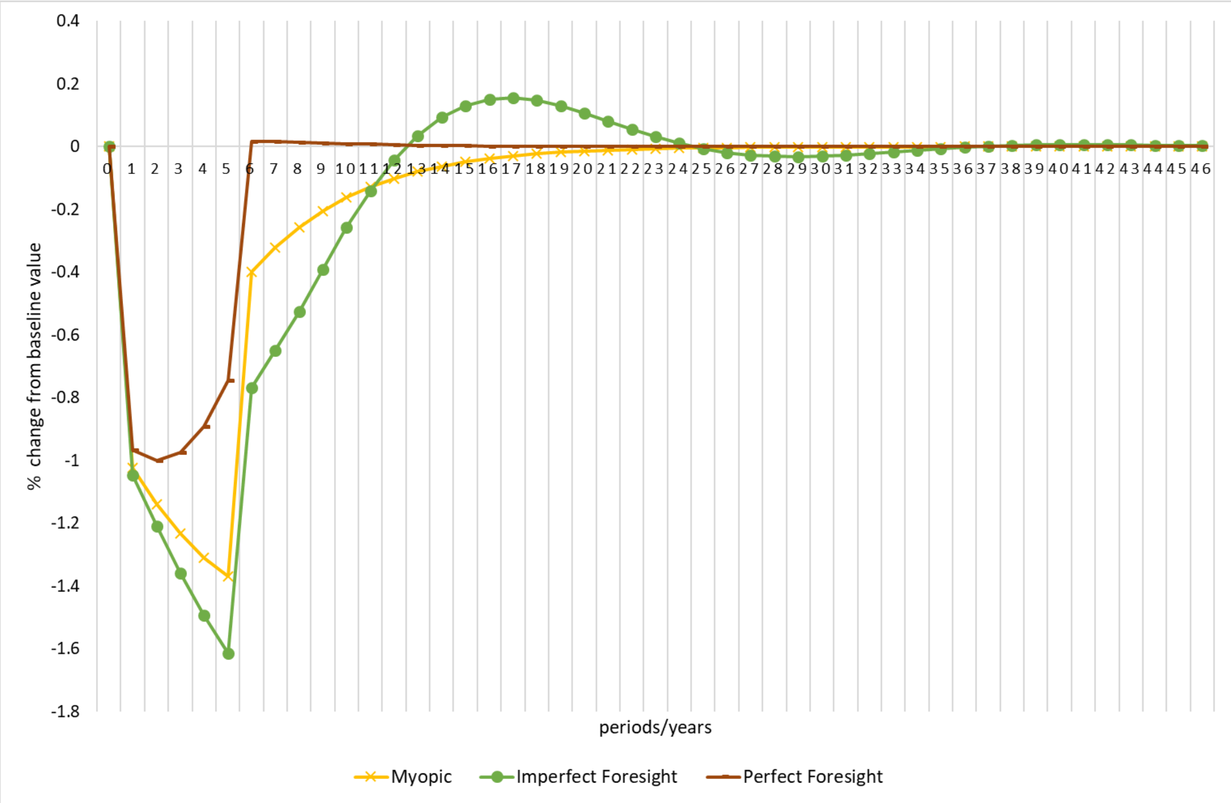

Table 1. Impact of a temporary 5% reduction in exports on key macroeconomic variables (% change from baseline values)

	Perfect foresight				*Myopic*				*Imperfect foresight*			
Time period	**SR**	6	11	16	**SR**	6	11	16	**SR**	6	11	16
GDP	-0.29	0.01	0.01	0.00	-0.31	-0.76	-0.24	-0.07	-0.32	-1.16	-0.37	0.20
CPI	-0.95	-0.01	-0.01	0.00	-0.99	0.26	0.10	0.03	-1.00	0.24	0.24	-0.01
Unemployment Rate	4.63	-0.20	-0.09	-0.02	4.96	4.38	1.38	0.40	5.09	7.44	1.91	-1.35
Nominal Gross Wage	-1.46	0.01	0.00	0.00	-1.53	-0.22	-0.05	-0.01	-1.55	-0.57	0.02	0.15
Real Gross Wage	-0.51	0.02	0.01	0.00	-0.55	-0.48	-0.15	-0.05	-0.56	-0.81	-0.21	0.15
Total Employment	-0.41	0.02	0.01	0.00	-0.44	-0.39	-0.12	-0.04	-0.45	-0.66	-0.17	0.12
Replacement cost of capital	-0.98	-0.06	-0.01	0.00	-1.09	0.44	0.07	0.01	-1.13	0.40	0.18	-0.13
Investment	-2.44	0.14	-0.01	-0.01	-3.25	0.62	0.28	0.09	-3.58	-2.14	1.64	0.87
Capital stock	-	0.01	0.02	0.01	-	-1.38	-0.44	-0.13	-	-1.94	-0.74	0.31
Household consumption	-0.97	0.02	0.01	0.00	-1.02	-0.40	-0.13	-0.04	-1.05	-0.77	-0.14	0.15
Total Import	-2.62	-0.02	-0.01	0.00	-2.79	0.12	0.05	0.02	-2.85	-0.41	0.32	0.14
Total Export	-2.93	-0.07	0.01	0.00	-2.87	-0.81	-0.26	-0.08	-2.84	-0.89	-0.52	0.06

6.1 Perfect foresight

For the perfect foresight model, the period-1 (short-run) response to the 5% negative export demand shock is a fall in all measures of aggregate economic activity. GDP, employment, investment and exports decrease by 0.29%, 0.41%, 2.44% and 2.93% respectively, accompanied by a 4.63% increase in the level of unemployment with a 0.51% decline in the real wage. The downward movement in production also reduces capital rentals and this, together with the fall in the wage, is reflected in the 0.95% decline in the consumer price index (CPI). The decrease in factor incomes and employment reduces household consumption by 0.97%.

Note first that the period-1 fall in total exports is less than the 5% exogenous reduction in export demand. This is because the drop in domestic prices increases the competitiveness of Scottish exports, which goes some way to counterbalancing the negative demand shock. Second, there is a relatively large short-run fall in investment. In the initial equilibrium investment just covers depreciation. The reduction in investment occurs as firms attempt to downwardly adjust their capital stock, producing an accelerator effect where the proportionate fall in investment is greater than the corresponding reduction in output.

Figure 1 indicates that in the perfect foresight case, investment is at its minimum point in period 1. From period 2 to 5 investment is increasing, and by period 4 is actually above the base-year value. This anticipates the return of the initial export demand conditions and takes advantage of low capital replacement costs. Its maximum, period-5, value is 2.19%, and in period 6 the aggregate capital stock is also slightly higher than its initial value.

In tracking aggregate economic activity, note that the negative demand shock from lower investment expenditure is reduced in the periods immediately after the introduction of the shock. However, the negative impact on supply from lower capacity is initially more powerful. As Figures 2 and 3 indicate, this leads to falling GDP and employment in periods 2 and 3, reaching minimum values of 0.48% and 0.47% below base respectively. Whilst both variables begin to rise in periods 4 and 5, they remain below their base-year levels. Figure 4 indicates that household consumption falls in periods 1 and 2 but starts to increase in period 3.

In the first period in which the exogenous export demand shock is reversed, GDP, employment and aggregate capital stock are higher than in the base period. However, there is still less than full sectoral adjustment to the restored export demand, with exports 0.07% below their initial value. In subsequent periods investment falls and asymptotically approaches the base-year level from above. GDP is maximised at a positive value of 0.02% in period 8. By period 11 the economy is very close to its initial equilibrium.

6.2 Partial adjustment, myopic expectations

Variation in the period-1 results across simulations is driven solely by differences in the scale of the negative demand shocks coming through reduced investment. In the myopic case firms attempt to adjust their capital stock taking present output as the best estimate of future output. This is associated with a 3.25% fall in investment in period 1, whichis greater than the reduction under perfect foresight, producing a fall in GDP, employment, household consumption and exports of 0.31%, 0.44%, 1.02% and 2.87% respectively.

Again, as in all the period-1 results, the relative size of the GDP and employment impacts is explained by labour market flexibility. Employment falls by a greater proportionate amount than GDP because in the short run capital stock is fixed and cannot immediately be fully adjusted downwards. The proportionate reduction in household consumption is then greater than that in employment because household income is affected by both the fall in employment and the accompanying decline in the real wage.

In the myopic case, in periods 2 to 5 - that is, in the remaining period during which the negative export shock operates - investment rises slightly but remains well below the initial level. GDP falls continuously whilst the export shock is in place and by period 5 is at its minimum, 0.97% below its base-year value. In period 6 investment rises to 0.62% above - but GDP and employment are still 0.76% and 0.39% respectively below - their initial values. The low level of aggregate economic activity in period 6 reflects the reduced capital stock, which is 1.38% below its base-year figure. This means that even though employment, and therefore also the real wage, is below its initial level, domestic prices are not. Again the negative effect on competitiveness reduces aggregate economic activity.

From period 6 investment approaches its initial value asymptotically from above, whilst GDP, employment and household consumption asymptotically approach theirs from below. However, it takes an extended length of time before the economy is back in long-run equilibrium. For example, in periods 11 and 16 GDP is still 0.24% and 0.07% respectively below its base-year level.

6.3 Partial adjustment, imperfect foresight

In the myopic case, firms make investment decisions using the heuristic that present output is the best estimate of future output. However, as we have seen, output varies systematically after the introduction of the export demand shock. In particular, both the adverse demand and supply effects of reduced investment and the resultant fall in the capital stock exacerbate the initial impact of the drop in export demand. This means that in periods 1 to 4 the myopic firms will always overestimate, and then in subsequent periods underestimate, the next-period output. Whilst it appears unrealistic that firms have a correct model of the economy, it also seems equally unlikely that they would not update the investment heuristic. In this case we assume that the firm estimates the output in the next period as a linear projection of the evolution of output, as given in equations (6), over the past four periods.

This variant of the model produces the largest period-1 fall in investment, 3.58%. Further, during the subsequent interval up to, and including, period 5 investment is continuously falling. Investment, GDP, employment and household consumption all reach their minima in period 5 at 4.36%, 1.26%, 0.98% and 1.61% respectively down on their initial levels.

When the export shock is reversed, investment increases but only surpasses the base-year value in period 8. It reaches a maximum of 1.71% above base in period 12 but drops below base again in period 19. There is clear overshooting which causes similar, but lagged, damped cycles in GDP, employment and household consumption. employment and household consumption become greater than their initial values In period 12, and GDP in period 13. These variables all reach a maximum at period 16 and fall below their initial values in period 25.

7. Regional Resilience

Martin and Sunley (2015, p. 3) maintain that whilst it is a prominent and potent concept in regional analysis "… there is as yet *no theory* of regional economic resilience." They identify 28 factors that affect resilience; that is, a region's resistance to, and ability to recover from, exogenous disturbances. A key group of factors, labelled "agency and decision making", comprise perception, expectations, confidence and convention. But again they maintain that we "… know surprisingly little about the role of market psychology and decision-making in shaping agents' behaviour following a major economic disruption, nor about how such behaviour and decision-making interact with local context. Yet, arguably, expectations, confidence and attitudes may prove to be critical factors" (Martin and Sunley, 2015, p.35).

The present paper illustrates how flexible CGE modelling can complement case studies and econometric work in the analysis of regional resilience. In this instance, the CGE framework is employed as a test bed in order to study the effect of varying a key determinant of resilience in a controlled theoretical and empirical environment. Specifically, the model identifies how variations in investment behaviour, driven by differences in confidence and expectations, affect the size of the impact, the rate of descent and the subsequent speed of recovery associated with a temporary negative demand shock. This is done whilst holding constant the size and nature of the initial shock, together with other key elements of the regional economy, including other determinants of resilience such as the degree of wage and price flexibility.[13]

The economic response to the temporary demand shock differs, both in size and timing, across the three investment scenarios. In particular, where there is perfect foresight the maximum impact on regional economic activity is small. Also the reduction in the level of economic activity is limited to the periods over which the shock is imposed, and the descent and recovery are symmetric. Of course, the perfect-foresight closure assumes that firms have accurate expectations and associated high business confidence. In periods 2 and 3 aggregate investment is increasing though GDP and employment are falling and in periods 4 and 5 investment is above its initial value, whilst GDP and employment are still below theirs.

For the simulations where firms use heuristics in determining investment decisions, the size of the impacts are greater and the negative demand shock leaves a much longer tail. GDP and employment fall continuously for the duration of the negative shock, but once the shock is reversed both GDP and employment begin to increase. In the imperfect foresight case the negative impact is greatest, but both the rates of decline and recovery are more rapid than for the myopic closure. At the point where the export demand returns to its original specification, the simulations employing heuristics have a capital stock level that is much lower than under perfect foresight. Because firms using heuristics fail to foresee the return of the export demand, expectations and business confidence are at this point low. Firms do not begin to increase their capital stock in the final periods of the negative export shock. This produces a substantial and drawn out sequence of negative impacts for the myopic case and overshooting and damped cycles with the imperfect foresight simulations.

Table 2. Impact on cumulative GDP in m£

	Undiscounted			Discounted		
Time period	**6**	**11**	**16**	**6**	**11**	**16**
Perfect foresight	-202944	-194016	-190819	-376224	-531360	-570489
Myopic	-430390	-638270	-700504	-469286	-759993	-751719
Imperfect foresight	-540055	-929100	-912225	-183039	-176430	-174417

[13] We consider here only deviations from a static equilibrium, though recall that this could be configured as an equilibrium growth path. Martin and Sunley (2015) also identify the possibility that an exogenous shock could alter the whole regional growth trajectory.

Table 2 reports the absolute and discounted reductions in GDP for the three simulations, cumulated to periods 6, 11 and 16. The figures are given in £ million in 2010 prices. These results reinforce the more qualitative impression given by Figures 1 to 4. Note first that the ordering of the models is always the same: the perfect foresight model produces the lowest cumulative reductions in GDP, followed by the myopic partial adjustment and then imperfect foresight cases. Second, the cumulated aggregate differences are substantial. The GDP reductions for the myopic and imperfect foresight models are never less than double the comparable figures for perfect foresight, and are often much greater. Third, these differences become larger, the longer the time period over which they are measured. This reflects the long thick tail that characterises their adjustment paths. In the undiscounted myopic case the cumulated reduced GDP in periods 7 to 16 equals just over 60% of the cumulated impact for periods 1 to 6. For the imperfect foresight case it is almost 70%. That is to say, where firms' investment decisions use these heuristics, much of the negative impact occurs after the shock has ended.

8. Conclusion

This paper has three main aims. The first is to show that CGE modelling is an extremely flexible tool that can be used to illustrate and explore a wide range of approaches to regional analysis. The second is to construct a regional economic model that incorporates behavioural/Keynesian insights, particularly into the determination of investment. The third is to run model simulations embodying these elements against more mainstream neo-classical approaches in simulating regional resilience in the face of a temporary export demand disturbance.

In introducing behavioural elements into the model, we highlight the treatment of investment, which necessarily involves risk and uncertainty. In standard economic theory, firms have perfect foresight, which we here replace with decision taking using heuristics. This brings the analysis closer to behavioural and Keynesian perspectives. The simulations suggest that adopting different plausible assumptions over the way investment decisions are taken has a major impact on the simulated effects of a temporary demand shock.

Though this paper focusses primarily on the investment decision, behavioural economics also has insights into consumption decisions and the operation of the labour market. Here we have suggested non-maximising interpretations of these aspects of the model but we intend in the future to make more extensive adjustments in these areas, including hyperbolic discounting and consumer inertia. Similarly, the CGE framework is not restricted to dealing with homogeneous representative transactors; it is readily augmented to accommodate heterogenous transactor groups. An example would be the disaggregation of consumption expenditure by household types, who might use different heuristics in forming their expectations. It would also be consistent with Keynesian and behavioural approaches to endogenous technical change through incorporating mechanisms such as the Verdoorn relationship, for example, thereby allowing hysteresis and path-dependency.

In terms of resilience, the simulation results reported here are illustrative; the form of resilience studied is limited and the nature of the shock is somewhat arbitrary. However, it is useful to demonstrate the potential importance for resilience of factors that have, as yet, been little explored. It also highlights the possible ideological power of standard neo-classical theory in presenting the market economy as a smoothly adjusting mechanism.

There are a number of ways to develop further the resilience work. First, it would be valuable to investigate other investment heuristics and the resultant evolution of regional economic activity tested against actual responses to exogenous demand shocks. Second, situations where there is more uncertainty concerning the nature of the exogenous shock, in particular its duration and severity, should be studied. The third exogenous supply-side, as well as demand-side, disturbances need to be considered. Finally, similar simulations should be performed to study the sensitivity of resilience to other regional characteristics that are thought to affect it. These would include industrial structure, regional openness and labour market flexibility, including wage setting and migration behaviour.

We see the present work as making initial steps in the direction of a more fully formed behavioural CGE model. However, we would maintain that the underlying arguments carry equal force for other regional modelling methods. In a stochastic context, for example, the implication is that Dynamic Stochastic General Equilibrium (DSGE) models typically neglect key aspects of behavioural (and Keynesian) economics as, indeed, do Overlapping Generation (OLG) models.

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