Towards a Behavioural Computable General Equilibrium Model*

Grant Allan¹, Gioele Figus², Peter G. McGregor² and J. Kim Swales²

University of Strathclyde

May 2018

1. Department of Economics, University of Strathclyde, Glasgow
2. Fraser of Allander Institute, Department of Economics, University of Strathclyde, Glasgow

* The authors would like to thank participants at the Reginal Science Association (British and Irish Section) Annual Conference, Harrogate, 2017, and Strathclyde University Brown Bag seminar, 2018, for valuable comments on earlier versions of this paper.
1. Introduction

There has emerged a strong and widespread critique of economics centred on its inability both to predict the onset of the financial crisis, to question the institutions which created that crisis, and to provide subsequent policy advice (Earle et al, 2017; Kwak, 2017; and Wren-Lewis 2015). A key element of this critique has been the perceived adverse influence of abstract theory and, in particular, general equilibrium analysis. However, we wish to argue strongly for retaining an approach that can simultaneously incorporate both micro and macro-economic perspectives in an internally consistent and flexible manner. It is important to stress that general equilibrium models are not necessarily constrained by the conventional neo-classical straightjacket. Moreover, with increased computing power their potential scope and sophistication is further enhanced.

It is not fundamentally problematic that general equilibrium models present a simplified version of the economy. All theories abstract in order to focus on those aspects and relationships which are thought to be the most important and/or the subject of concern. The issue really is whether these simplifications improve understanding of the underlying phenomena. As the Argentinian writer Borges (2000, p. 137) states: “To think is to ignore (or forget) differences, to generalise, to abstract”.

This paper has three primary aims. The first is to outline a Computable General Equilibrium (CGE) modelling framework that can encompass a wide range of approaches to the operation of the economy. The second is to illustrate this flexibility by developing a behavioural general equilibrium model for Scotland, whose key characteristics are inspired by the work of behavioural psychologist Daniel Kahneman and leading Keynesian economist, Joan Robinson. This model has an eclectic, broadly Keynesian, flavour following Robinson (1960) but is influenced by the work of Kahneman (2012) in the treatment of consumption and investment. The paper’s third aim is to use this model to investigate the effect of different expectation-formation processes on the level of investment and the impact this has on the response of overall regional economic activity to a temporary exogenous demand shock.

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 regional model has been adapted to incorporate behavioural ideas. Section 4 discusses the calibration and parameterisation of the model. Section 5 gives the simulation strategy and Section 6 reports and analyses the results. Section 7 is a short conclusion.
2. Background

A basic underlying research programme in economics was initiated by Milton Friedman (1953). This research programme has as its positive heuristic the injunction that the researcher should seek to explain human behaviour as being the result of rational, maximising decisions. In a sense Friedman’s methodology was bolstering a movement in Economics that goes back to the marginal (later neo-classical) revolution in the 1870s (Robinson, 1962). This research programme has subsequently proved theoretically progressive, having been applied to many facets of human behaviour such as crime, fertility, education and even addiction. As Gary Becker (1976, p.5) states: “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.”

Further, within a formal general equilibrium analysis, both Arrow and Debreu were awarded the Nobel Prize in Economics, at least partly for their separate work on the existence and uniqueness of general equilibria under these conditions, even though this analysis has almost no practical application. However, important welfare results apply under such equilibria. In this way the 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).

However, this research programme’s empirical success is much less certain. In his Journal of Economic Perspectives “Anomalies” column, Richard Thaler teased other economists with instances of behaviour that seemed inconsistent with traditional microeconomic theory. Similarly, through the development of game theory, rational strategic behaviour under perfect and imperfect information was extensively studied. But experiments with many simple games failed to replicate the theoretical results. Moreover, models adopted in macroeconomics, through the imposition of the efficient markets hypothesis and rational expectations, led to the hegemony in the academic literature of the macroeconomic models that failed to predict the

---

1 McKenzie, who independently published key results marginally earlier than the other two missed out (Duppe and Weintraub, 2014).

2 A detailed account of the growth of behavioural economics as a sub-discipline, see Thaler (2015)
financial crash. But much more importantly, they were of little use in dealing with the aftermath (Vines and Wills, 2018; Wren-Lewis, 2015).

Computable General Equilibrium analysis initially had a strong development stream with a non-neoclassical basis but this seems to have been swamped by off-the-shelf conventional models 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.

A typical example of such a computable general equilibrium model has been used by HM Treasury in assessing the economic impact of fiscal changes (HM Revenue and Customs, 2013; HM Treasury and HM Revenue and Customs, 2014). In this model the level of domestic investment is governed by domestic savings and these savings are set at a level that maximises utility from the path of consumption over time. This optimal path is determined by the degree of time preference. There is perfect competition in the labour market, with the supply of labour being decided by the trade-off between leisure and consumption.

Neo-classical economics is therefore presented as the single dominant approach, fundamentally based on universal and consistent rational behaviour. In 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).\(^3\) 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).

But also are economic agents rational and fully informed? Kahneman (2012) makes the distinction between Type 1 and Type 2 thinking. Type 1 thought processes cover automatic responses to stimulate 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

\(^3\) See also Rodrik (2016) for a similar viewpoint.
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, intuition, gut feel and rules of thumb. So whilst neoclassical general equilibrium theory implies that all decisions are made using Type 2 processes, there is extensive evidence that behaviour by economic agents is simply not of this type.

It is often argued that there has been a behavioural revolution in economics. However, such a revolution appears only skin deep. The assumption of rationality is so basic to both the analytic and normative elements of economics that its replacement would require a significant reorientation of the subject. However, behavioural economics has actually been accommodated within the conventional neo-classical approach. 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.” What would seem to imply a rather radical questioning of standard neo-classical theory has been accommodated within it.

In this paper we run simulations with neo-classical and behavioural specifications of the investment function. We wish to both demonstrate the potential flexibility of CGE modelling and also to see this as a first step in the construction of a model that incorporates behavioural assumptions in a fundamental way.

3. A Behavioural Regional CGE

In this paper we develop a behavioural extension of the AMOS regional CGE model for Scotland (Harrigan et al. 1991). The primary focus will be on alternative specifications of the investment function which incorporates behavioural characteristics. However, we also discuss other elements of the model, such as household consumption and the labour market, which can be given behavioural interpretations.

A key characteristic of Computable General Equilibrium (CGE) 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
condition is imposed by Keynesian, Marxian, neo-Ricardian and standard neo-classical models. 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 and distorted time preference, plus there is a general difficulty in dealing rationally with uncertainty and probability. Other inconsistencies are more idiosyncratic. For example, an individual’s response to a specific choice might depend crucially on how that choice is framed. Further, firms are aware of consumer informational asymmetries and irrationality and use this 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 consumption using deterministic consumption functions which are price sensitive, we do not assume that these represent welfare maximising under constraints and do not 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.

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.

Labour supply is not treated here in the conventional neo-classical manner. Rather we consider wage determination to be governed by social and legal institutions and constraints. We

---

4 There are many examples of firms and industries acting against their own customers’ interests. 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.
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:

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

In equation (1), \( w \) represents the nominal wage, \( CPI \) is the consumer price index, \( u \) is the unemployment rate and the \( t \) subscript stands for the time period. The parameter \( \varepsilon \) is the elasticity of the real wage with respect to the unemployment rate and \( \theta \) is calibrated so as to reproduce the base year data. This wage curve can be motivated through a bargaining or efficiency wage interpretation. In each there is involuntary unemployment so that workers cannot necessarily choose whether to work; 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 institution. This has the implication that both saving and investing are undertaken by the household, so that they become essentially the same activity. This runs counter to a key element of Keynesian analysis, which is that these activities are carried out by two quite separate groups of people. Further, saving and investment will not necessarily be equilibrated through movements in the interest rate, which is governed by liquidity preference. They therefore have to be analysed separately.

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 Schiller, 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.

A related concern is the role of expectations in governing investment decisions, with Keynes stressing the role of uncertainty, expressed in terms of animal spirits and liquidity preference, and this is an aspect of his work emphasised by Robinson. These ideas are strongly supported by behavioural economics, such as Akerlof and Shiller (2009). As Thaler (2015, p. 209) states: “Keynes … was a true forerunner of behavioural finance”. This having been said, whilst authors have previously explicitly linked Keynesian and behavioural approaches, the
discussion in behavioural economics of animal spirits as such 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.

There are many experimental studies of people’s choices under risk, where the odds of particular outcomes are known (Kahneman, 2012). The reason for studying this kind of risk seems to be to sharpen the behavioural results and make their existence absolutely clear. This work shows that peoples’ choices are often inconsistent, failing the very lowest form of rationality, which is clearly problematic for conventional economic theory. Whilst the nature of such decision making might differ again where outcomes are uncertain and their probabilities are unknown, it is difficult to accept rationality. Behavioural experiments also reveal loss aversion as an important factor governing behaviour. This is extensively used in prospect theory, which suggests asymmetric reactions to risk involving benefit and losses (Angner, 2012, Kahneman and Tversky, 1979).

Loss aversion should also affect decisions under uncertainty. The literature on wellbeing stresses that the familiar hedonistic (or, as in economics, the more specifically utilitarian) notion that our choices are determined by seeking pleasure and avoiding pain, is potentially misleading. These forces are not symmetrical (Kahane, 2016). Our reaction to pain is typically much more powerful than to pleasure and this could be an important factor in decision making under uncertainty. A common interpretation of our aversion to pain is that this is a survival mechanism, at least partly hard-wired into our nervous system. This might be thought to reinforce the loss-aversion argument.5

Finally, in behavioural finance work around speculative bubbles and financial crisis, the role of the projection of past trends and of Keynes’s “beauty contest” has been stressed. A similar phenomenon, in a smaller scale setting, is the mistaken “hot hand” belief amongst basketball players (Gilovich, et al, 1985). In this present paper, the key behavioural element we wish to explore is the way in which different expectation formation assumptions affect the level of investment. In particular, we measure the sensitivity of simulation results to alternative

---

5 Interestingly, research by Kahneman et al. (1993) shows that we typically have defective memory of pain when compared to the objective measures made when it was actually occurring. Given that decisions over future experiences potentially involving pain are based on memories of previous pain, again inconsistencies can occur. In this case the hedonistic measure of wellbeing differs from the choice-decision evaluation.
specifications of the investment function. In what we label as the behavioural case, the firm’s expectations are determined by projecting forward the growth of past output.

Specifically, we consider three alternatives set of expectations. The first formulation is forward looking, with perfect foresight. Within our 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:

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

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

The cash flow is given by profit, $$\pi_{i,t}$$, less private investment expenditure, $$I_{i,t}$$, subject to the presence of adjustment cost $$g \left(\omega_i\right)$$ where $$\omega_i = I_{i,t} / K_{i,t}$$, and $$\delta$$ is the rate of physical depreciation. In the simulations we adopt two versions of the perfect foresight model. In one the temporary demand shock is anticipated. In the second, the onset of the shock is unanticipated, though the subsequent size and duration of the shock is known.

The two other approaches involve a partial adjustment mechanism. Here, 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 actual $$K_{i,t}$$ capital stock now. This implies:

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

In both partial adjustment methods, the desired capital stock in period $$t+1$$ is determined by the existing output price and cost of capital, and the expected output in period $$t+1$$, $$Q_{i,t+1}^e$$, so that:

$$\text{(4)} \quad K_{i,t+1}^* = K_i \left(Q_{i,t+1}^e, p_{i,t}, r_{i,t} \right)$$

The difference between the two variants rests solely on the expected future output. In the first partial adjustment method, which we refer to as myopic, the firm takes the existing industry output as the best estimate of output in the next period. Therefore in the myopic case:

$$\text{(5)} \quad Q_{i,t+1}^e = Q_{i,t}$$
In the second approach, which we label as imperfect foresight, expected output in time \( t+1 \) is determined by a very straightforward heuristic. Past output growth over the last \( n \) years is projected linearly into the future. This implies that with imperfect foresight:

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

### 4. Model Calibration, Parameterisation and Simulation Strategy

The 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.\(^6\) 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. Also for the present simulations government expenditure is held constant in real terms and tax rates are fixed. This primarily reflects the position of the UK system of devolved public finances in operation at the time. The Scottish government had essentially no control over tax rates and public expenditure in Scotland was independent of the taxes raised in Scotland.

We simulate the impact of a temporary exogenous demand shock in the following way. The model is initially in long-run equilibrium. This means that if the model were run in period-by-period mode with no change in exogenous variables, the level of none of the endogenous variables would change. We introduce a 5\% step reduction in all Scottish exports in period 5. We maintain the reduction for 5 periods and then reverse the export demand change. This means that in period 10 the export demand function returns to its original form.\(^7\) The model is then run forward for a further 40 periods.

We run four versions of the model with different expectation-formation characteristics. The first is a full forward-looking version with an anticipated demand shock. This means that firms

---

\(^6\) This does not imply that employment is fixed, as participation/unemployment is allowed to vary. It does imply that migration is zero, though versions of the model are available which include endogenous inter-regional migration.

\(^7\) This does not mean that the actual period-10 level of exports goes back to the original value, as the actual value also depends on competitiveness.
know from period 1 that there is to be a demand shock in period 5 and can adjust their investment behaviour in the periods prior to the demand shock. We refer to this simulation as perfect foresight with an anticipated shock. The second is again fully forward-looking but in this case there is no anticipation of the exogenous shock so that the first change in investment occurs in period 5. We call this simulation perfect foresight with an unanticipated shock. The third is the standard partial adjustment which we label myopic. The fourth is the behavioural partial adjustment where the output projection in each industry is the growth rate over the past four years, so that the value of n in equation (6) is 4. This is the imperfect foresight simulation.

All the results are reported as percentage changes from the corresponding base-year values.

6. Simulation Results

Table 1 reports the period 1, 5, 10, 15 and 20 period simulation results for a set of key variables. (Of course, given the transitory nature of the disturbance, all long-run results exhibit zero change from the base year.) Detailed period-by-period impacts on investment, GDP, employment and household consumption are given in Figures 1, 2, 3 and 4. We begin by going through the results for the perfect foresight, anticipated simulation. Given that this is the most sophisticated conventional case, it serves as a benchmark against which the other results can be compared.

6.1 Perfect foresight with an anticipated shock

In this simulation, the export shock imposed in period 5 is anticipated, which is to say that it is foreseen in period 1. In this case, regional investment responds immediately with a 1.71% reduction in the first period. Given that the economy is initially taken to be in equilibrium, this implies that the level of investment is now below depreciation, so that capital stock falls in the next period. This fall in investment has a demand impact in period 1 and a supply impact in period 2, both of which are negative. In period 1 employment and GDP fall by 0.06% and 0.04% respectively. The slackening in the labour market generates lower real and nominal wages, reducing the cpi. The falling prices lead to an improvement in competitiveness and an increase in exports of 0.13% and a reduction in imports by 0.35%. However, the stimulus to
the economy through the improvement in trade is not enough to offset the fall in investment demand and the negative impact of the fall in household incomes on household consumption.

Figure 1 indicates that investment continues to fall in the subsequent three periods and reaches its lowest point in period 4, immediately before the introduction of the negative demand shock so that in period 5, the capital stock is 1.18% below its initial value. Figures 2, 3 and 4 show that in period five, the combined effect of the 5% reduction in export demand and reduced productive capacity leads to a sharp fall in GDP, employment and household consumption. Table 1 reports that in period 5 exports are 3.64%, and investment 1.46%, below their initial levels. Employment, GDP and household consumption are 0.74%, 0.92% and 1.28% lower than their period 1 values. Figures 2, 3 and 4 reveal that for the perfect foresight model with a pre-announced shock, economic activity reaches its lowest point in this period.

For the duration of the negative export shock, that is from period 5 to 9 inclusive, investment is rising. By period 7 it is above its base-year level and continues upward so that by period 10 the capital stock is only 0.25% lower than in period 1. However, this means that in period 10, industrial capacity is slightly lower than in the initial period. Therefore when the negative export shock is reversed, the cpi is above, and therefore competitiveness is below, its base-year value. Therefore despite relatively high investment in period 10, lower exports mean that GDP and employment are 0.13% and 0.05% below period 1 levels. From period 10 onwards, capital stock gradually returns to its original equilibrium level and by period 15 the economy is very close to equilibrium, with gross investment again equal to depreciation.

---

8 The exports do not fall to 5% below their initial value because of the increased competitiveness accompanying the lower wage and employment levels.
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 in % change from baseline values

<table>
<thead>
<tr>
<th>Time period</th>
<th>Perfect foresight announcement</th>
<th>Perfect foresight no announcement</th>
<th>Myopic</th>
<th>Imperfect foresight</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SR 5 10 15 20 LR</td>
<td>SR 5 10 15 20 LR</td>
<td>SR 5 10 15 20 LR</td>
<td>SR 5 10 15 20 LR</td>
</tr>
<tr>
<td>GDP</td>
<td>-0.04 -0.92 -0.13 -0.01 0.00 0.00</td>
<td>0.00 -0.29 0.01 0.01 0.00 0.00</td>
<td>0.00 -0.31 -0.76 -0.24 -0.07 0.00</td>
<td>0.00 -0.32 -1.16 -0.37 0.20 0.00</td>
</tr>
<tr>
<td>CPI</td>
<td>-0.07 -0.69 0.06 0.01 0.00 0.00</td>
<td>0.00 -0.95 -0.01 -0.01 0.00 0.00</td>
<td>0.00 -0.99 0.26 0.10 0.03 0.00</td>
<td>0.00 -1.00 0.24 0.24 -0.01 0.00</td>
</tr>
<tr>
<td>Unemployment Rate</td>
<td>0.65 8.29 0.60 0.06 0.00 0.00</td>
<td>0.00 4.63 -0.20 -0.09 -0.02 0.00</td>
<td>0.00 4.96 4.38 1.38 0.40 0.00</td>
<td>0.00 5.09 7.14 1.91 -1.35 0.00</td>
</tr>
<tr>
<td>Nominal Gross Wage</td>
<td>-0.14 -1.58 -0.91 0.00 0.00 0.00</td>
<td>0.00 -1.46 0.01 0.00 0.00 0.00</td>
<td>0.00 -1.53 -0.22 -0.05 -0.01 0.00</td>
<td>0.00 -1.55 -0.37 0.02 0.15 0.00</td>
</tr>
<tr>
<td>Real Gross Wage</td>
<td>-0.07 -0.90 -0.07 -0.01 0.00 0.00</td>
<td>0.00 -0.51 0.02 0.01 0.00 0.00</td>
<td>0.00 -0.55 -0.48 -0.15 -0.05 0.00</td>
<td>0.00 -0.56 -0.81 -0.21 0.15 0.00</td>
</tr>
<tr>
<td>Total Employment</td>
<td>-0.06 -0.74 -0.05 -0.01 0.00 0.00</td>
<td>0.00 -0.41 0.02 0.01 0.00 0.00</td>
<td>0.00 -0.44 -0.39 -0.12 -0.04 0.00</td>
<td>0.00 -0.45 -0.66 -0.17 0.12 0.00</td>
</tr>
<tr>
<td>Replacement cost of capital</td>
<td>-0.22 -0.60 0.00 0.00 0.00 0.00</td>
<td>0.00 -0.98 -0.06 -0.01 0.00 0.00</td>
<td>0.00 -1.09 0.44 0.07 0.01 0.00</td>
<td>0.00 -1.13 0.40 0.18 -0.13 0.00</td>
</tr>
<tr>
<td>Investment</td>
<td>-1.71 -1.46 0.46 0.05 0.01 0.00</td>
<td>0.00 -2.44 0.14 -0.01 -0.01 0.00</td>
<td>0.00 -3.25 0.62 0.28 0.09 0.00</td>
<td>0.00 -3.58 -2.14 1.64 0.87 0.00</td>
</tr>
<tr>
<td>Capital stock</td>
<td>-1.18 -0.25 -0.03 0.00 0.00 0.00</td>
<td>- - 0.01 0.02 0.01 0.00</td>
<td>- - 1.38 -0.44 -0.13 0.00</td>
<td>- - 1.94 -0.74 0.31 0.00</td>
</tr>
<tr>
<td>Household consumption</td>
<td>-0.12 -1.28 -0.05 -0.01 0.00 0.00</td>
<td>0.00 -0.97 0.02 0.01 0.00 0.00</td>
<td>0.00 -1.02 -0.40 -0.13 -0.04 0.00</td>
<td>0.00 -1.05 -0.77 -0.14 0.15 0.00</td>
</tr>
<tr>
<td>Total Import</td>
<td>-0.35 -2.42 0.05 0.01 0.00 0.00</td>
<td>0.00 -2.62 -0.02 -0.01 0.00 0.00</td>
<td>0.00 -2.79 0.12 0.05 0.02 0.00</td>
<td>0.00 -2.85 -0.41 0.32 0.14 0.00</td>
</tr>
<tr>
<td>Total Export</td>
<td>0.13 -3.64 -0.23 -0.03 0.00 0.00</td>
<td>0.00 -2.93 -0.07 0.01 0.00 0.00</td>
<td>0.00 -2.87 -0.81 -0.26 -0.08 0.00</td>
<td>0.00 -2.84 -0.89 -0.52 0.06 0.00</td>
</tr>
</tbody>
</table>
6.2 Perfect foresight with no anticipation of the shock

For the perfect foresight model with no pre-announcement, the economic variables remain fixed for the first four periods. With unchanging exogenous variables the model simply replicates the initial equilibrium. In period 5 the export reduction occurs and the subsequent economic response is similar to, but rather more muted than, that reported in the previous section with pre-announcement.

Table 1 shows that in period 5 with perfect foresight and no anticipation, there is a large fall in investment of 2.44% generating a reduction in GDP and employment of 0.29% and 0.41% respectively. As can be seen from Table 1 and Figures 2, 3 and 4, although the investment level is lower than where the shock is anticipated, there is a smaller negative impact on economic activity. Why is this so? The answer lies in the reduction in capacity that already exists in period 5 with an anticipated shock. In the unanticipated case there is a degree of excess capacity that leads to a reduction in capital rentals. This means that with no anticipation in period 5 although employment and the real wage is higher, the epi is lower than in the anticipated case. These lower domestic prices generate greater competitiveness which limits the actual fall in exports in period 5.9

Again in periods 5 to 9 investment is rising and is above the base-year level in periods 8 and 9. This anticipates the return to initial export demand conditions and takes advantage of low capital replacement costs. GDP and employment reach a minimum value in period 7 with values below base of 0.48% and 0.47% respectively. In period 10 the capital stock is slightly above the period 1 value and therefore so is GDP and employment. 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 12. By period 15 the economy is very close to its initial equilibrium.

6.3 Myopic Investment

As in the simulation with perfect foresight but unanticipated shock, changes in economic variables only first appear in period 5. Differences in the period-5 results for these two

9 Note from Table 1 that the period-5 fall in exports with no preannouncement is 2.93% as against 3.64% with pre-announcement.
simulations are driven solely by the differences in the scale of the negative demand shock coming through reduced investment.

In the myopic case, firms are attempting to adjust their capital stock on the assumption that the best estimate of the future output is present output. Unlike perfect foresight, they have no information about future changes in exogenous variables. Further, they have no model of how the economy operates in aggregate, so that they do not factor in to their own decisions the similar decisions of others. On this basis, there is a 3.25% reduction in investment in period 5, which is greater than the reduction with perfect foresight. This produces a fall in GDP, employment and household consumption of 0.31%, 0.44% and 1.02% respectively.

As in the period 5 results for all three simulations with no pre-announcement, the relative size of the GDP, employment and household consumption impacts is explained by employment flexibility. Employment falls by more than GDP because in the short-run, capital stock is fixed and cannot be adjusted downwards. Household consumption then falls by more than employment because household income is affected by both the fall in employment and the accompanying reduction in real wage.

In periods 5 to 9, during which the negative export shock operates, investment rises slightly, but in each year remains well below the initial level. GDP falls continuously whilst the export shock is in place and by period 9 is at its minimum, 0.97% below its base-year value. In period 10 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 reflects the reduced capital stock, which is 1.38% below its period-1 value. This means that even though employment, and therefore also the real wage, is below its base year level, domestic prices are not. Again the negative effect on competitiveness reduces aggregate economic activity.

From period 10 investment asymptotically approaches its initial value from above, and GDP, employment and household consumption asymptotically approach their initial values from below. However, it takes an extended length of time before the economy is back in long-run equilibrium. For example, in periods 15 and 20 GDP is still 0.24% and 0.07% respectively below its initial values.

6.4 Imperfect Foresight

In the myopic case, firms use as a heuristic in investment decisions the rule that the present output level is the best estimate of future output. However, we can see from Figure 2 that output
varies systematically after the export demand shock which is determined by the decisions that the firms make in adjusting to the shock. In particular, the demand and supply impacts of reduced investment and resultant capital stock are both negative exacerbating the initial impact of the fall in export demand. This means that in periods 4 to 8 the myopic firms will always overestimate, and then in subsequent periods underestimate, the next-period output. Whilst it seems unrealistic that firms have a correct model of the economy, it also seems equally unlikely that the firms do 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.

Using this investment heuristic, the period-5 fall in investment is slightly bigger, at 3.58%, than with myopic firms. Further, during the subsequent interval up to and including period 9, investment is falling to reach its minimum level of 4.36% below its base year value, leaving the capital stock 1.94% below its period 1 value in period 10. GDP, employment and household consumption also reach their minima in period 9 at 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 12 and reaches a maximum of 1.71% above base in period 16 and drops below base again in period 24. There is clearly overshooting here, which causes similar, but lagged, damped cycles in GDP, employment and household consumption. In period 17 employment and household consumption become greater than their initial values, and GDP in period 18. These variables all reach a maximum at period 21 and fall below their initial values in period 30.

6.5 Comparison

It is very clear that the economic response to the temporary demand shock is very different, both in terms of the size and timing, across the four investment scenarios. In particular, where there is perfect foresight but the shock is unanticipated, the impact is small and the reduced level of economic activity is limited to the periods in which the shock is imposed. Perhaps surprisingly, where the shock is anticipated and firms have complete foresight the negative impact is greater and begins before, and continues after, the shock is imposed. This reflects the fact that in this simulation capital is implicitly being redirected more extensively to other regions.
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. In these simulations the capital stock is much lower at the point where the export demand returns to its original specification. Because firms fail to foresee this change, they 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 gives the absolute and discounted reductions in GDP for the four simulations cumulated to periods 10, 15 and 20. The figures are given in £ million in 2010 prices. Note first that the unanticipated foresight model produces the lowest cumulative cost, for each time period, discounted or undiscounted. For the cumulative impact to period 10, the myopic model gives the next best result, whether discounted or undiscounted but is around double the negative impact of the unanticipated perfect foresight case. The imperfect and anticipated perfect foresight simulations produce very similar undiscounted values cumulated to period 10. However, because the anticipated foresight GDP reductions come sooner, they are less heavily discounted.

Where the losses over longer time periods are calculated, the simulations where the investment is driven by the myopic or imperfect foresight mechanisms give higher GDP losses than the models with foresight. This reflects the long thick tail that characterises their adjustment paths. In the undiscounted myopic case the cumulated GDP reduction in the 10 years after the shock equals just over 60% of the cumulated impact during the shock. For the imperfect foresight it is almost 70%.

7. Conclusion

In this paper we have 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 in a general equilibrium context. The second is to construct a regional economic model that incorporates behavioural/Keynesian insights into the determination of investment. The third is to run model simulations against more mainstream neo-classical approaches using the same data base. 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.

In introducing behavioural elements into the model we focus here on investment. We argue that investment decisions necessarily involve risk and uncertainty. The standard method of dealing with this in economics is to assume that firms have perfect foresight. We here replace this with decision taking that uses heuristics, which bring the analysis closer to behavioural and Keynesian perspectives. There are three natural ways to develop the work further along these lines. The first would be to investigate other investment heuristics and to test the resultant evolution of regional economic against actual responses of regions to exogenous demand shocks. The second would be to deal with situations where there is more uncertainty concerning the evolution of the exogenous shock; in particular the length and severity of the shock. The third would be to consider supply-side, as well as demand side, exogenous disturbances.

In this paper we focus solely on the investment decision. However, behavioural economics also has insights into consumption decisions and the operation of the labour market. In the present paper we suggest non-maximising interpretations of these aspects of the model but we intend to make more extensive adjustments in these areas. It would also be consistent with Keynesian and behavioural approaches to endogenise technical change. We see the present work as making initial steps in the direction of a more fully formed behavioural model.

The completely consistent, logically based perfect foresight, rational expectations model has a strange attraction for economists. Even those whose work might be thought to challenge this approach find it curiously compelling. For example, in a textbook on behavioural economics Angner (2012, p. 4) states that behavioural economists believe that “deviations from rationality are large enough, systematic enough, and consequently predictable enough to warrant the development of new descriptive theories of decision.” However, rational-choice theory, on which neo-classical theory is based, is “normatively correct”. He appears to be ambivalent as to whether both types of theory can coexist and seems loath to jettison the rigour for reality. Similarly, Wren-Lewis (2015, 2018) argues persuasively against the hegemony of the logically-consistent micro-foundations for the macro-economic models prevalent in the academic literature. He argues that this hegemony has been unhelpful in dealing with the practical problems facing policy makers. However, he still wishes to maintain both the practical and logically rigorous macro-models: he sees the logically consistent models as some kind of
benchmark to which the policy models should aspire. It is tempting to reflect that perhaps a more radical rethink is required in economics.
References


HM Revenue and Customs (2013), “HMRC’s CGE model documentation”

HM Treasury and HM Revenue and Customs (2014), “Analysis of the dynamic effects of fuel duty reductions”


