Conceptual differences between macro-econometric and CGE models

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This paper discusses the main similarities and differences between macro-econometric and Computable General Equilibrium models. It shows that, while both types of models are based on a core input-output and national accounting framework, differences in the underlying behavioural assumptions mean that the direction of causation of many of the key flows in the model is reversed.

The discussion of differences in approach starts with the key assumption about how uncertainty is treated in the models. We show that if the existence of fundamental uncertainty is accepted, it becomes impossible for agents to optimise decision making by maximising expected utility and hence an alternative approach to modelling behaviour is required. In the absence of optimisation, the properties of the modelling system change substantially, with the level of output determined by demand-side factors rather than the most efficient use of the available factors of production, given a production function and factor prices.

We then move to the critical discussion of how the financial sector is treated, which is increasingly noted as an important difference in approach. We note that, within each modelling approach, there is consistency between treatment of the real economy and financial sectors, with the CGE approach allocating a fixed supply of money optimally, and the macro-econometric model assessing the demand for money.

Throughout the discussion, the models' theoretical and structural assumptions will be compared against the relevant strands of macroeconomic theory.

We conclude with a summary of key characteristics and assumptions that is designed to help policy makers and the other users of model results to interpret the findings from models.

Introduction

This paper is part of a special session at the IIOA conference titled:

Input-output and sectoral macro-econometric modelling: Part of the same family

The previous paper (Lewney et al, 2019) discussed how to build a macro-econometric model from an input-output accounting framework. In this paper we compare some of the properties of this model with those of the more common Computable General Equilibrium (CGE) approach.

Before starting the discussion, it is important to be clear on the terminology of the different modelling approaches used. In this paper the term 'macro-econometric' model means one that is based on post-Keynesian macroeconomic theory. It does not include CGE models that include econometrically-estimated parameters. By 'CGE' model we mean a model based on a standard Arrow-Debreu general equilibrium framework, drawing on neoclassical macroeconomic theory. The authors note that there are CGE models that have been further developed beyond this basic structure, for example the GEM-E3 model.

The aim of this paper is not to suggest which modelling approach is 'better' or to feed into that debate in any way. The authors have worked principally with macro-econometric models directly, but in consortia involving both types of models.

The next section describes the key differences between the two modelling approaches, covering both the underlying theory and the practical outcomes in a few example cases. We then discuss the different treatments of the financial sector in the two modelling approaches, which has previously been described as an important distinction. The final section summarises the main differences.

Modelling uncertainty

Introduction: How uncertainty is treated in models

Lewney et al (2019) describes the different modelling approaches from an accounting perspective. Here we focus more on the behavioural assumptions. The starting point is the treatment of uncertainty in the modelling.

Regarding uncertainty, the differences between the modelling approaches are almost polar opposites:

- A standard CGE model is based on assumptions about 'perfect knowledge', meaning that agents are aware both of every opportunity open to them and how to combine those opportunities to maximise either profits (firms) or utility (households).
- Macro-econometric models allow for the possibility of fundamental uncertainty, as defined in Keynes (1921). Agents are aware that there are 'unknown unknowns' in the system and may choose to plan accordingly.

Uncertainty has been a core characteristic of post-Keynesian economics. Keynes' 1921 *Treatise on Probability* was published more than a decade before his *General Theory* (Keynes, 1936). The existence of uncertainty explains several key features of both the real economy and the financial system, as we describe further down.

It should be noted that it is not only post-Keynesian economics that allows for uncertainty in the economy system. Recent agent-based models (see e.g. overview in Beinhocker, 2007) are based on

the limited knowledge available to individual agents, which then produce macro outcomes through their interactions. Frydman and Goldberg (2007) also explored the issue as a main departure from theories of neoclassical economics.

The link between uncertainty and optimising behaviour

From a modelling perspective, a critical link is the one between the existence of uncertainty and the ability to behave in an optimal manner (as economists describe, 'fully rational'). The relationship is summarised in Table 1.

Table 1: The relationship between uncertainty and human behaviour

	Optimising behaviour	**Non-optimising behaviour**
Perfect knowledge	CGE model	Generally not modelled
Uncertainty	Not possible	Macro-econometric model

The key entry in the table is the one in the bottom-left corner. Under conditions of fundamental uncertainty it is not possible to optimise behaviour. To put it another way, if there are outcomes that the agents do not know about, then it is not possible to construct a probability distribution function of outcomes in which the probabilities sum to one.

It is therefore not possible to model optimising behaviour in macro-econometric models.

If one assumes perfect knowledge then both options are open. In a standard CGE model, optimising behaviour is assumed. Although theoretically feasible, there are not many examples of where perfect knowledge is assumed but optimising behaviour is not. The reasons for this are partly historical; the assumption of perfect knowledge was only adopted so that it would be possible to model optimising (rational) behaviour. An important difference between the models is therefore the direction of thought regarding these two key assumptions: CGE models assume perfect knowledge so that they can model optimising behaviour; macro-econometric models do not include optimising behaviour because they are based on conditions of uncertainty.

One important question is how human behaviour is determined in a macro-econometric model. If the model does not assume optimisation then an alternative assumption is required to populate the model parameters. In principle, any approach could be used, including calibration or the model builder specifying his or her own parameters. The aim is to replicate real-world behaviour, hence the models are sometimes called simulation tools.

The approach that is generally adopted by macro-econometric models again draws on Keynes' analysis that our best estimates of future behaviour are the trends that we can currently see. Although Keynes was famously sceptical about econometric analysis, which he saw as potentially a tool that could obscure more valuable qualitative insights, econometrics is the best tool we currently have to derive quantitatively the behavioural relationships. This is why the models are referred to as 'macro-econometric'.

Other relevant assumptions

There is a further assumption that further differentiates the modelling approaches. In a CGE model, markets are assumed to be frictionless, with prices adjusting to balance supply and demand. This assumption follows from those of perfect knowledge and optimal behaviour in that buyers and sellers could interact directly to force prices to an equilibrium level. The CGE model is therefore simply assuming that there is not something from preventing this from happening.

The macro-econometric model, however, already has two reasons why smooth price adjustments might not happen. Buyers/sellers may not be aware of each other and they may not act optimally anyway. Therefore, prices do not automatically move to market-clearing rates.

Resulting model characteristics

The main differences in model characteristics can mostly be derived from this small number of assumptions. In a CGE model, the number of input factors of production is fixed and the model works out the optimal way to distribute these resources in the production process. However, in a macro-econometric model, there may be limits on the factors of production, but the level of production is instead determined by the level of aggregate demand in the economy.

In both models, demand is equal to supply (an accounting identity) but in the macro-econometric model, both may be less than potential supply. The following equations express the relationship:

CGE model: Demand = Supply = Potential Supply

Macro-econometric model: Demand = Supply <= Potential Supply

From an input-output perspective, the macro-econometric model is akin to a multiplier analysis. If there is a shock to aggregate demand (e.g. higher exports) then that will create supply-chain ripple effects that create further demand in other sectors. Economic multipliers are indeed a feature of macro-econometric models. However, the models go further than tracking changes in intermediate demands; they also include endogenous treatments of final demand and allow prices to vary as well.

The CGE model also involves input-output calculations, but they flow in the opposite direction to assess the maximum output for the given inputs available.

Policy implications

The most obvious outcome from the equations outlined above is that the macro-econometric model includes an 'output gap'. The quotation marks are used because the output gap is not observable and is therefore not a fixed value in the macro-econometric model as it sometimes is in more aggregate central bank models. It does, however, exist.

In real-world data, the output gap can be seen through persistent involuntary unemployment and survey data that show firms typically operating at around 80% of full capacity (European Commission, 2017). The latter point reflects not just uncertainty about current trading conditions but about future conditions as well; firms keep capacity available in case there is a sudden increase in the demand for their products. This point is discussed further in the next section.

When used for policy making, the models give two different types of insights. CGE models provide an assessment of how the optimal use of the available resources might change, given a set of policy constraints. Macro-econometric models also provide an assessment of how the efficiency of resource use might change, but in addition show the impacts of using more or less of the available resources (and how policies might influence the resources used).

The impacts on model results may be profound. The introduction of a regulatory policy in a CGE model is treated as an additional constraint in the model. Moving from an optimisation to a constrained optimisation can only reduce the potential and therefore actual level of output in the model. In contrast, in a macro-econometric model there could be an increase in the level of output, if the regulation is able to draw upon previously idle economic resources. For example, if the policy creates jobs then the newly-employed workers will gain incomes that they can spend elsewhere, providing an overall stimulus effect.

This brings us to the issue of finance and how it interacts with the wider economy.

Role of the financial sector

The treatment of money and finance has recently been identified as one of the main sources of differentiation between the two modelling approaches (Pollitt and Mercure, 2018). In fact, the assumptions about finance are in both cases in line with the assumptions described in previous sections.

In a CGE model, money is used as a means of exchange only. As the economy is already operating at full capacity (i.e. output = potential supply) then an increase in the money supply would only lead to higher demands for the same number of resources, i.e. inflation. The money supply is therefore fixed in real terms.

In a macro-econometric model, the supply of money is determined endogenously by a number of factors, including the degree of uncertainty. For example, if a worker is threatened with unemployment, he/she is unlikely to make a large purchase (e.g. a new car) and will instead save his/her income. Money that is saved does not create the demand for new products and the jobs that go with these new products. If many workers face the same position, then the economy may enter a slump (and some of the workers' fears may be realised). But this outcome is only possible because of uncertainty about future economic conditions.

None of this would matter if it were not for differences in the treatment of the banking sector in the two modelling approaches. With a fixed supply of money, in CGE models, banks lend out the deposits that they receive and no more (interest rates will adjust so that a balance is maintained). In a macro-econometric model, there is no requirement that the levels of savings and borrowing should match. Instead the central bank provides the necessary deposits and the supply of money is allowed to vary. According to the Bank of England (McLeay et al, 2014) and other central banks, this is an accurate depiction of how the financial system works in the modern economy.

The difference is important with regards to the issue of the 'crowding out' of capital. In an investment-intensive scenario, including most scenarios of low-carbon development, an increase in investment in one sector will:

- in a CGE model lead to a displacement of investment in other sectors
- in a macro-econometric model lead to higher levels of investment overall

This difference in treatment is a key determinant of the differences between model results.

Summary and conclusions

Depending on your viewpoint, the differences between macro-econometric and CGE models either stem from their assumptions about fully optimal ('rational') behaviour, in which case perfect knowledge is a requirement, or from their assumptions about uncertainty, in which case optimal behaviour is not possible. This is a straight-forward contra-positive logical relationship (if A implies B then not B implies not A).

However, most of the differences between the two different modelling approaches can be traced back to this starting point, or to assumptions that are closely related. The key characteristics are summarised in Table 2.

Table 2: Summary of model characteristics

	CGE approach	**Macro-econometric approach**
Model type	Optimisation	Simulation
Degree of uncertainty	Perfect knowledge	Fundamental uncertainty
Human behaviour	Optimising	Derived from past data
Price adjustment	Fully flexible	Sticky
Money supply	Fixed in real terms	Endogenous
Output determined by	Supply-side factors	Aggregate demand
Impacts of regulation	Usually negative	Either positive or negative

Although this paper has focused on the differences between the modelling approaches, there are also many similarities. For example, both approaches are centred around input-output tables and a national accounting structure. The differences are in the treatment of human behaviour.

It is not the aim of this paper to identify which modelling approach is 'better' but it should be clear that the models are answering slightly different questions. CGE models are designed to answer questions related to the allocation of resources and the efficiency of different allocations. Macro-econometric simulation models are more suitable for assessing demand-side shocks and looking at the real-world impacts of these shocks.

Most importantly, the users of model results need to understand the main assumptions that underlie the results from either type of model. This summary paper aims to provide a starting point in that direction.

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