1. What are the Computable General Equilibrium (CGE) Models?

What are CGE models?

CGE models are large numerical models which combine economic theory with real economic data in order to derive computationally the impacts of policies or shocks in the economy.

CGE models fit economic data to a set of equations which aim to capture the structure of the economy and behavioural response of agents (firms, households, government). This provides a framework to simulate policy changes and trace the impact on key economic variables, including income and expenditure flows.

How does CGE modelling work?

The economic impact of the policy or economic shock being modelled is estimated by comparing the economy before and after the shock.

The pre-policy baseline is generated by fitting the model equations and the behavioural parameters to the base year data. In general, this will mean that the base year to which the shock is applied will reflect the current structure of the economy. Our current model, for example, is calibrated using a wide range of sources of economic statistics for Scotland and the UK.

The baseline assumes that the economy starts from a stable or equilibrium position i.e. markets clear, although some models, including the Scottish Government's own, relax some of these assumptions, for example by allowing for unemployment.

When a policy change or economic shock is introduced, the economy converges to a new equilibrium, governed by the economic relationships as specified in the system of equations.

The model derives a solution by finding a new set of prices and allocation of goods and factors such that the economy is in an equilibrium again.

Some CGE models, such as the one used by the Scottish Government, are able to trace the path of adjustment to the new steady-state, whereas static ones will show long-run changes only. Modelling the adjustment path provides a much richer understanding of the evolution of the economy in response to a given shock or policy.

Why are CGE models used?

CGE models take into account the inter-dependencies between different sectors, agents and markets in the economy. CGE analysis can therefore shed light on the wider economic impact of policies and sometimes reveal their indirect or unintended effects.

Since CGE models are grounded in economic theory, results can be explained using economic intuition, with the advantage that the economic impact can also be quantified using real data.

CGE models capture both the economy's supply and demand side and therefore allow for an adjustment in both quantities and prices following a policy shock.

Their main strength lies in their flexibility, as they can be adapted to simulate a wide range of policies and shocks.

CGE models are widely employed by governments, international and research organisations, academics and private sector consultancies. The World Bank, OECD, IMF, HMRC, PWC have all made use of CGE frameworks in the past.

How does CGE differ from other modelling approaches?

In contrast to partial equilibrium models, which focus on one section of the economy only, CGE models capture the entire economy and take into account the interactions and knock-on effects between its different segments.

Unlike input-output models, which capture only the demand side and assume there are no capacity constraints, CGE models incorporate the supply side and hence allow for price movements.

Compared to macro-econometric forecasting models, CGE models have a stronger foundation in economic theory. Macro-econometric forecasting models tend to be more data-driven, combining time series data with economic theory and often omit the detailed industrial data provided in CGE models.

Whilst sharing many features with CGE models, Dynamic Stochastic General Equilibrium models (DSGE) aim to capture business cycle fluctuations and thus have a stronger focus on the shorter-term impacts. Unlike many CGE models, these types of models are less disaggregated and allow for random variation to account for uncertainty.

Which data feed into the CGE model?

The dataset which forms the backbone of the CGE model is the Social Accounting Matrix (SAM). It captures the flows of all economic transactions which take place in the economy in a single year. Its primary data sources are the Input-Output tables and the National Accounts, complemented by a range of other data on taxes, income and expenditure. This ensures that the model closely reflects the actual structure of the Scottish economy.

Some parameter values, e.g. elasticities which govern the demand and supply responsiveness to price, are not determined within the model. Their values are mostly taken from empirical studies.

However, most of the coefficients and exogenous variables have to be estimated using the base year data. This is done via a process called calibration which fits the data values to the model equations. If the model is calibrated correctly, it should replicate the base year equilibrium in the absence of any shocks.

What are the key features of the Scottish Government's CGE model?

The Scottish Government's CGE model is a detailed one-region model of the Scottish economy which covers the onshore economic activity at a detailed industrial level.

The model is based on a SAM for Scotland, that was constructed specifically for this purpose, and is complemented with data from other sources.

The model was originally built by the University of Strathclyde, although the Scottish Government version has now undergone a number of in-house enhancements.

The modelling framework is large-scale and contains around 200 groups of variables. Most of these groups of variables are further specified as variables for individual sectors.

CGE models attempt to replicate the base structure of the economy. Although the base year is an equilibrium, this will capture features of real economy such as level of unemployment, spare capacity and export demand. For example, in the Scottish Government model, it is not assumed that the economy is operating at its full capacity in the base year and unemployment can go up or down depending on policy, as labor demand will depend on firms' optimizing behavior. Hence, not all markets will necessarily clear. This provides a degree of flexibility in the modelling.

The model allows the impacts of policies and shocks to be traced through time. A steady-state should always be reached in the long-run when the model is correctly specified.

The model's equations are specified and solved using GAMS (General Algebraic Modelling System) software - a high-level modelling system for mathematical programming and optimisation. Some modellers use a sub-system of GAMS - MSPGE (Mathematical Programming System for General Equilibrium) - that simplifies the modelling process for a specific type of CGE model.

What flexibility does the model offer?

The framework provides flexibility to change a number of assumptions. This is useful for conducting scenario and sensitivity analyses.

For example, the model offers a range of options with regards to specifying wage-setting behaviour and migration. It also allows for different assumptions to be made about the nature of households' and firms future expectations.

The underlying SAM data allows disaggregation into 104 industries. For computational and practical reasons these are usually aggregated into 25-35 broader sectors. However, the aggregation is flexible and can be adapted to policy – for example, if the manufacturing sector is of greater interest for a particular simulation, more industrial detail can be included for that sector.

The model can also be modified on a case-by-case basis to accommodate a range of various assumptions particular to specific policies. For example, various fiscal arrangements by which government spending in Scotland is determined can be specified.

Which policies can be modelled using the Scottish Government's CGE model?

As with most CGE models, the Scottish Government's model is used most extensively for modelling fiscal policy scenarios. For example, the model is capable of simulating changes in various taxes, such as the Income Tax, Corporation Tax, Value Added Tax and National Insurance Contributions among others. It can also assess the impacts of changes in the level and profile of government spending.

In addition, it can model the impacts of economic shocks such as changes in export demand, investment, productivity and labour supply. These shocks can be made specific for certain industries if desired.

More detailed policies can also be modelled if sufficient additional data exists to modify the framework or do off-model analysis before running simulations.

CGE models are versatile and can be amended and improved on a continuous basis to incorporate more detail about the economy. Hence, whilst it is possible to put together a list of policies and shocks that can be simulated, it would not be comprehensive.

What is the role of the Rest of the UK in the model?

Currently, the Rest of the UK (RUK) is treated as an exogenous region. Although trade and transfers to and from RUK are separated from the rest of the World, changes in policy in RUK cannot be modelled directly, although off-model analysis can still be incorporated into the modelling framework. At the moment, it is not possible to simulate how changes in policy in Scotland affect RUK endogenously in the model.

The Scottish Government has commissioned an extension to the model that will extend the current framework into a 2-region model of the UK. It is currently in the process of testing and making a final amendment to the model, whilst developing the internal capacity to use it for policy simulations.

Once finalized, the new model will be capable of simulating policies in both Scotland and the rest of the UK separately and capture the interactions between the two economies. It is expected that the model will be operational in 2016.

Is the model capable of distributional analysis?

Currently, the model does not differentiate between different types of households and hence is not capable of distributional analysis.

However, the Scottish Government is currently co-funding research to develop an additional dataset incorporating household heterogeneity by income and type. The extension will allow distributional analysis to be taken forward which will increase the scope for modelling more detailed fiscal policy. This capacity is expected to be developed in 2016.

How long does it take to complete simulations?

The length of time it takes to run a set of simulations depends on the policy or shock being modelled and each new simulation is likely to require an individual approach.

Most simulations involve several stages, such as formulating the modelling strategy, making modifications to the programming code, interpreting simulations and performing sensitivity analyses.

These are time-consuming tasks and undertaking new CGE simulations can take several weeks to complete, although this depends on the analysis in question. Updating previous work usually takes less resources, although analysts will still spend a significant amount of time on quality control.

2. What inputs does it require? (Powered by Copilot)

✔ **Economic Data**: Detailed data on the economy, often presented as an input-output table or a social accounting matrix (SAM). This includes transaction values, sectoral coverage, commodities, primary factors, and household types.

✔ **Exogenous Variables**: Variables that are determined outside the model, such as technology, consumer tastes, and government instruments (e.g., tax rates). These variables are set by the modeler and remain constant during the simulation.

✔ **Endogenous Variables**: Variables determined within the model, such as prices, quantities, and incomes. These variables adjust in response to changes in exogenous variables and policy interventions.

✔ **Behavioral Parameters**: Elasticities that capture behavioral responses, such as export demand elasticities, which specify how export volumes might change if export prices increase.

✔ **Production and Utility Functions**: Equations describing the behavior of producers and consumers, often assuming cost-minimizing behavior by producers and utility-maximizing behavior by consumers.

✔ **Market Clearing Conditions**: Assumptions about how markets clear, which may include non-market clearing for labor or commodities.

✔ **Policy Variables**: Information on policy changes being analyzed, such as changes in tax rates, subsidies, or trade policies.

3. Has it been implemented before?

✔ Open CGE Python library

✔ PyCGE

✔ gegravity library focuses on General Equilibrium Gravity Modeling in Python.

✔ This paper has presented an external module for programs written with the Python language and for the SAGE mathematical software. This module allows the definition and solution of non-linear systems and optimization problems, described in a way very similar to GAMS and programs alike. The key common characteristic of PAMS.py and GAMS is the automatic indexing of parameters, equations and variables.

4. Find three related articles about the model:

✔ Computable General Equilibrium Models and Their Use in Economy-Wide Policy Analysis

✔ Using Computable General Equilibrium Models to Analyze Economic Benefits of Gender-Inclusive Policies

✔ PAMS.py: a GAMS-like Modeling System based on Python and SAGE

✔ Open CGE Python library

✔ PyCGE