Global Computable General Equilibrium (CGE)

Modelling: Online Course

"All models are approximations. Essentially, all models are wrong, but some are useful"
(G Box)

Introduction

This course is an **advanced** course in practical computable general equilibrium (CGE) modelling for a global model using the General Algebraic Modelling System (GAMS) software. The course is designed for individuals who want to develop the theoretical and technical skills required for CGE modelling. The course caters for two different types of participants:

1. CGE model users – participants who want to be able to formulate and code appropriate policy experiments and interpret and **explain** the results from CGE based studies and only make 'small' changes to the model's behavioural equations. These participants will, typically, take the Single Country or Global CGE model course.
2. CGE modellers - participants who want to be able to change and develop the behavioural equations in a model, i.e., generate a new model variant, and formulate and code appropriate policy experiments and interpret and **explain** the results from CGE based studies. These participants will often take both the Single Country and Global CGE model course.
3. CGE modellers and model users - participants taking either or both the Single Country or Global CGE model courses as preparation for taking the Recursive Dynamic CGE Course.

The course is designed to provide training for those persons that have **completed** the Introduction to Practical CGE Modelling course (http://www.cgemod.org.uk/practical.html). This course assumes that you have completed the introductory course and does not provide recaps. If you have **not** completed the introductory course, you will find there are substantial parts of this course that may be opaque and/or confusing.

PLEASE DO NOT COMPLAIN TO US ABOUT THIS DESIGN FEATURE.

CGE models are **NOT** 'black' boxes': they are mathematical models and hence all model insights are ultimately deterministic. Given an understanding of general equilibrium (GE) microeconomics, and some macroeconomics, and the ability to read a simple programming language, all (well coded) CGE models transparent. GE systems may be complex, just as the world is complex; but an unwillingness to learn enough economics and a 'language' does not make a CGE model a 'black box'. Unfortunately, all too many CGE practitioners fail to identify the insights derived from CGE models and do not **explain** the results, which encourages the claims that the models are 'black boxes'.

But CGE models are approximations. Moreover, CGE models are numerical theoretical models that depend on deductive logic, in contrast to econometric models that employ inductive logic. Consequently, CGE models are, and never can be, forecasting models. Rather CGE models are designed to run experiments that can be used to better inform policy makers about the potential consequences of decisions. Hence CGE modellers are well advised to avoid over stating the precision of the results from CGE models.

The course further develops an understanding of the theory of general equilibrium (GE), CGE databases, GAMS coding skills, CGE model coding skills, and exponential functional forms. But the course places most emphasis on the formulation of appropriate policy experiments and the interpretation of the results from simulation models.

The materials are organised in 4 modules with a total of 19 components, each of which requires approximately 4 to 6 hours of input from the participants. The final module of the course is a research project that requires about 12-18 hours of input. Thus, participants should allocate some 120-180 hours to complete the course.

The course assumes that the participants have completed the Introduction to Practical CGE course (http://www.cgemod.org.uk/practical.html) and have an in-depth knowledge of microeconomic theory, especially general equilibrium theory, and an understanding of standard techniques of mathematical economics, especially those relating to differentiation and linear homogenous functions.

It is presumed that participants have completed the courses on 'GAMS and GAMS Studio' (http://www.cgemod.org.uk/gams_studio.html), 'Social Accounting Matrices

(SAMs)' (http://www.cgemod.org.uk/int_sam.html) and 'Introduction to Practical CGE Modelling course' (http://www.cgemod.org.uk/practical.html). This course does **not** revisit the materials covered in those courses. Participants should expect the GAMS/GAMS Studio course to take 20-40 hours, SAM course to take 10-20 hours and Introduction to CGE course to take 160-240 hours. The methods used in this course require an understanding of the mechanics of GAMS and GAMS Studio, an understanding of accounting relationships in Social Accounting Matrices (SAMs) and an understanding of the basic principles of CGE modelling in GAMS.

The course is delivered online from www.cgemod.org.uk\training .

Software

The course use GAMS and assumes that participants use GAMS Studio as the editor; the version of GAMS should be 49 or higher[1]. Participants need a licensed version of GAMS (https://www.gams.com/download/) with license for at least the Base Module and the PATH solver (the CONOPT solver is also advised but not essential). The demonstration license is **NOT** adequate for this course. Participants on the course need to make their own arrangements to access a licenced copy of the GAMS software.

The materials were developed in a MS Windows environment. While GAMS and Studio are also available in MacOS and LINUX variants, we cannot guarantee that all the techniques used are available in the Mac and LINUX environments.

It is assumed that participants have access to readers for pdf and mp4 files, and word processing and spreadsheet programmes (we use MS Office, but other programmes may be adequate).

This course does NOT use a GUI (Graphical User Interface) to access GAMS. Experience has demonstrated that the use of a GUI by participants on training programmes typically limits the development of the skills needed to be a good CGE modeller or user of CGE models, while encouraging the belief that CGE models are 'black boxes'. Basic GAMS programming skills, and an understanding of economic theory, demonstrates that allegations

[1] The current version of the course was last tested with GAMS 51.2 and Studio 1.22.2. Some of the details in the exercise documents may be not be correct for earlier versions of GAMS or Studio.

that CGE models are 'black boxes' are false. The development of GAMS, or GEMPACK, programming skills greatly extends the ability of the user to exploit the power of CGE models, and, at the same time, opens the potential that participants can, in the future, change behavioural relationships in CGE models.

Course Overview

CGE models are essentially systems of behavioural relationships expressed as non-linear and linear simultaneous equations that are derived from Walrasian microeconomics; hence they are firmly grounded in microeconomic theories and the concepts of constrained optimisation. The non-linear equations are almost invariably derived from linear homogenous equations that are linear in logarithms and use standard functional forms, e.g., Cobb-Douglas, Constant Elasticity of Substitution, etc. The databases for **ALL** CGE models can be expressed as Social Accounting Matrices (SAM) with satellite accounts; the data for all models used in cgemod courses are SAMs with satellite accounts. Once the principles, especially the determinants of prices, are understood, SAMs provide a simple way to understand the data used in CGE models and identify the economic transactions that must be included in a CGE model.

CGE models, as are arguably all economic models, are underdetermined systems in the sense that there are more variables than equations. To bridge this gap CGE models require the specification of market clearing conditions, for all markets but most importantly for factor markets., and macroeconomic closure conditions. The macroeconomic closure conditions require that CGE modellers understand the implications of different macroeconomic closure assumptions and their relationships with different 'schools' of macroeconomic thought.

This course does not teach ***THE*** model. Rather our courses are designed to aid the development of generic CGE skills. The models used by the course (see below) are designed so that participants can develop CGE skills using progressively more sophisticated models, by starting with the simplest CGE model and subsequently adding more complex behavioural relationships. All the models use the same range of behavioural relationships and functional forms with common notation, so the transition from simple to more complex models involves progressively learning techniques not starting afresh.

We do not advocate that `ANARRES_t` should be used unchanged. It is arguably as 'standard' model that **SHOULD** be used to develop models suited to specific studies. We strongly advocate that **ALL** CGE models should be adjusted to fit the economic circumstances in a country as reflected in the data, i.e., SAM, and that the data should **NEVER** be adjusted to fit a predetermined CGE model.

Course Aims and Objectives

Course Aims

To develop the CGE modelling skills of participants (using GAMS) so they

i) understand the behavioural relationships used in CGE models;
ii) understand the impact of different behavioural relationships used in CGE models;
iii) understand the calibration of the behavioural relationships in CGE models;
iv) can formulate appropriate CGE policy experiments; and
v) can interpret the results generated by single country CGE models.

Course Objectives

On completion of the course the participants will be able:

vi) formulate and code appropriate policy experiments;
vii) identify and understand the strengths and limitations of CGE models;
viii) make some modifications to behavioural relationships;
ix) interpret the results from single country CGE models; and
x) identify, and present, the policy implications of simulations using single country CGE models.

Pedagogic Method

The course emphasises the fact that CGE modelling is a practical skill that is best learnt-by-doing. However, it is recognised that developing the skills needed by CGE modellers and users can be daunting, because they require the development of

a) computer programming skills,
b) techniques needed to convert economic theories into computer equations,
c) an understanding of social accounts,
d) meaningful policy experiments, and
e) skills to analyse and interpret large numbers of results.

The pedagogic method adopted is inspired by the KISS – Keep It Simple 'Stupid' – principle, where 'stupid' is understood as saying that not keeping it simple is 'stupid'. Accordingly, the course progressively builds up the required economic theory, computer coding and policy experiment and analysis skills by starting with small and simple models before ending with an advanced, and scalable, CGE model.

Each module in the course builds on skills learnt in previous modules; it is important to complete each module. Each module has a work programme supported by detailed model documents, PowerPoint slides, PowerPoint videos, exercises, and computer code. For each module there are a series of exercises that are guided by detailed instructions: the exercises cover both computer coding exercises and policy experiments and interpretation. Most modules have an associated deliverable, which is typically based on the final exercise of the module.

The methods used in this course assume participants have completed the Introduction to Practical CGE course (http://www.cgemod.org.uk/practical.html).

While all too often CGE modellers regard data as a 'tedious distraction from the more important work of modelling' we strongly disagree.[1] We recommend continuous enhancement of your understanding of the potential for developing Social Accounting Matrices (SAMs) to better reflect economic systems.

The course is delivered from the cgemod website (www.cgemod.org.uk) and is not supported by a tutor.

However, if you find errors in the material and/or suggestions for improvements, we are grateful for feedback.

[1] The economic realities of different economies are different. You should regard SAMs that adopt the same account structure for commodities, activities, institutions, taxes and factor types for different economies with extreme scepticism.

Course Models

This course uses one 'standard' model, `anar_t`[1], which is, c 2015, a state-of-the-art CGE model designed for the analyses of a wide range of real-world policy issues. It is a 'standard' model in the sense that is provides an advanced basis for the further model development; not in the sense that is one size that fits all.

The domestic behavioural relationships in the ANARRES_t model are derivatives of the smod_t model. It is organised in an identical way and uses (largely) common notation and coding techniques: it is however a step change from the smod_t. The international transactions in the anar_t are generalisations of the Armington insight and hence the 123 model.

1 `ANARRES_t` is a development of the `GLOBE_2` model first produced in the early 2000s. It has however been revised, customised, and further developed for this course.

Programme Module G1: ANARRES_t Theory

	Topic	Tasks	Exercises
O11:1	Intro to ANAR_t	Review the model and note the extensions to SMOD_on used in the Practical CGE modelling course	Exercise G1: Run model setup and check solution
O11:2	Trade in ANAR_t	The modelling of trade relationships in a global model	No exercises
O11:3	Prices, Taxes and Accounting in ANAR_t	The modelling of price and tax relationships in a global model	**Project G1.1:** Calculating trade prices for the region Rest of World
O11:4	Production and Demand in ANAR_t	The modelling of production and demand relationships in a global model.	No exercises
O11.5	FTA Exercise	Code trade liberalization simulations; loop over simulations; access results in GDX with Studio.	Exercise G2: Trade Policy - OECD and Africa form an FTA
O11:6	Accessing Model Results	Access results written to gdx files using GAMS Studio; filter results and export to Excel.	Exercise G3: Model Results with GAMS Studio **Project G1.2**

Programme Module G2: ANARRES_t Model Exercises

	Topic	Tasks	Exercises
	Topic	**Tasks**	**Exercises**
O12:1	Introduction to the ANARRES_t Database	Understanding the structure of the database	No exercises
O12:2	Configuring the ANARRES_t Model	Understanding the structure of, and data used in, ANAR_t; use the control sheet	Exercise G4: Model setup and calibration
O12:3	Macroeconomic Closure Conditions	Code alternative macroeconomic closures; loop over sim and clos	Exercise G5: Trade policy and macroeconomic closures
O12:4	Factor Market Clearing Conditions	Code alternative factor market clearing conditions; loop over sim and clos	Exercise G6: Trade policy and factor market specification
O12:5	Sensitivity Analyses	Analysing an Africa OECD FTA	Exercise G7: Sensitivity analyses Exercise G8: Save and restart
O12:6	Analysis of FTA Results	Coding appropriate sims and clos for FTA analysis described in the deliverable.	**Project G2**

Programme Module G3: Interpreting ANARRES_t Model Results

	Topic	Tasks	Exercises
	Topic	**Tasks**	**Exercises**
O13:1	Analysing and Reporting Results	Appreciating the formulation, interpretation and presentation of policy experiments	No exercises
O13:2	Interpreting Model Results (I)	Analysing an OECD Africa free trade agreement (FTA)	Exercise G9: Interpreting Model Results I: Trade Policy **Project G3.1**
O13:3	Interpreting Model Results (II)	Analysing efficiency gains in a global context	G10: Interpreting Model Results II: Competitiveness Shocks **Project G3.2**

Programme Module G4: ANARRES_t Course Project

The objectives of the project are to develop your ability to (i) implement policy experiments in a small global CGE model; (ii) interpret the results of your policy experiments, (iii) carry out systematic sensitivity analyses and (iv) present a report. There are five elements to the project: model recalibration, experiment programming, policy experiments and interpretation, sensitivity analyses and project report.

The available data are from GTAP 8: the database has been partially aggregated. You will need to devise an (further) aggregation consistent with your proposed project and set up the supporting Excel database.

Your remit is that of an economic consultant who has been employed to analyse policy issues that are relevant and current to your chosen country and can be conducted using a global CGE model. You are required to identify the policy issue, code the policy experiments, interpret and write up the results and conduct sensitivity analyses. The final report will be a maximum of 15 pages, including all tables and graphics

	Topic	**Tasks**	**Exercises**
O14:1	ANARRES_t Project Proposal	Develop your project proposal which includes the backstory, aggregation and experiments	Run the ANARRES_t model with your policy experiments **Project G4.1 (**Proposal**)**
O14:2	ANARRES_t Project Data	Aggregate the course database to a specification appropriate for your policy question	Generate the project database
O14:3	ANARRES_t Project Model	Run the ANARRES_t model with your aggregation	Set up the project model's database
O14:4	ANARRES_t Project Analysis	Set up and implement policy experiments in the ANARRES_t model. interpret the results of your policy experiments	Run the ANARRES_t model with your policy experiments **Project G4.2:** Report