# Closure in CGE Models

Short Course on CGE Modeling, University of the South Pacific

John Gilbert

Professor
Department of Economics and Finance
Jon M. Huntsman School of Business
Utah State University
jgilbert@usu.edu

July 23-27, 2012

# Introduction

- In any economic model we must make a choice as to what is to be determined within the model (the endogenous variables) and what is to be considered external to the model (the exogenous variables).
- A model, numerical or otherwise, is just a way of explaining the endogenous variables in terms of the exogenous.
- Where we choose to draw the line between endogenous and exogenous and exactly which variables we choose to be exogenous depends on a number of factors, including model tractability, and the purpose for which the model simulations are to be used.
- The choice that we make is called the model closure. In this session we discuss some of the issues surrounding closure for CGE models.

# Session Outline

1. Closure Concepts
2. Microeconomic Closure
3. Macroeconomic Closure
   - Closed Economy
   - Closed Economy with Government/Investment
   - Open Economy

# Closure Concepts

- Mathematically, ensuring that a model is 'closed' amounts to ensuring that we have enough independent equations to explain the endogenous variables.
- If a model is closed and we want to explain another exogenous variable, we must either add a new equation to the model to explain it, or switch it for a currently endogenous variable.
- Because the choice of a closure defines the direction of causality in a model, our choices can have significant implications for the behavior of the model.
- In static CGE models we are most often concerned with elements of the factor market closure, and with macroeconomic elements relating to investment and government spending.

# Factor Market Closure

- Changes in the capital market closure are usually used to represent different adjustment time frames.
- Consider the specific factors and HOS models of production. The key difference between them is that in the former the stock of capital in each industry is exogenous, and the price of capital in each sector is endogenous.
- We can think of this as a closure choice — the specific factors model does not attempt to explain the allocation of capital. By contrast, the HOS model does, and to do so it must introduce two new conditions. These are full employment of capital and capital price arbitrage.
- Which of these closure options we choose will depend on the adjustment time-frame that we want the results to represent, with the specific factors case being thought of as 'short run' and the HOS case as 'long run.'

# Steady State Closure

- Another alternative is sometimes called a ‘steady-state’ closure.
- In this case, the price of capital is assumed to be at a long-run equilibrium rate and the capital stock is at its optimal level given that return.
- Increases in the return to capital caused by a shock to the economic system would induce an increase in investment, thereby driving the marginal product of capital down to its original level.
- Hence, to implement the closure we ‘swap’ the exogenous/endogenous status of the capital stock and the return to capital. The expansion of the capital stock generates an endowment effect that can be thought of as capturing the dynamic effects of the shock.

# Labor Market

- When it comes to the labor market, we have similar closure choices.
- Most common closures are neoclassical — the wage rate is assumed to vary to ensure full employment of labor.
- We can instead fix the wage rate and endogenize the level of employment or the labor stock.
- If we want to allow both the price of labor and the quantity of labor supplied to vary, we are drawing the line for what is inside the model in a different place. We would need to provide another equation to describe the labor supply. This could be accomplished by allowing for the consumption of leisure by the household and adding a time constraint, or by specifying an immigration function.

# Macroeconomic Closure

- In CGE models we usually introduce government spending and investment since these are significant sources of final demand.
- Nonetheless, their introduction to the model sits somewhat awkwardly within the static economic framework.
- This is because the models represent a single period, but investment and saving (by the household or the government) represent activities directed to future periods which are not explicitly modeled.
- Similarly, government expenditure presumably reflects, at least in part, investment in public goods, but the optimization process behind spending choices is not explicitly modeled.
- This necessitates that a closure choice be made for key macroeconomic variables (or building a dynamic model).
- In particular, we need to specify the workings of the savings-investment balance, the government balance, and the trade balance.

- Begin by considering a closed economy in which there is no government.
- From the income identity we know that $Y = C + I$.
- By definition, consumption is equal to income less savings, i.e., $C = Y - S$, but that of course means that $S = I$.
- This is the most simple form of the balance identity for a closed economy.
- While the equation does not usually appear within our models directly, it is implicit.

# Implications

- One way to think about this is that we have one equation — the balance identity — with which to determine two variables ($S$ and $I$).
- Since this can't be done, we need to either add another equation to determine one of the variables, or treat one of the variables as exogenous.
- The method we choose is our solution to the closure problem.
- We will run into a difficulties if we try and fix both (or if we add equations to determine both) because the model will be over-identified.

# Savings vs Investment Driven Closure

- In this simple case we have two options.
- We can determine the value of total investment within the model and let the balance identity determine savings. This is called an investment-driven or 'Johansen' closure.
- Or, we can determine the value of saving (perhaps a fixed proportion of disposable household income) and let the balance identity determine the value of total investment. This is called a savings-driven closure.
- So which should we use? That depends on what we are trying to do with the model.

# Closed Economy with Government

- Now let's suppose that we have a government.
- The government collects tax revenue $R$, makes transfers to the household (social security and so on) of $T$, and spends on consumption $G$.
- The income identity is now $Y = C + I + G$.
- The government deficit is $D = R - G - T$, while household consumption is $C = Y - R + T - S$. This implies that $S + D = I$.
- In other words, the sum of household savings and government savings must equal investment.
- Now we have only one equation with which to determine three values. We have to find some way of determining two of them.

# Closure Options

- Suppose that we treat $I$ as exogenous. If tax policy instruments are fixed, government revenues are determined. If we also fix government spending (both $G$ and $T$) then $D$ is determined. Private savings must be left free to properly close the model.
- We can interpret the results of simulations with a model closed this way as representing the effect of a shock for given levels of investment, provision of public services, and taxes.
- What if we believe the government faces a binding budget constraint? In that case we fix $D$. If $T$ is also fixed, and $R$ is determined by fixed tax rates, then $G$ must vary to maintain the government deficit level. Fixing either $S$ or $I$ then closes the model.
- Instead of changing expenditures to maintain the budget, perhaps the government changes revenues. Suppose we believe the government will adjust a sales tax to achieve its spending aims. Then we can fix both $D$ and $G$, but must allow the tax rate to be endogenous so that $R$ can adjust to maintain the balance.

# Open Economy

- Now let's briefly consider the open case. Again, we'll use an economy in which there is no government to simplify.
- From the open economy income identity we know $Y = C + I + X - M$. Using the definition of private savings, this implies that $S - I = CA$.
- This is the basic balance identity for an open economy. It states that the difference between domestic savings and investment must equal the current account balance. The latter reflects savings/borrowing from the rest of the world.
- To close the open economy model we need to determine two of $S$, $I$ and $CA$. We can fix the current account balance and investment and let private savings adjust to maintain balance, or we can fix savings and the current account and let investment adjust, or we can fix savings and investment and let the current account adjust.

# Current Account

- In practice, for almost all CGE models the current account is fixed, and then either a savings-driven or investment-driven closure is chosen. Some of the reasons are:
  - Many CGE models are of developing economies, and foreign credit may in fact be limited, so a fixed current account may simply reflect economic reality.
  - We can interpret the results of simulations with such a closure as representing the economic effect of a policy for a given level of foreign borrowing and investment in future consumption.
  - Measures of economic welfare based on household consumption become invalid if the current account is free (since borrowing foreign funds increases consumption in the current period, and the model does not account for paying the debt back).
- If the exchange rate is used as the numéraire we can fix the current account directly. Otherwise we may set another numéraire (perhaps a CPI index) and allow the exchange rate to vary to maintain current account balance.

# Summing Up

- No closure is the 'right' closure, it just depends on which you believe characterizes the most important aspects of the economy of interest most accurately.
- Whatever closure you choose for your own modeling work, however, it is good practice to be very clear about it so that readers can properly evaluate the results of your study.
- You can use sensitivity analysis to help evaluate the implications of different closure choices.

# Further Reading

- This discussion is based on Gilbert and Tower (2012), chapter 26.
- A classic reading on closure rules in computable general equilibrium models is Dewatripont and Michel (1987).
- Robinson and Lofgren (2005) give a nice overview of the macroeconomic stories that underlie common closure rules.