Calibration

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Big Picture: How should we take macro models to the data?

- We want to understand how the macroeconomy works. That is we want to understand how the activities of millions of people aggregated together effect things like total output and the general price level.

  We can't run experiments (for the most part) and there is too much activity going on for any one person or small collection of people to absorb. So we write down theories, really models, to help us understand the macroeconomy.

- So what is a model or a theory?

  Robert Lucas' definition is a good one:

  > an explicit set of instructions for building ... a mechanical imitation system

  Let me re-phrase it as a model is something we can write down, solve, and simulate.

The Scientific Method

- Now we often call ourselves scientists and claim to use scientific methods to understand social phenomena.
- So what is the "scientific method"?

  1. Write down a model.
  2. Solve the model for a refutable hypothesis
  3. Take the model to the data
  4. If the model is consistent with the data, accept the hypothesis and keep the model. If the model is inconsistent with the data reject the hypothesis and discard the model.

- Theories must formulate testable hypotheses. That is the common definition of the scientific method.
- But any macro model can be rejected when confronted with enough data.
- So why is writing down and solving model an useful exercise?

Science as Data Reduction

- That is we want to compress data. A good theory compresses data with minimal loss of information.
- Chris Sims uses an example from the physical sciences as an example:
  - Tycho Brahe accumulated large amount of reliable data on the movement of the planets. In doing so he could accurately predict the motion of planets.
  - But then Kepler came along and noticed that planets move on an elliptical orbits with the sun at a focus, allowing the movements of the planets to described by a small set coordinates
  - Newton then found the inverse-square law, thus developing a formula that compressed the data further and gave predictions to the paths of new planets.
- Brahe's theory was not false, but Kepler's theory was better since it allowed the data to be summarized in a more compact form.

- We have been studying models of the form:

$$\max \sum_{t=0}^{\infty} \beta^t \left(u(c_t) + v(1 - h_t) \right)$$

subject to

$$\begin{aligned} c_t + i_t &= A_t k_t^{\theta} h_t^{1-\theta} \\ k_{t+1} &= (1 - \delta) k_t + i_t \\ \lambda_{t+1} &= (1 - \gamma)\bar{\lambda} + \gamma \lambda_t + \epsilon_{t+1} \end{aligned}$$

This is a useful way to organize and compress data. It provides a compact theory that can integrate growth theory with business cycle theory.

- Prior to the RBC model, we had one model for long-run growth (i.e. Solow) and one model for short-run business cycle fluctuations (i.e. IS-LM)

- Having a model in which the short-run and the long-run are consistent is very appealing from a theory as data-compression standpoint though it makes it that much easier to reject the model from a hypothesis testing standpoint.

- The model matches some basic data facts (i.e consumption smoothing, generates cycles).
- But it fails along many important dimensions
  - the model is stochastically singular (i.e. everything is driven by a single shock)
  - it can not match all the second moments of the data
- Now the question is how do we use this model?
- There is an old tradition going back to Haavelmo who argued that one should embed an economic model within a complete probabilistic framework.
- However, this model does not provide a complete probabilistic structure for all the variables under consideration. As we will see to analyze such a model with say maximum likelihood, we would need to augment the model with additional random components. Inferences drawn from these expanded models are meaningful only to the extent that the additional random components do not mask or change the salient features of the original economic model.

Kydland and Prescott Approach

Another approach has been articulated by Kydland and Prescott. They propose the following research strategy.

1. Pose a Question

- For example, the main question Kydland and Prescott want to ask is

  > How much of the U.S. postwar economy would have fluctuated if technology shocks had been the only source of fluctuations?

2. Use Well-Tested Theory

- Pick components that match some basic facts:
  - Cobb-Douglas production function implies stable capital and labor shares of income.

$$\max E_0 \sum_{t=0}^{\infty} \beta^t \left(u(c_t) + v(1 - h_t)\right)$$

subject to

$$\begin{aligned} c_t + i_t &= \lambda_t k_t^{\theta} h_t^{1-\theta} \\ k_{t+1} &= (1 - \delta) k_t + i_t \\ \lambda_{t+1} &= (1 - \gamma) + \gamma \lambda_t + \epsilon_{t+1} \end{aligned}$$

- But the term "well-tested" is a little funny here. Does "well-tested" mean familiar?

3. Construct a Model Economy
  - So if you use the above model to address this question you will need to pick parameter values, solve the model, generate decision rules, then use the decision rules to answer your question.

4. Calibrate the Model Economy

- So how should one pick parameter values? Well Kydland and Prescott argue

  > In fact, searching within some parametric class of economies for the one that best fits a set of aggregate time series makes little sense, because it isn't likely to answer an interesting question. For example, if the question is of the type, "how much of fact X is accounted for Y," then choosing the parameter values in such a way as to make the amount accounted for as large as possible according to some metric is an attempt to get a particular – not a good – answer to the question.

- So Kydland and Prescott propose calibrating the model. Often when I hear in graduate student talk that someone is calibrating their model, it usually means "I took the parameters from some other paper" or "I picked the values everybody else uses."

  This is not what Kydland and Prescott mean when they state that they are calibrating their model.

- The term calibration is used in the natural sciences in that you calibrate a thermometer such that water freezes at 0 degrees centigrade and boils at 100 degrees centigrade. And they note that you would to recalibrate the thermometer is you were at sea-level or in the mountains.
- In practice what they are going to do is pick parameters such that the model matches long-run averages such as average output growth, consumption-output ratio, labor's share. For other parameters such as elasticities of substitution between consumption and leisure, they argue using micro estimates.
- Now this has some appeal. Much of the appeal of modern macro models are that they are "micro-founded."
- They emphasis that they are not picking parameter values that best match the data. Because they are not asking the question "how well can the neo-classical growth model fit the data?" They are asking if the economy is only driven by technology shocks, how much of the short-run fluctuations could you explain?

5. Run the Experiment

- Solve the model for an equilibrium.
- Derive ergodic distributions directly or by simulation.
- Figure out the intuition.
- Run counter-factual scenarios
  - make the simulated data as comparable as possible to the real world data (filtering, time period, time aggregation, point sampled versus averages, ...)
- Argue that fraction of the business cycle fluctuation that can be attributed to technology shocks is 70 percent.
- Argue that this finding is robust to lots of modifications in the model.

Gary Hansen's JME (1985) paper

- In Gary Hansen's paper he looks at two models. One in which

$$u(c_t) + v(1 - h_t) = \log c_t + A \log(1 - h_t)$$

which he called the divisible labor model, and the second in which

$$u(c_t) + v(1 - h_t) = \log c_t + B(1 - h_t)$$

which he called the indivisible labor model.

- He wanted to compare these two models.
- So he needed to find parameter values for θ , δ, β, A, γ, and the standard deviation of the error term.

"Methodology for choosing parameters from growth observations and micro studies"

- choose θ to match capital's share of income, 0.36.
- choose δ to match average quarterly depreciation rate, 0.025.
- choose β to imply a steady state annual risk free interest rate of 4 percent.
- Set A to 2 so agents spend 1/3 of of their time engaged in work.
- Set γ to 0.95 to match the serial correlation in the Solow residual

$$\log \lambda_t = \log y_t - \theta \log k_t - (1 - \theta) \log h_t$$

Then Hansen states it is tough to get a measure for σ_ϵ because of measurement error (e.g. variable capital utilization).

He chooses $\sigma_\epsilon = 0.00712$ because it implies that the mean standard deviation of of output for the economy with indivisible labor is equal to the standard deviation of GNP for the U.S. economy.

- Gary Hansen argues that the indivisible labor model is better description of the real world for several reasons:

  1. increases the volatility of the output for a given level of σ_ϵ. Prefer lower values of σ_ϵ.
  2. increase in the variability of hours worked.

- States the model still underestimates the variability of consumption and investment. Hansen argues that it must due to measurement error (e.g. distinction between durable and nondurables).

Some Comments

- Neither Kydland and Prescott nor Gary Hansen claim that their models explain all the characteristics of the data. They are going to make no attempt to augment the model with additional random components to more accurately describe the data.

  This makes it easier to interpret the results since the model is not complicated by additional random components added solely for statistical convenience.

  On the other hand, since the model does not provide a complete probabilistic structure, inference procedures are necessarily ad hoc.

- In the 1980s there was a view that macro researchers could plug micro-level parameters (in particular, elasticities) in macro models. But this idea that empirical microeconomics would provide accurate parameters for macro model has pretty much vanished.

- There was this view (and both Hansen and Kydland and Prescott state it) that they are just using growth observations and micro studies to pick their parameter values. But to get parameters for γ and σ_ϵ they are using neither growth nor micro observations.

- I want to add an additional step to Kydland-Prescott recipe for doing research. Call it step 4.5

  Evaluate the goodness of fit.

- You need a metric for how well the model fits the data of interest. And Kydland and Prescott are correct in arguing that you don't want to use the same moments to both pick parameters and evaluate goodness-of-fit. That isn't very interesting.

- One way to interpret standard RBC calibration is that they use the first moments (primarily) of the data to estimate the parameters of the model and the second moments to evaluate the goodness of fit. But keep in mind to estimate the shock process they need to use some second moments.

  But if this is your view, then it easy enough to be more explicit about the particular criterion you are using calibrate the model.

- Often calibraters are criticized for not reporting standard errors, but I think the more important criticism (and this can be mitigated by thoughtful discussion) is that the criterion used to pick parameter values is not explicit and often not well thought often and specified.
- Also researchers are often happy to write down specific functional forms without thinking about robustness but if you write down parameter without a standard error the audience goes berserk ... This kind of logic turns you into a Bayesian ...