Temes de Macro:
Macro Modeling at Central Banks

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June 14, 2010

The Plan

1. What do central banks do?
2. What makes a model useful to a central bank?
3. Structural Vector Autoregressions (SVARs)
4. Dynamic Stochastic General Equilibrium (DSGE) Models

Reading package available at http://www.kris-nimark.net/

What do central banks do?

- Right now, a lot of things: Buys and sells banks, assets,...
- In normal times:
  - Regulate banks
  - Handle borrowing needs of governments
  - Set (nominal) interest rates: Monetary Policy

We will focus on the last point.

Monetary policy and flexible inflation targeting

Inflation costly to society

- Cost of printing menus etc more often
- Unexpected inflation leads to wealth redistribution
  - High inflation tend to be more volatile
- With staggered (non-synchronized) price changes, inflation leads to relative price distortions
- With very high levels of inflation, money loses its function as a store of value between transactions: Hyper inflation often leads to barter.

Monetary policy and flexible inflation targeting

The high inflation in the 1970s (and in some countries the 1980s) and new insights from academic research lead to institutional changes

Theoretical advances:

- Lucas (1972): Inflation-output trade off may an illusion: Long run Phillips curve is vertical
- Kydland and Prescott (1977) Rules vs Discretion

Institutional changes:

- Introduction of *Inflation Targeting*
- Central bank independence

What are the goals of a central bank when it sets interest rates?

Most OECD countries have inflation targeting central banks, either explicitly or implicitly.

$$L = \sum_{s=0}^{\infty} \beta^s \left[\left(\underbrace{\pi_{t+s} - \overline{\pi}}_{\text{inflation gap}} \right)^2 + \lambda \left(\underbrace{y_{t+s} - \overline{y}_{t+s}}_{\text{output gap}} \right)^2 \right]$$

- If $\overline{\pi}$ is fixed and publicly known, central bank is an explicit inflation targeter
- The Fed is often viewed as an implicit inflation targeter, the ECB is an explicit one.
- If $\lambda = 0$ minimizing the loss function is referred to as "strict" inflation targeting.

To minimize the loss function, the central bank must have an instrument at its disposal that affects future inflation and output

Inflation targeting in practice

Most central banks use a short term interest rate as the instrument of policy

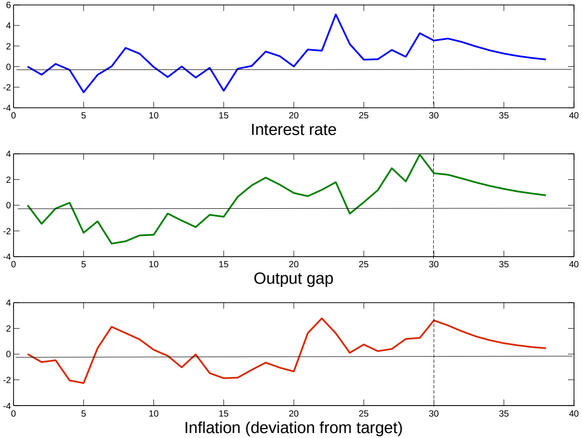
- If prices are sticky, controlling nominal interest rates allow the central bank to control expected real interest rates (in the short term, at least)
- Expected real interest rates affect spending (e.g. consumption and investment) decisions

The decision process

- What is the likely path of future inflation and output gaps?
  - No bank relies on a single model, but have several models and "sector specialists".
  - This path is always conditional on a path of the policy instrument
    - Most likely policy (i.e. the best forecast, conditional on past observables)
    - Holding policy fixed
- Are we happy with the paths of the target variables?
  - If yes, set interest rate equal to value that projection was conditioned on
  - If no, we need to set interest rate so that a more desirable path for inflation and output is more likely

Central bank need some way to quantify how a change in the interest rate will affect the likely trajectory of the economy

Illustrating the decision problem



What should a central bank ask from a good (statistical) model?

The model should describe the dynamics of the target variables

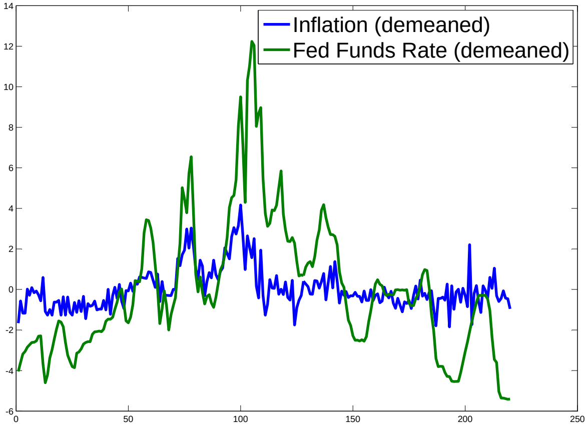
- Important as policy is necessarily forward looking

The model should capture how the policy instrument affects the target variables

- Without this link, the model cannot provide guidance for policy decisions

The second point is more subtle than might first appear:

- Are historical correlations enough?
- What is the correlation between inflation and interest rates?


Inflation (demeaned)
Fed Funds Rate (demeaned)
14
12
10
8
6
4
2
0
-2
-4
-6
0
50
100
150
200
250

Inflation and interest rates: What is the relationship?

If you estimate the equation

$$\pi_t = \beta r_t + \epsilon_t$$

on 50 years of US data you will find $\beta = 0.2$

- Does this accord with your prior expectations?

Statistical model for policy evaluation

Two important issues:

1. Identification
2. The Lucas (1976) critique (next time)

Identification: Quantifying the effect of interest rates on output and inflation

Can't we just run a regressions of the form

$$\begin{aligned} y_t \quad = \quad & +\delta_1 y_{t-1} + \ldots + \delta_p y_{t-p} \\ & +\phi_0 r_t + \phi_1 r_{t-1} + \ldots + \phi_p r_{t-p} \\ & +\gamma_0 \pi_t + \gamma_1 \pi_{t-1} + \ldots + \gamma_p \pi_{t-p} \\ & +u_t^y \end{aligned}$$

for y_t and π_t?

No, we cannot estimate the coefficients consistently because of simultaneity bias

- Both inflation and interest rates may be correlated with the error term

Identification: 1960s and 1970s

Large models mostly based on national account identities (1st and 2nd generation in Fukac and Pagan (2009) terminology)

- Dynamics added after NA identities, often taking simple forms
- Supply was taken as more or less fixed: Economic theory only used to determine what drives demand
- Fitted the data quite well...
- ...but models with full dynamics often unstable

Identifying the effects of policy

- Exclusion restrictions

SVARs: Sims (1980)

Sims (1980):

- "Incredible identifying assumptions"
- Exclusion restrictions seemed often to be implausible

Suggested that we estimate reduced form VARs and then impose weak restrictions to identify the effect of a policy change

- "Weak restrictions" mean restriction on parameters that are likely to hold in a wide range of plausible models
- No way to tell from looking at the data whether restrictions are "correct"
- In this framework, "policy change" means deviation from historical pattern

SVARs: Sims (1980)

Sims (1980) suggested the following strategy:
Most linear model can be nested in a system of equations

$$
\begin{aligned}
A_0 \begin{bmatrix} r_t \\ y_t \\ \pi_t \end{bmatrix} &= A_1 \begin{bmatrix} r_{t-1} \\ y_{t-1} \\ \pi_{t-1} \end{bmatrix} + A_2 \begin{bmatrix} r_{t-2} \\ y_{t-2} \\ \pi_{t-2} \end{bmatrix} + \ldots + A_p \begin{bmatrix} r_{t-p} \\ y_{t-p} \\ \pi_{t-p} \end{bmatrix} + \mathbf{u}_t \\
E\left(\mathbf{u}_t \mathbf{u}_t'\right) &= I
\end{aligned}
$$

- The matrix A_0 captures the contemporaneous relationships between the variables
- The three variables here are fewer than in many actual models, but the example captures the main idea.

SVARs: Sims (1980)

Pre-multiply both sides with A_0^{-1} to get

$$Y_t = A_0^{-1} A_1 Y_{t-1} + A_0^{-1} A_2 Y_{t-2} + \ldots + A_0^{-1} A_p Y_{t-p} + A_0^{-1} \mathbf{u}_t$$

or

$$Y_t = \Phi_1 Y_{t-1} + \Phi_2 Y_{t-2} + \ldots + \Phi_p Y_{t-p} + \mathbf{e}_t$$

where $Y_t = \begin{bmatrix} r_t & y_t & \pi_t \end{bmatrix}'$ and $E\left(\mathbf{e}_t \mathbf{e}_t'\right) = A_0^{-1}\left(A_0^{-1}\right)' \equiv \Omega$

The matrix A_0^{-1} governs how a structural shocks affects Y_t

Language

Structural form:

$$A_0 Y_t = A_1 Y_{t-1} + A_2 Y_{t-2} + \ldots + A_p Y_{t-p} + \mathbf{u}_t$$

Reduced form:

$$Y_t = \Phi_1 Y_{t-1} + \Phi_2 Y_{t-2} + \ldots + \Phi_p Y_{t-p} + \mathbf{e}_t$$

The data can tell us about the appropriate reduced form, but we need additional assumptions to find the structural form.

Estimating the reduced form

Since everything on r.h.s. of the reduced form is predetermined, we can estimate the Φs and Ω consistently using OLS.

Denote $X_t = \begin{bmatrix} Y'_{t-1} & Y'_{t-2} & \cdots & Y'_{t-p} \end{bmatrix}'$ then

$$\begin{bmatrix} \Phi_1 & \Phi_2 & \cdots & \Phi_p \end{bmatrix} = \sum_t Y_t X'_t \left[\sum_t X_t X'_t \right]^{-1}$$

and

$$\Omega = \frac{1}{T-p} \sum_t \mathbf{e}_t \mathbf{e}'_t$$

Identifying assumptions

- Identifying restrictions allows us to recover the structural form the reduced form.
- It is common to assume that output and inflation do not respond within the month/quarter to a change in policy.

Imposing this assumption means setting some elements of A_0 in structural form

$$A_0 Y_t = A_1 Y_{t-1} + A_2 Y_{t-2} + \ldots + A_p Y_{t-p} + \mathbf{u}_t$$

equal to zero, i.e.

$$Y_t = \begin{bmatrix} r_t \\ y_t \\ \pi_t \end{bmatrix}, \quad A_0 = \begin{bmatrix} x & x & x \\ 0 & x & x \\ 0 & (x) & x \end{bmatrix}$$

In addition, it is often assumed that inflation do not respond within the quarter to output, i.e. $(x) = 0$.

Identifying assumptions

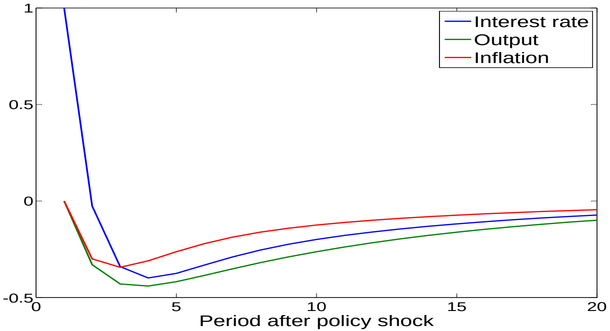
We then have an equation in 6 unknowns and six restrictions (since Ω is symmetric and triangularity is preserved under inversion)

$$\begin{aligned} A_0^{-1}\left(A_0^{-1}\right)' &\equiv \Omega \\ A_0^{-1}\left(A_0^{-1}\right)' &= \frac{1}{T-p}\sum_t \mathbf{e}_t\mathbf{e}_t' \\ \begin{bmatrix} x & x & x \\ 0 & x & x \\ 0 & 0 & x \end{bmatrix}\begin{bmatrix} x & 0 & 0 \\ x & x & 0 \\ x & x & x \end{bmatrix} &= \frac{1}{T-p}\sum_t \mathbf{e}_t\mathbf{e}_t' \end{aligned}$$

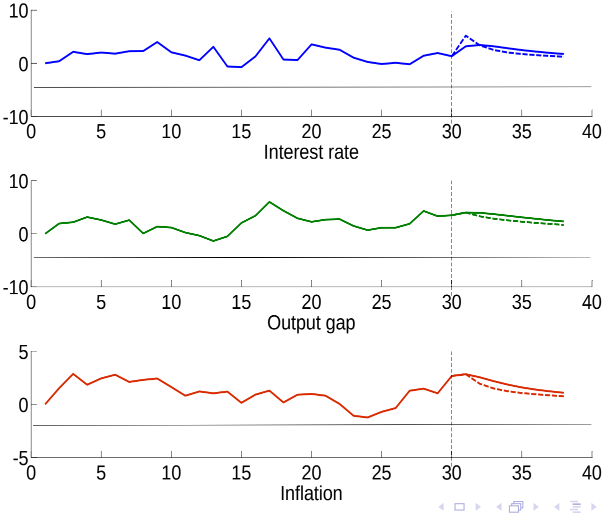
After solving for A_0 (using the Cholesky decomposition) we can find the other matrices in the structural form by $A_1 = A_0\Phi_1, A_2 = A_0\Phi_2$,..., and so on.

Impulse response functions

To illustrate the effect of a policy change on the inflation and output, we can compute an impulse response function of Y_t to an exogenous change in r_t.



Illustrating the decision problem



SVARs

1. Estimate reduced form using OLS
2. Impose identifying assumption
3. Back out structural form

The procedure will be accurate if contemplated policy changes are small relative to historical "shocks"

- See literature on "modest policy interventions"

SVARs

Pros:

- Imposes few assumption
- Allows for very flexible dynamics
- Easy to estimate

Cons:

- Hard to interpret
- Hard to combine with other information
- Perhaps uses too little economic theory?

Suggested readings

Svensson, L.E.O. (1998,2008): Discusses inflation targeting in theory and practice

Leeper, Sims and Zha (1998): A thorough analysis of SVARS and US data

Reading package available at http://www.kris-nimark.net/

Next time:

The Lucas Critique

Dynamic Stochastic General Equilibrium Models