Macroeconomic Theory Lecture 7

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Today: Real Business Cycle and New Keynesian Models.

Key Reading: Romer, Chapter 5, Ball, Mankiw, Romer

- NK & RBC
- A 'flavour' of DSGE.

Back to the 1970s

- ▶ The Lucas critique: Macroeconomists should build structural models, i.e. models where the agents behavior is invariant with respect to policy/Microeconomic foundations/General Equilibrium
- ▶ No distinction between micro and macro: Economic theory.
- ▶ Explicitly dynamic models from the outset, implies a need for Dynamic optimization
- ▶ Need for a theory of expectations formation. The Rational Expectations Revolution of the 1970s is the logical outcome of Lucas research program
- ▶ The Methodological Proposal: New analytical and computational instruments (Lucas/Stokey and Prescott, Kydland and Prescott)
- ▶ A new equilibrium concept: recursive equilibrium and "from a point to a path" type solutions.
- ▶ Importance of expectations in the design of policy experiments. Nice because explicit welfare analysis. A stochastic description of the economic system.

Motivation

- Must allow for leisure/labour tradeoffs, motivating why unemployment could exist within an equilibrium model.
- Fluctuations in factor productivity become the predominant cause of fluctuations in business activity.
- RBCs do well explaining co-movements in output, consumption, investment, employment. But three issues:
    1. Labor supply elasticity.
    2. Productivity shocks and their frequency.
    3. Monetary policy shocks.

Basic Setup, 1/2.

- A Solow model in a dynamic optimisation framework
- Savings rate is no longer constant
- TFP shocks (i.e. the A matrix gets whacked)
- Policy uncertainty

Basic Setup, 2/2.

- A Central planning problem.
- As before, with set up problem, derive FOCs.
- Derivation and interpretation very standard.
- impose balanced growth conditions via log-linearisation
- return to FOCs
- Evidence on technological progress?

US Saving Rate

Source: U.S. Department of Commerce: Bureau of Economic Analysis

Shaded areas indicate US recessions - 2014 research.stlouisfed.org

Variables

- t, time
- y output
- A technology level (exogenous)
- L, labour
- K, capital
- c consumption
- I investment
- w wage
- r interest rate

Baseline model

- ► See Romer pg 195-199.
- ► Production function is Cobb Douglas: $Y_t = K_t^{\alpha}(A_t L_t)^{(1-\alpha)}$.
- ► Output divided into consumption C, government spending G, investment I. Depreciate at δ, so $K_{t+1} = K_t + Y_t - C_t - G_t - \delta K_t$.
- ► labour and capital get paid their marginal products, population grows exogenously. This is a market-clearing world.
- ► Household maximises $U = \sum_{t=0}^{\infty} e^{-\rho t} u(c_t, 1 - l_t) \frac{N_t}{H}$
- ► Let c = C/N and l = L/N. Assume u() is log linear according to: $u_t = \ln c_t + b \ln(1 - l_t)$
- ► Technological disturbances are autoregressive: $\ln A_t = \rho \bar{A}_{t-1} + \epsilon_{A,t}$..
- ► Shocks to government spending are also autoregressive: $G_t = \rho_G G_{t-1} + \epsilon_{G,t}$

Maximisation

- Form the Largrangian: $L = \ln c + b \ln(1 - l_t) + \lambda(wl - c)$.
- FOCS: $\frac{1}{c} - \lambda = 0$ and $\frac{-b}{1-l} + \lambda w = 0$
- A bit of algebra yields $\frac{-b}{1-l} + \frac{1}{l} = 0$.
- How to read this? Note we're actually solving a sequence of static optimisation problems rather than a dynamic one.

Solution(s)

- Find the deterministic steady state (where $\epsilon = 0$)
- Linearise all equations around the steady state
- Get the linearised solution of the form $x_t = Ax_{t-1} + B\epsilon_t$., where x is the vector of all variables in the model. The matrices A and B are the outcome of the model's solution.

Impulse Response

Now that we have the equilibrium of the economy, how does it react to a one time shock? The solution is linearised, so any shock will be an 'impulse response' where you see the dynamic properties of the system.

- ▶ Start from $x_0 = 0$.
- ▶ Set $\epsilon_1 = 0.01$.
- ▶ Set $\epsilon_t = 0$, repeat for $t = 2, 3, \ldots$.
- ▶ Now simulate the motion of the system, see tutorial notes for more details.

Issues with RBCS

- If all the important shocks are productivity shocks, then worker hours and productivity should move together.
- Thus productivity should be highly positively correlated with output and hours. In the real world, the correlation is negative (if at all).
- Need for an highly elastic labour supply translates into serious labour market problems. The increase in productivity translates to an increase in hours worked and to an increase in real wages. The effect on the real wage is relatively stronger the lower is the elasticity of labor supply. In the extreme case of a fixed labor supply all the increase in labor demand would translate into an increase in the real wage.
- There is no evidence of the large, economy-wide disturbances that drive these models.
- The models do not account for the periodicity of cycles. They do not match reality at all because they offer only weak explanations for the propagation of the effects through time.

Now for a bit of context

		Mkts clear?	Mkts clear?
		Yes. Classical	No. Keynesian
Market	Labour	Friedman	Sticky wage (eff. wage)
Imperfection	Product	Lucasian islands	Menu costs, other excuses.

Moving on. Models with Sticky Prices

- ▶ Contrary to the RBC type models which are dynamic equilbrium models with smoothly adjusting prices for capital and labour, another school of economists has always emphasized the 'sticky' nature of price movements.

- ▶ These guys came to prominence in the 1980s are are called the New Keynesians. Big paper: Clarida et al, 1993

- ▶ Keynesian arguments based upon rational expectations and microeconomic foundations. This deeply annoys another splinter group called 'post-Keynesians', but there are many others annoyed by these assumptions.

- ▶ These models usually take the form of
  1. Contracting models
  2. Sticky price models based upon transactions cost or menu costs
  3. Efficiency wage models.

- ▶ They differ from RBC type modelers in their treatment of micro-policy and monetary policy.

Modeling issues

- ▶ An optimizing model of households and firms. Requires a production function, usually labour first.
- ▶ Differentiated goods and monopolistic competition. Allows suppliers ability to set prices.
- ▶ Sticky price adjustment, obviously.
- ▶ Provide a mechanism for price level determination via interest rate rules of the type used by central banks. So a big focus on stuff like Taylor rules, etc.
- ▶ Model focuses on interest rate policy which is counter to the traditional focus on changes in base money. Squares with actual practice.
- ▶ CB decision-makers mainly discuss changes in the nominal, overnight interbank interest rate target, leave manipulations of base money to achieve those targets to trading specialists.
- ▶ Policy is rule-based.

Wicksellian solution

Knut Wicksell defined many of the major issues in macroeconomics. He proposed setting nominal interest rates to stabilise the price level, so

$$i_t = \bar{i} + \theta p_t \qquad (1)$$

or

$$\Delta i_t = \phi \pi_t \qquad (2)$$

Where p_t is the log of the price level and $\pi_t = p_t - p_{t-1}$..

Taylor

More modern interest rate rule relate the nominal interest rate target to the inflation rate rather than the price level, and also often add output stabilization as a goal.

$$i_t = \bar{i} + \pi_t + \theta_\pi(\pi_t - \bar{\pi}) + \phi_y(y_t - \bar{y}) \tag{3}$$

Here $\bar{i}$ is the target interest rate, $\bar{\pi}$ is the target inflation rate. $y_t - \bar{y}$ is the output gap.
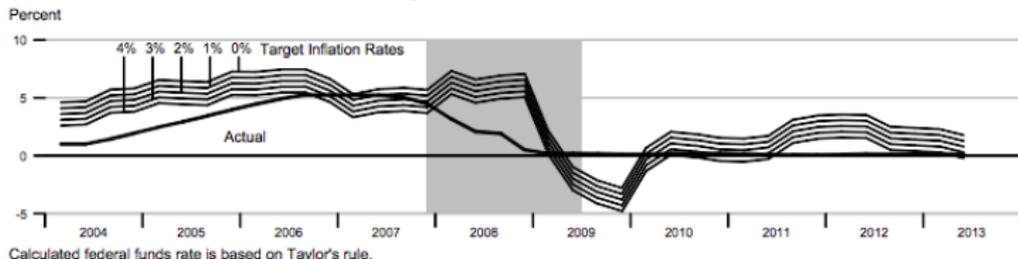
(Another way to think about the rule is: Target Fed Funds = Inflation + Target Real Rate + param1*(Inflation Gap) + param2*(Output Gap).)

The Taylor rule (and its many variants) do reasonably well at characterising movements in interest rate targets.
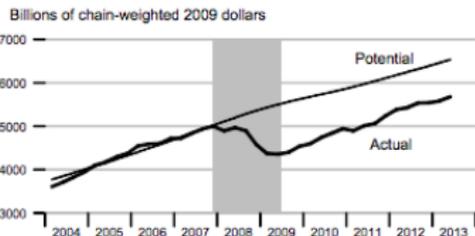
US Data on Taylor rules

See: http://research.stlouisfed.org/publications/mt/page10.pdf

Federal Funds Rate and Inflation Targets

Percent

4% 3% 2% 1% 0% Target Inflation Rates

Actual

Calculated federal funds rate is based on Taylor's rule.

Components of Taylor's Rule

Actual and Potential Real GDP

Billions of chain-weighted 2009 dollars

Potential

Actual

See notes section for further explanation.

PCE Inflation

Percent change from year ago
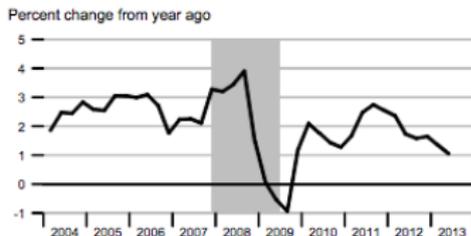
Data on Wage Stickiness: Wages *are* sticky

Le Bihan, Montornes, and Heckel. 2012. "Sticky Wages: Evidence from Quarterly Microeconomic Data" American Economic Journal: Macroeconomics, 4(3): 1-32
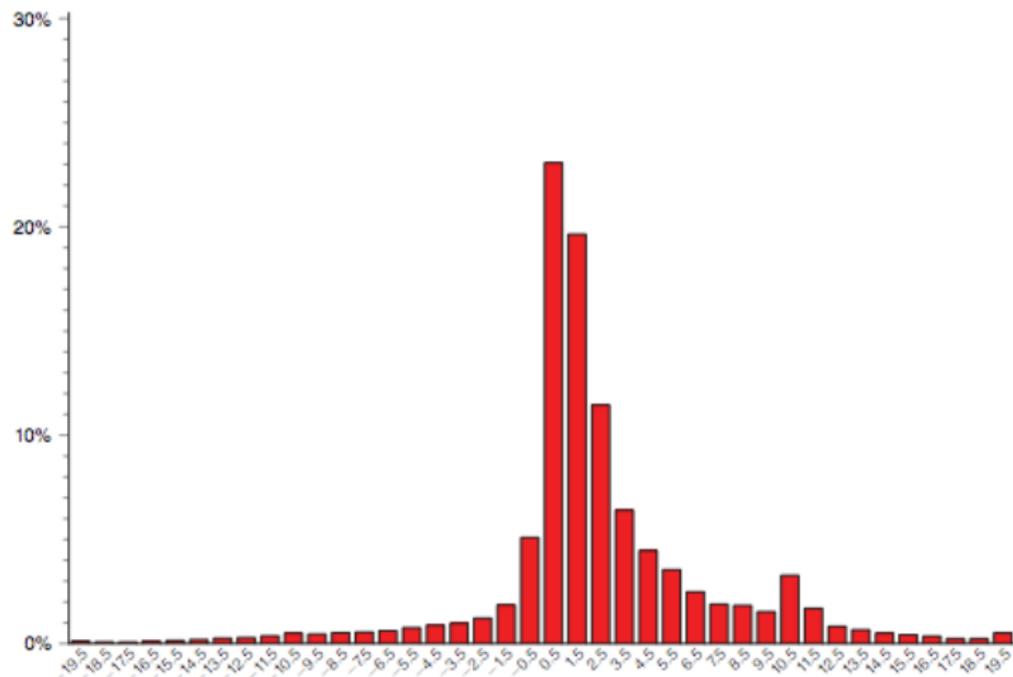

FIGURE 2. DISTRIBUTION OF (NONZERO) WAGE CHANGES

Simple Model from Dixit and Stiglitz

- Only consumption goods here.
- Consumers maximize $U(Y_t)$ over a continuum of goods.
- So:

$$Y_t = (\int_0^1 Y_t(i)^{\frac{\theta}{\theta-1}})$$

- they demand in the form

$$Y_t(i) = Y_t(\frac{P_t(i)}{P_t})^{-\theta}$$

- Here P is a price index defined as

$$P_t = (\int_0^1 P_t(i)^{1-\theta} di)^{\frac{1}{1-\theta}}$$

Introducing price rigidity via Calvo

▶ Assume that at any moment some fraction $1 - \alpha$ of firms can change their prices but everyone else has to keep theirs the same–this is a *menu cost* assumption.

▶ Then otherwise firms are all the same.

▶ the price level then evolves according to

$$P_t = ((1-\alpha)X_t^{1-\theta} + \alpha P_{t-1}^{1-\theta})^{\frac{1}{1-\theta}}$$

▶ Here X is the price set by those who can reset what they choose.

▶ This then gets rewritten as

$$P_t^{1-\theta} = (1-\alpha)X_t^{1-\theta} + \alpha P_{t-1}^{1-\theta}$$

Solving the NK Model

- Like RBC models it is done via log linearisation and then fairly standard dynamic programming.
- The firms have to pick a set of prices relative to their cost functions over time.

$$\{p_t\} = \beta E_t \pi_{t+1} + \frac{(1-\alpha)(1-\alpha*\beta)}{\alpha}(mc_t - p_t)$$

Ye Wha?

- The New Keynesian Phillips curve relates price movements to marginal cost (mc) and prices, which are themselves functions of the output gap $mc_t - p_t = \rho(y_t - y_t^*)$

- Here y_t^* is the output the economy would produce if it had no inflation band all the factors of production were being used optimally.

DSGEs: Introduction

- ▶ Dynamic Stochastic General Equilibrium (DSGE) models are the dominant modeling method in macro today. Regardless of whether you think these models are great or not, it is important you know what these are.

- ▶ A continuum of infinitely-lived agents (households and firms) solve intertemporal optimizing problems to choose how much to consume, to work, to accumulate capital, to hire factors of production and so on.

- ▶ Idea is to use the welfare of private agents (in fact, of the representative agent) as "a natural objective in terms of which alternative policies should be evaluated". (Woodford 2003, 12).

Hubris?

"The state of macro is good"

(IMF Chief economist Olivier Blanchard, The state of macro, NBER WP14259, August 2008)

"Over the last three decades, macroeconomic theory and the practice of macroeconomics by economists have changed for the better. Macroeconomics is now firmly grounded in the principles of economic theory"

(V. V. Chari and P. Kehoe (2006), Modern macroeconomics in practice: how theory is shaping policy, Journal of Economic Perspectives, Fall, pp. 328)

Using the Solow model to understand business cycles

- ▶ Basic Question: can the Neoclassical growth model be used to study business cycles, following Brock (1974)?

- ▶ Kydland and Prescott (1982): Yes, if you use stochastic technology shocks with rational expectations.

- ▶ agent behaviour in the RBC model was governed by the optimisation under uncertainty framework straight from the micro-economist's toolbox.

- ▶ Problem: optimisation in the Neoclassical growth model yields non-linear behaviour.

- ▶ Solution: linearise the model about the steady state of the system and consider an approximate solution via simulation/calibration.

- ▶ More technically: a first-order approximation to the equilibrium conditions around the non-stochastic steady-state to study the behaviour of endogenous variables in response to small stochastic perturbations to the exogenous process.

Next steps

- Calibration step. This involves choosing parameters on the basis of long-run data properties and judgment (sometimes guided by microeconomic evidence).
- Judicious parameter selection is required.
- Cutting edge DSGEs use Bayesian methods (see Smets and Wouters (2012, 2013).

DSGE Stylised Facts

These are cross country correlation studies, basically.

- consumption is less volatile than output
- investment is much more volatile than output
- hours worked are about as volatile as output
- capital is much less volatile than output.
- both labour productivity and the real wage are much less volatile than output.

(The Kaldorian facts from 1957 include: the shares of income components and output components are roughly constant, the capital/output ratio is constant -both variables grow at the same rate, the consumption-to-output ratio is roughly constant.)

A baseline DSGE

There is a perfectly competitive economy containing a representative household that maximizes utility given an initial stock of capital. The household simultaneously participates in the goods, capital and labour markets. The economy also contains a representative firm, which sells output produced from capital, labour and technology according to

$$Y_t = (A_t N_t)^\alpha K_t^{1-\alpha}$$

Here Y is output, A is technology, N is the labour hours worked, K is the capital stock, and $0 < \alpha < 1$.
Capital accumulates according to

$$K_{t+1} = (1-\delta)K_t + Y_t - C_t$$

Here δ represents depreciation while C is consumption.

Basic Setup

The household has log utility in consumption and power utility in leisure, so"

$$\sum_{i=0}^{\infty} \beta^i [\log(C_{t+i}) + \theta \frac{(1 - N_{t+i})^{1-\gamma}}{1 - \gamma}]$$

Here the elasticity of intertemporal substitution of leisure is $\sigma = 1/\gamma$ and β is the discount rate.

Firms invest according to the usual marginal assumptions. The return on capital is

$$R_{t+1} = (1 - \alpha)(\frac{A_{t+1} N_{t+1}}{K_{t+1}})^\alpha + (1 - \delta)$$

First order conditions

$$\frac{1}{C_t} = \beta E_t \frac{R_{t+1}}{C_{t+1}}$$

and

$$\theta(1 - N_t)^{-\gamma} = \frac{W_t}{C_t} = \alpha \frac{A_t^{\alpha}}{C_t} (\frac{K_t}{N_t})^{1-\alpha}$$

the marginal utility of leisure is set equal to the real wage Wt times the marginal utility of consumption. Given a competitive labour market, the real wage also equals the marginal product of labour. This reflects the between-periods aspect of the problem, so that labour supply is dictated by intertemporal substitution.

Results

- ▶ DSGEs have very low forecasting power.
- ▶ Sims (2007) considers DSGE models only storytelling devices and not 'scientific' theories. (See https://www.princeton.edu/ceps/workingpapers/155sims.pdf)
- ▶ Kocherlakota (2007) shows a model that fits the available data perfectly may provide worse answers to policy questions than an imperfectly fitting model.
- ▶ DSGE as prior generator?
- ▶ Transmission mechanisms.
- ▶ Role for money/debt/default?

Applications: Solving DSGE Models in practice and comparing them to Agent-Based models.

1. Macroeconomic Policy in DSGE and Agent-Based Models
2. Real wages and monetary policy: A DSGE approach
3. RBCs and DSGEs: The Computational Approach to Business Cycle Theory and Evidence
4. Ho's lecture notes on DSGEs
5. Recent Developments in Macroeconomics: The DSGE Approach to Business Cycle in Perspective

Review of DSGE models

- Based on RBCs with real world data.
- Designed to provide welfare comparisons of varying important policy parameters
- Explicitly equilibrium models, see previous lecture for criticisms.
- Biggest criticism post-2008: the RBC/DSGE models are empirical failures, specifically with respect to the real effects of monetary disturbances and financial frictions.
- much work has been done by the DSGE community post 2008 to rectify these lacunae.

What is the point of all of this complexity?

- Latest and greatest models are very complicated, eg. Smets and Wouters (2003, 2008), Christiano et al, 2005.
- Big plus is microeconomic foundations of these models. But also a big minus if you consider the series of problems identified with maximising behaviour over the last 30 years by behavioural economists.

The ECB's DSGE Model

- Based on Smets and Wouters (2007)
- A BVAR approach, See Christoffel et al. (2010)

    ...the new generation of DSGE models provides a framework that appears particularly suited for evaluating the consequences of alternative macroeconomic policies. (Christoffel et al., 2010:3)

- Really?