Lecture: Extending basic New Keynesian model

Advanced Macroeconomics

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Plan of the Presentation

So Far

- RBC theory: business cycle fluctuations are *efficient* responses to exogenous variations:
  - No need for stabilization policies
  - Money is neutral
- A simple NK model combines important elements of RBC theory with Keynesian features such as nominal price rigidity
  - There is a role for active monetary policy to mitigate distortions due to nominal rigidities
- But simple model performs poorly
  - Dynamics in the model do not match dynamics of the data
  - We want a model for policy analysis

What Do We Need

- Model specification more complex than the canonical New Keynesian model
- Sound microfounded structure suitable for policy analysis with a good probabilistic description of data
- Nominal and real frictions that improve model fit

Baseline Policy Models

1. Christiano, Eichenbaum and Evans (2005), "Nominal rigidities and the dynamic effects of a shock to monetary policy," *Journal of Political Economy* 113-1, pp 1-45.
2. Smets and Wouters (2003), "An estimated Dynamic Stochastic General Equilibrium Model of the Euro Area," *Journal of the European Economic Association* 1, pp 1123-1175.
3. Smets and Wouters (2007), "Shocks and frictions in US business cycles: A Bayesian DSGE approach," *American Economic Review* 97(3), pp 586-606.

Plan of the Presentation

Medium-Sized Model

Extend the simple 3-equation New Keynesian model:

- Habit formation in consumption
- Capital and
  - investment adjustment costs
  - variable capital utilization
- Sticky wages
- Inflation (and wage) indexation

Agents

Represetative household consumes, supplies labor and *owns* capital

Intermediate-good producers rent capital and labor to produce an intermediate differentiated good

Final-good producers manufacture a final good using a continuum of intermediate goods as inputs supplied by monopolistic producers

Unions, labour agency aggregate different labour services into a homogeneous labor input that they rent to intermediate good producers

Government as a monetary authority sets the one-period nominal interest rate

Households Utility

- Households maximise expected lifetime utility

$$U_t = E_t \sum_{j=0}^{\infty} \beta^{t+j} \psi_{t+j} \left(\frac{(c_{t+j} - h c_{t-1+j})^{1-\sigma}}{1-\sigma} - \vartheta \frac{l_{t+j}(i)^{1+\varphi}}{1+\varphi} \right)$$

- Note that households get utility from the level of consumption relative to past consumption, $0 \leq h \leq 1$
- Empirical reason: habit can help solve the *excess smothness* puzzle in the PIH literature
- It generates hump-shaped responses of macro variables to shocks (Fuhrer, 2000)

Households Budget Constraint

- Budget constraint:

$$c_{t+j} + \frac{B_{t+j}}{P_{t+j}} + T_{t+j} + i_{t+j} + a(u_{t+j})K_{t-1+j} =$$
$$\frac{R_{t-1+j}B_{t-1+j}}{P_{t+j}} + \frac{w_{t+j}l_{t+j}(i)}{P_{t+j}} + \frac{R^k_{t+j}(u_{t+j}K_{t-1+j})}{P_{t+j}} + Div_{t+j}$$

- Expenditures:
  - consumption, bond purchases, taxes
  - investment (i_t) and cost of capital utilization $(a(u_t)K_{t-1})$
- Income:
  - return on bond, wage income, dividends
  - return (R^k_t) on utilized capital $(u_t K_{t-1})$

Investment Adjustment Cost

- Capital accumulation

$$K_t = (1-\delta)K_{t-1} + \varepsilon_t^i[1 - S(\frac{i_t}{i_{t-1}})]i_t \ ,$$

  where $S(\cdot)$ is the adjustment cost function with $S(1) = S'(1) = 0$ and $S''(\cdot) > 0$
- Investment adjustment costs induce inertia and hump-shape in investment response
- Cost of changing the level of investment is a key mechanism that signicantly improves the quantitative performance of the model

Capital Utilization I

- Household can increase the supply of rental services from capital either by investing in additional capital, i_t, which takes one period to be installed...
- ...or by changing the utilization rate of already installed capital, $u_t K_{t-1}$
- Higher capital utilization is costly: $a(u_t)K_{t-1}$ with $a(\cdot)$ increasing convex, $a(1) = 0,\ a'(1) > 0$

Capital Utilization II

- After a positive monetary policy shock, variable capital utilization helps dampen the large rise in marginal costs, and hence prices (CEE (2005))
- Empirical evidence shows significant variation of the capital utilization rate over the business cycle (e.g. Burnside, Eichenbaum and Rebelo (1995))
- Variable capital utilization was introduced to generate realistic levels of output volatility (see, Greenwood, Hercowitz and Huffman (1988))

Firms

- As before
  - Final-goods firms produce output by combining intermediate goods
  - Intermediate-goods firms produce using labour and capital

Final-Goods Firms

- Final-goods firms produce according to the CES production function (Dixit-Stiglitz aggregator):

$$y_t = \left(\int_0^1 y_t(i)^{\frac{1}{1+\mu}} di \right)^{1+\mu}$$

where:

  - μ is a mark up over marginal cost and $\frac{1+\mu}{\mu}$ elasticity of substitution between individual intermediate goods

- First order condition yield the demand for intermediate input i

$$y_t(i) = \left(\frac{P_t(i)}{P_t} \right)^{\frac{-(1+\mu)}{\mu}} y_t$$

- Aggregate price level

$$P_t = \left(\int_0^1 P_t(i)^{-\frac{1}{\mu}} di \right)^{-\mu}$$

Intermediate-goods Firms

- Intermediate-good firm i uses capital services, $K_t^s = u_t K_{t-1}$, labour, and pay fixed costs, Φ,

$$y_t(i) = z_t K_t^s(i)^{\alpha} l_t(i)^{1-\alpha} - \Phi$$

- Total factor productivity z_t is common to all firms and follows an AR(1) process
- Labour and capital inputs are rented from households

Marginal Cost

- Firms choose $l_t(i)$,$K_t^s(i)$ to minimise the real cost subject to production function $y_t(i)$, i.e.

$$\min_{l_t(i),K(i)} w_t l_t(i) + R_t^K K_t^s(i) \quad \text{s.t.} \quad y_t(i) = z_t K_t^s(i)^\alpha l_t(i)^{1-\alpha} - \Phi \quad (\omega_t)$$

- Capital and labour demand satisfy

$$(1-\alpha) R_t^K K_t^s(i) = \alpha w_t l_t(i)$$

- Total cost becomes

$$w_t l_t(i) + R_t^K K_t^s(i) = \lambda_t(i) y_t(i), \ \lambda(i) = (1-\alpha)^{-1} w_t [K_t^s(i)/l_t(i)]^{-\alpha}$$

- The marginal cost is common to all firms

$$\omega_t = mc_t(y_t(i)) = mc_t = \alpha^{-\alpha}(1-\alpha)^{-(1-\alpha)} w_t^{1-\alpha} (R_t^k)^\alpha z_t^{-1}$$

Price Setting with Sticky Prices I

- Calvo scheme: Each period each firm with probability $1-\theta$, $\theta \in [0,1]$ receives a signal to reoptimise its prices (i.e. a constant proportion $1-\theta$ reoptimises) and chooses $P_t^{new}(i)$.
- The fraction θ of firms partially indexes their prices according to

$$P_t(i) = P_{t-1}(i)\,\bar{\pi}^{\varsigma}\pi_{t-1}^{1-\zeta},$$

  - it allows for hump shaped monetary policy impulse response functions
- As before
  - Firms allowed to reset their price take into account that they may not be allowed to do so in the future.
  - The probability that in period $t+j$ the price of intermediate-goods firm i is not reoptimised equals θ^j
  - The expected time of a given price remaining not reoptimised is $(1-\theta)^{-1}$.

Price Setting with Sticky Prices II

- Intermediate-good firm i chooses $P_t^{new}(i), \{y_{t+j}(i)\}_{j=0}^{\infty}$ to maximise:

$$E_t \sum_{j=0}^{\infty} (\beta\theta)^j \Lambda_{t,t+j} \left(P_t^{new}(i) \Pi_{t,t+j} - mc_{t+j} \right) y_{t+j}(i)$$

subject to the demand function $y_t(i) = \left(\frac{P_t^{new}(i)\Pi_{t,t+j}}{P_t} \right)^{\frac{-(1+\mu)}{\mu}} y_t$ with $\Pi_{t,t+j} = \prod_{k=1}^{j} (\bar{\pi}^{\varsigma} \pi_{t-1+k}^{1-\zeta})$

Price Setting with Sticky Prices: Log-linearised Equation

- Dynamic AS curve (Phillips curve)

$$\theta\left(\hat{\pi}_t - \zeta\hat{\pi}_{t-1}\right) = (1-\theta)(1-\beta\theta)\,\hat{mc}_t + \beta\theta E_t\left[\hat{\pi}_{t+1} - \zeta\hat{\pi}_t\right]$$

- Because of partial indexation, inflation depends positively on past and expected future inflation and negatively on the current price markup

Labour Market

- Households supply each of many varieties of differentiated labour services
- Households (or union representing them) are monopolistic suppliers and set their wage rate (Erceg, Enderson and Levin (2000))
- It is convenient to assume that there is a representative labour aggregator (i.e. an employment agency) that combines labour hours in the same proportions as firms would choose. This labour bundler/packer is perfectly competitive

The employment agency's problem

- The labour supplier aggregates the differentiated labour of households according to

$$L_t = \left[\int_0^1 l_t(j)^{\frac{1}{1+\lambda_w}} dj \right]^{1+\lambda_w}$$

- Agency chooses $l_t(j)$ to maximise profits

$$\max_{l_t(i)} w_t L_t - \int_0^1 w_t(j) l_t(j) dj$$

- From the FOC and zero profit condition the demand for differentiated labour equals and the aggregate wage index are respectively

$$l_t(j) = \left(\frac{w_t(j)}{w_t} \right)^{-\frac{1+\lambda_w}{\lambda_w}}, \qquad w_t = \left[\int_0^1 w_t(j)^{-\frac{1}{\lambda_w}} dj \right]^{-\lambda_w}$$

Staggered wage setting

- Sticky wages are introduced in a way analogous to price stickiness
- Assume now that unions adjust their wages infrequently:
  - Each period, there is a probability $(1-\theta_w)$ that the union will be able to adjust optimally their wage, independently on past history
- The remaining fraction θ_w of unions cannot optimally set their wages:
  - they can follow a rule-of-thumb, typically, $w_t(j) = w_{t-1}(j)$
  - or, they can update wages by the one-period lagged gross inflation rate, $\pi_{t-1} = P_{t-1}/P_{t-2}$
  - Which rule is chosen has important consequences on the dynamics of the model.

Implications of wage rigidity

- If nonoptimizing unions use the partial indexation rule, wage infation will depend positively on past real wages; past, current, and expected future inflation; and the wage mark-up
- Wage setting frictions help to account for the response of inflation and output to a monetary policy shock monetary policy shock
  - sticky wages makes labour supply highly elastic
  - postive monetary policy shock leads to big increase in employment and ouput but small increase in cost and, hence, inflation

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Extending a simple New Keynesian model

- We have barely scratched the surface
- These few frictions allows the model to account for key features of economic responses to monetary and technology shocks
- But many elements are still missing
  - no unemployent
  - no financial frictions
  - no fiscal policy
  - closed economy
  - rational expectations

THANK YOU