Monetary Policy and Business Cycle

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Lecture III

Business Cycle Theory I: New Classical Economics and Real Business Cycle

"Motto"

"If business cycle phenomena are present in the behaviour of our model economy, they are perfectly consistent with ideal economic efficiency."

(Long and Plosser, 1983)

Outline

- Some General Comments
- Imperfect Information - New Classical Economics
  - The Lucas model
  - Further developments ...
- Productivity Shocks - Real Business Cycle
  - Simplest model
  - The basic RBC model
- Summary

Some General Comments

- Lecture 1, among others, concluded that the consensus from the empirical literature on the *short-run effects* of money (monetary policy) is that
  - monetary policy shocks produce hump-shaped movements in real output
  - output response reaches its peak after a lag of several quarters (two or three years) and then dies out

- consequently, for an economic model to be plausible, it must replicate the latter evidence

- remember that the Classical Economics assumes all the markets to be flexible and prices to adjust immediately to monetary policy actions, leaving the real economy untouched

- Robert Lucas (1972, 1973) developed a model assuming flexible markets and yet producing real effects of monetary policy shocks (*Expectations and the Neutrality of Money*)

- as Lucas's seminal contribution is viewed the incorporation of the rational expectations into macroeconomic model, however, precise microfoundation of his model is also crucial

- although New Classical Economics emphasizes the role of the supply side and raise doubts about the need, and effectiveness, of the activist demand policies, aggregate demand still plays a certain role

- the Real Business Cycle Theory, originating from Kydland and Prescott's (1982) seminal contribution, goes one step further, and offers a *pure* supply-side explanation for business fluctuations

- according to the RBC theory, exogenous fluctuations in the level of total factor productivity make steady reallocation of the factors of production necessary for an efficient economic allocation

- it follows that observed business fluctuations are the variations necessary for the maintenance of full economic efficiency

New Classical Economics - The Lucas Model

- Lucas model does not make a distinction between workers and producers:
  - Lucas's economic individuals are *specialists* in production and *generalists* in consumption
  - they allocate their available time endowment to production or to leisure
  - and produce goods which are sold in one market i and consume goods from all n markets

- the logarithm of output in market i is denoted by y_i and p_i denotes the logarithm of the price level

- the aggregate price index then comes as $p \equiv \frac{\sum_{i=1}^{n} p_i}{n}$

- it is further assumed that the price level in market i is determined by the price index and a sector-specific shock ϵ_i:

$$p_i = p + \epsilon_i \tag{1}$$

- there are two possible reasons why prices p_i in market i may rise:
  - an increase in a general price level p

  - or a shift in the relative price level $p_i - p = \epsilon_i$

- since agents are specialists in production and generalists in consumption, an increase in the relative $p_i - p$ makes production more attractive relative to leisure

- if the aggregate price level was known with certainty, agents in market i would reduce their leisure and expand production y_i whenever $p_i - p$ rises

- however, information is *imperfect* in the sense that agents *observe* the price in their market p_i but *do not observe* the aggregate price level p

- as a result they *have to disentangle* changes in the observed price level p_i into relative price shifts and general inflation

- and this is the very point where *rational expectations* come into play
  - as we know already *rational expectations* are expectations that are implied by the structure of the model an agent has in his mind, and his personal information set
  - consequently, since the information sets are different (producers in different markets i observe different market prices p_i) they hold different expectations of the aggregate price level p

- it follows that the production y_i in market i is a function of relative price $p_i - \sum_i p$ expected by the agents in market i:

$$gy_i = p_i - E_i p \tag{2}$$

where g is a positive constant

- on aggregate level new classical economics follows the quantity theory tradition, and the average output $y \equiv \frac{\sum_{i=1}^{n} y_i}{n}$ is determined by:

$$m - p = \phi y \tag{3}$$

where m is the log of the supply of money

- central bank is assumed to tie the supply of money to past realizations of the money supply (m_{t-j}), output (y_{t-j}), and prices (p_{t-j}), according to the feedback money supply rule:

$$m_t = a + \sum_{j=1}^{\infty} b_j m_{t-j} + \sum_{j=1}^{\infty} c_j y_{t-j} + \sum_{j=1}^{\infty} d_j p_{t-j} + \eta_t \tag{4}$$

where a, b_j, c_j, d_j are policy parameters

- central bank, however, does not control the money supply perfectly, so m_t has a random component η_t

- the way to the *equilibrium* is as follows:
  - to begin with, suppose that $E_i p$ is a weighted mean of p_i and Ep

    $$E_i p = \theta p_i + (1 - \theta)Ep \qquad (5)$$

    where Ep represents the *general* expectations
  - the trick behind is that to equate $E_i p$ to Ep only, is a *non-rational* way of forming expectations as the infromation contained in the p_i observations is neglected
  - the same then holds if the expectations $E_i p$ are equated to p_i only as the rest of available infromations is neglected
  - for now, take the respective weights θ and $1 - \theta$ as given, during the seminar we show that θ can be chosen such that (5) really implies rational expectations
  - now, inserting (5) into individual supply function (2) yields $gy_i = (1 - \theta)(p_i - Ep)$
  - taking the sum over all i, dividing by n, using $p \equiv \frac{\sum_{i=1}^{n} p_i}{n}$ and $y \equiv \frac{\sum_{i=1}^{n} y_i}{n}$, and letting $\gamma \equiv \frac{g}{(1-\theta)}$, it follows that:

    $$\gamma y = p - Ep \qquad (6)$$

which is the so-called *Lucas supply function*

– normalising the expected aggregate production to equal zero, $Ey = 0$, Lucas supply function implies that aggregate output is above the natural rate if the aggregate price level is higher than rationally expected, and vice versa

– this is because producers in each market i *misperceive* a positive *'price surprise'* as an increase in the relative price of their respective good

– from the quantity equation (3) and $E_y = 0$ it follows that $Ep = Em$, so (6) can be rewritten as:

$$y = \frac{m - Em}{\phi + \gamma} \tag{7}$$

making the aggregate output an increasing function of the *'money surprise'*, $m - Em$

– since agents in this model use all the available informations, including past realizations of monetary policy (means they are aware of the *model of the economy*), only the current monetary shocks η come as a surprise (from the money supply rule (4), we have $m - Em = \eta$), then it follows that:

$$y_t = \frac{\eta_t}{\phi + \gamma} \tag{8}$$

- it is evident that equilibrium production is independend of the monetary policy parameters and that only unanticipated component of the supply of money affects output

- a crucial point is that a systematic policy is viewed as being *ineffective*

- so, Lucas model is on the one hand able to replicate short-run effects of monetary policy, however, there is no role for systematic policy in dealing with the business cycle fluctuations

- as a consequence Lucas model, like the monetarist model, calls for stable and predictable supply of money (monetary policy)

Lucas Model and Empirical Evidence

- is the prediction that only unanticipated monetary shocks do matter supported by the facts?

- Barro (1978):
  - ran regressions (US data) for M1 growth and identified the regression estimates with anticipated money growth and the regression residuals with unanticipated money growth
  - then he regressed real output on current and lagged values of unanticipated money growth
  - current and two lagged values were highly significant (1 per cent money surprise persists over four years period, real output in the fourth year rises by 3 per cent)
  - and when the unanticipated money growth was replaced with anticipated growth, the results were much less clear-cut

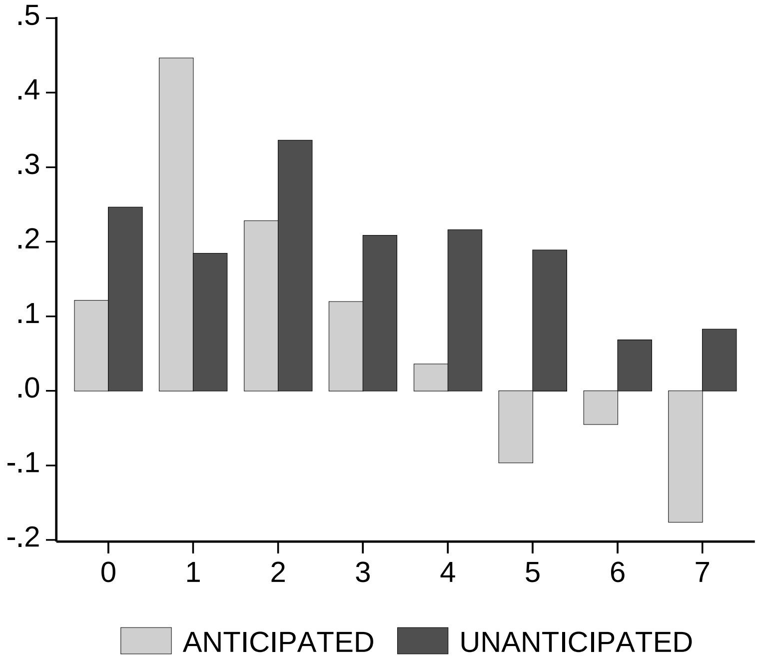
- however, in his influential study Mishkin (1982) regressed (US data) real output on both anticipated and unanticipated money growth and his results were much less favourable to the new classical economics

- Mishkin (1982) found that

- as for unanticipated money growth, only current unanticipated money growth was significant; all lagged values were insignificant
- by contrast, the current and seven lagged values of anticipated money growth were significant, morover the coefficients were much larger than those for unanticipated money growth
- so, Mishkin concluded that *'anticipated monetary policy does not appear to be less important than unanticipated monetary policy; rather opposite seems to be the case'*

• exercise similar to those of Barro and Mishkin and based on Czech data reveals following correlations between anticipated (unanticipated) money growth and real output

Barro (1978) 'style' exercise - correlation between real output and money growth



- the Figure plots the correlation between the real output Y_t and M_{t-j} against j where Y represents the growth of real GDP and M represent the growth of anticipated (unanticipated) part of the monetary aggregate $M1$

- Figure 1 seems to support rather Mishkin conclusions, i.e. systematic monetary policy *does matter*

Further Developments

- original Lucas's papers were based on money being a monetary policy measure

- however, especially in the 1990s it has become evident that central banks use interest rate as a policy tool

- consequently, Lucas model can be reformulated as follows:

$$\begin{aligned} y_t &= -\sigma(i_t - E_t\Delta p_{t+1}) + \epsilon_t && (9)\\ i_t &= (\Delta p)^* + cy_t + d[\Delta p_t - (\Delta p)^*] + \eta_t && (10)\\ \gamma y_t &= -(w_t - p_t) && (11)\\ w_t &= E_{t-1}p_t && (12) \end{aligned}$$

- equation (9) is the aggregate demand where the calculation of real interest rate $r_t = i_t - E_t\Delta p_{t+1}$ is based on rational expectations

- equation (10) is the monetary policy feedback rule, here for the interest rate, which makes money supply to be money demand driven

- in the interest rule, the $(\delta p)^*$ is the central bank target value for average inflation, and the interest rate rule says that central bank raises the interest rate i_t when output rises or inflation soars

- equations (11) and (12) are the aggregate supply and wage-setting equations, respectively

- the way to the *equilibrium* is as follows:
  - first, suppose that $(\Delta p)^* = 0$
  - then equations (9) and (10) imply

$$(1 + \sigma c)y_t = \sigma(E_t \Delta p_{t+1} - d\Delta p_t) + \epsilon_t \qquad (13)$$

  - while from equations (11) and (12) we get the Lucas supply function

$$\gamma y_t = \Delta p_t - E_{t-1}\Delta p_t \qquad (14)$$

  - solving those for y_t (seminar will deal with this in more detail), we get

$$y_t = \frac{\epsilon_t - \sigma\eta_t}{1 + \sigma c} \qquad (15)$$

- equilibrium output still depends on the policy shock η

- however, critical difference to the original model, is the presence of policy parametr c in (15), which makes the *policy ineffectiveness* proposition to be no more valid

- this comes from the fact that the central bank is able to react to current shocks (y_t and Δp_t appear in the interest rate rule instead of their lags)

Real Business Cycle - simplest model

- we begin our exposition with a grossly simplified model based on the asumptions that the propensity to save and the supply of labour are fixed, that capital depreciates fully within one period, and that production is Cobb-Douglas

- this model does not justice to the RBC approach, since *ad hoc* decisions rules are used instead of optimal planning, but it serves as a useful benchmark

- consider:
  - closed economy inhabited by a fixed number of infinitely-lived households
  - representative household is endowed with L units of labour, supplying them inelastically in the labour market
  - there is full employment, and the aggregate production is Cobb-Douglas:

$$Y_t = \Theta_t K_t^{1-\alpha} L_t^{\alpha} \tag{16}$$

    where K_t denotes the capital stock at time t and Θ denotes the random level of *total factor productivity* (TFP), which fluctuations represent productivity shocks

- capital K_t depreciates fully within one period and savings equal fixed fraction s ($0 < s < 1$) of aggregate income; hence $K_t = sY_{t-1}$
- inserting this into production function gives $Y_t = \Theta_t(sY_{t-1})^{1-\alpha}L^{\alpha}$, or after taking logarithms:

$$y_t = (1-\alpha)logs + \alpha logL + (1-\alpha)y_{t-1} + \theta_t \quad (17)$$

  where $\theta_t \equiv log\Theta_t$ is the logarithm of TFP, which is assumed to be stationary: $E\theta = 0$
- then the average output is given by $Ey_t = (1-\alpha)logs/\alpha + logL$ and the deviations $\tilde{y_t} \equiv y_t - Ey_t$ of output y_t from Ey_t obey:

$$\tilde{y_t} - (1-\alpha)\tilde{y_{t-1}} = \theta_t \quad (18)$$

- suppose first that θ_t is a white noise; obviously, aggregate production fluctuates and there is persistence
- the source of persistence is capital stock dynamics: if output is high in one period, then savings and, hence, the capital stock and output are still high in the following period

• however, this simple RBC model has two disturbing properties

- first, standard estimate of α is 2/3, which forces the degree of autocorrelation in predicted output to be relatively low, 1/3 while in the data it is around 0.9
- second, as mentioned in Lecture 1 econometric models predict hump-shaped impulse response function as an important characteristic of output fluctuations
- here, since $\tilde{y_t}$ obeys a first-order difference equation , the impulse response function is monotonic

- a way RBC theorists solve both problems is to assume that the TFP shocks θ are persistent: $\theta_t = \rho\theta_{t-1} + \vartheta_t$

- then, the simple RBC model can be written as follows

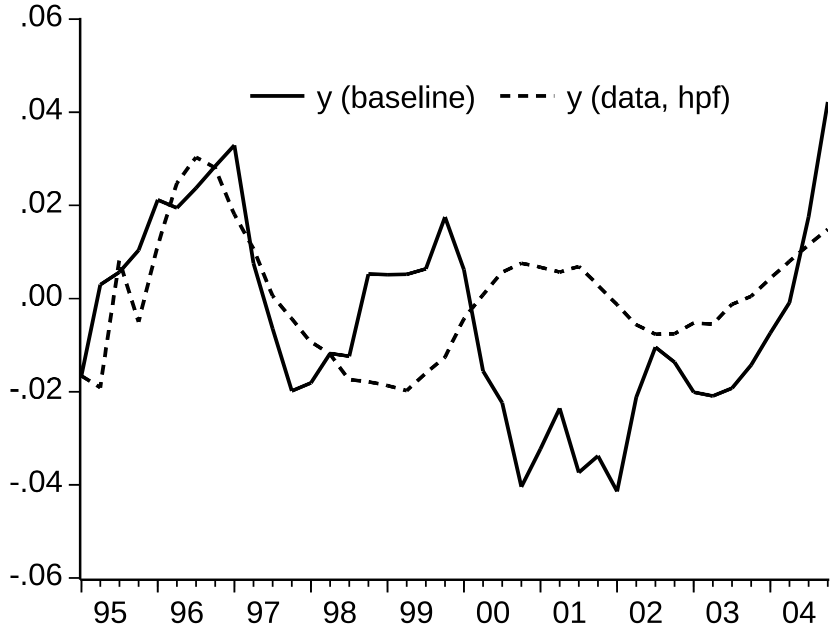
$$\begin{aligned} \tilde{y_t} &= (1-\alpha)\tilde{y_{t-1}} + \theta_t \\ \theta_t &= \rho\theta_{t-1} + \vartheta_t \end{aligned}$$

- natural question, of course, is: how well similar model does fit the data?
  - to answer we run the model over the 1Q1995 till 4Q2004 sample, assuming that
  - $\alpha = 0.57$, $rho = 0.8$, and ϑ follows a random process drawn from normal distribution with zero mean and standard deviation $\sigma_\vartheta = 0.013$

– $\sigma_\vartheta = 0.013$ is taken from the data; it is the standard deviation of estimated $\tilde{y}$ (HP filter)

- following figure depicts both predicted and observed $\tilde{y}$, assuming the same initial condition in 1Q1995

Output gap



- the simplest RBC model seems to fit the data relatively well (one should not forget that the forecast starts in 2Q1995)

Real Business Cycle - basic model

- the major goal of RBC theory is to demostrate that classical models with perfect markets are capable of describing observed business cycles

- one of the main RBC contributions is the precise derivation of the 'model' from microfoundations

- stylized RBC model can be desribed as follows:
  - there is a continuum of mass of identical, infinitely-lived agents
  - the representative agents' time endowment is normalized to equal unity; let N_t denote the time spend working, leisure then equals $(1 - N_t)$
  - at given point in time a worker obtains utility $u(C_t, 1 - N_t)$, from consumption C_t and leisure $1 - N_t$
  - utility function meets all the requirements: to be concave and continuously differentiable with positive and decreasing marginal utilities
  - intertemporal utility from time t is given by the discounted sum of current utilities:

$$\sum_{\tau=t}^{\infty} \beta^{\tau-t} u(C_t, 1 - N_t) \qquad (19)$$

where β ($0 < \beta < 1$) is the discount factor

- as in the simple model, there is only single homogenous output good Y_t, which serves for both consumption and investment
- as in the Lucas model representative agents are viewed as being not only consumers but also producers; production process is described by the neoclassical production function

$$Y_t = \Theta_t F(K_t, N_t) \tag{20}$$

where F is concave and continuously differentiable with positive, decreasing marginal productivities, and constant returns to scale

- capital depreciates at rate δ ($0 \leq \delta \leq 1$) and the capital formation is given by

$$K_{t+1} = (1-\delta)K_t + \Theta_t F(K_t, N_t) - C_t \tag{21}$$

- finally, the current supply shock Θ_t is observed before decisions are made in period t, so there are no 'productivity surprises'

• in general it holds that given the sequence of exogenous productivity shocks $\{\Theta_\tau\}_{\tau=t}^{\infty}$, the time paths for all variables are determined once paths for consumption $\{c_\tau\}_{\tau=t}^{\infty}$ and labour $\{n_\tau\}_{\tau=t}^{\infty}$ are chosen

- so, the propensity to consume and supply of labour are no more arbitrary

- however, since Θ_{t+1}, as well as all subsequent productivity shocks, are unknown as of time t, this is an dynamic optimization problem under uncertainty

- in order to proceed we use the case when the problem can be solved analyticaly (seminar will deal with general discussion of solution, as well as solution efficiency)

- which is when the production function is Cobb-Douglas, and contemporaneous utility is separable:

$$u(C_t, 1-N_t) = \frac{C_t^{1-\sigma}}{1-\sigma} + \nu \frac{(1-N_t)^{1-\phi}}{1-\phi} \quad (22)$$

$$\Theta_t F(K_t, N_t) = \Theta_t K_t^{1-\alpha} N_t^{\alpha} \quad (23)$$

- solution of the model is characterized by following *first-order conditions*

$$C_t^{-\sigma} = \nu \frac{(1-N_t)^{-\phi}}{w_t} \quad (24)$$

$$C_t^{-\sigma} = C_{t+1}^{-\sigma} \beta [1 + r_{t+1} - \delta] \quad (25)$$

- where w_t and r_{t+1} denote real wage and real interest rate respectively, and it holds that

$$
\begin{aligned}
w_t &= \alpha \Theta_t K_t^{1-\alpha} N_t^{\alpha-1} && (26)\\
r_{t+1} &= (1-\alpha)\Theta_t K_{t+1}^{-\alpha} N_{t+1}^{\alpha} && (27)
\end{aligned}
$$

- full specification enabling practical simulations then looks as follows:

$$
\begin{aligned}
C_t^{-\sigma} &= \nu \frac{(1-N_t)^{-\phi}}{w_t}\\
C_t^{-\sigma} &= C_{t+1}^{-\sigma}[1 + r_{t+1} - \delta]\\
K_{t+1} &= (1-\delta)K_t + \Theta_t F(K_t, N_t) - C_t\\
Y_t &= \Theta_t K_t^{1-\alpha} N_t^{\alpha}\\
w_t &= \alpha \Theta_t K_t^{1-\alpha} N_t^{\alpha-1}\\
r_{t+1} &= (1-\alpha)\Theta_t K_{t+1}^{-\alpha} N_{t+1}^{\alpha}\\
\theta_t &= \rho \theta_{t-1} + \vartheta_t
\end{aligned}
$$

- to show that *perfect markets* models are capable of explaining some of the most important features of observed business cycles the RBC models are *calibrated*

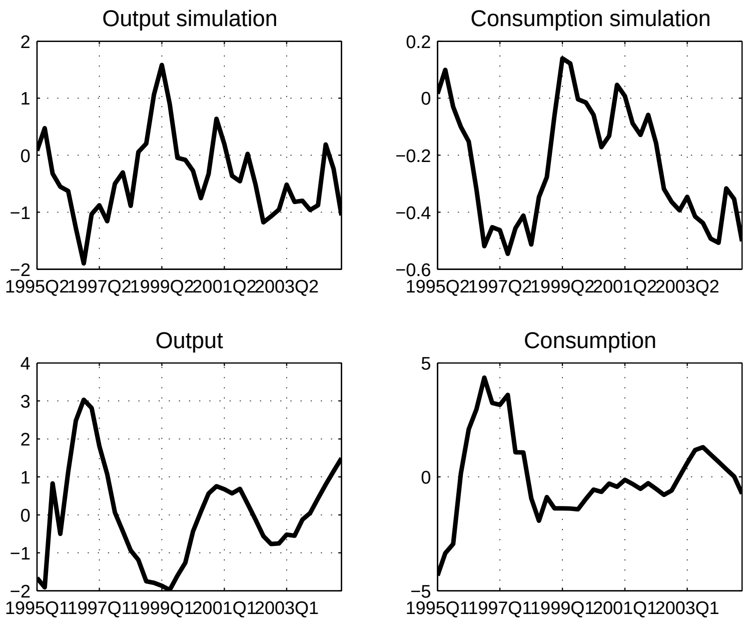
- which means that numerical values obtained from microeconomic and macroeconomic evidence are inserted for the model parameters and a proces for the productivity shocks is specified

- then simulations of the calibrated model are performed and the statistical moments of the simulated series are compared with their empirical counterparts (attention is focused on the second moments: standard deviations, autocorrelations, and cross-correlations)

- above specified model can be simulated using following calibration: $\beta = 0.98$, $\sigma = 1.5$, $\phi = 2$, $\nu = 1$, $\alpha = 0.57$, $\delta = 0.05$, $\rho = 0.8$, and $\sigma_\vartheta = 0.013$

- following figure finaly shows results of a random simulation of the model, and compares them with reality

RBC model simulation



- the aim of this exercise is to show similarities in correlation of output and consumption implied by basic RBC model and observed in real data
- as the comparison of correlations is usually used by RBC theorists in order to defend their approach
- however, as everything in economics (and fortunately for central bankers), also RBC models are heavily criticized; mainly two arguments are used:
  - first, much of the variability and persistence generated by calibrated models is due to exogenous productivity shocks
  - second, in the basic RBC model, hours worked are not volatile enough to match the data (this problem can be solved from RBC perspective using the indivisible labour, however, unfortunately for RBC theory, it can be solved also by introduction of nominal wage rigidities)

Summary

- both New Classical Economics and RBC theory have had an outstanding methodological impact on the science of economics

- without doubts, economic theorizing conform to different standards after Lucas's, and Kydland and Prescott's papers:
  - rational expectations and Lucas critique
  - microfoundation
  - dynamic modelling and calibration

- however, yet, the mainstream economics does not seem to accept *perfect* markets and *supply side* explanation of business cycle completely

- indeed, *'demand side'* and *'rigidities'* are required ...