

## Business Cycles

### Approaches to business cycle modeling

Definition: Recurrent pattern of downswings and upswings:

- Across many industries
- With common pattern of co-movement among major variables
  - Output
  - Employment
  - Investment
  - Consumption
  - Wages
  - Prices
  - Interest rates

Key business cycle question:

- Variation in  $g$ ?
  - “Stochastic growth models” allow variations in underlying growth rate of natural output that could cause cycles
- Deviation of actual  $Y$  from natural  $Y$ 
  - Natural output has steady trend but actual fluctuates around it
- This is the fundamental distinction between “real” business cycle models and Keynesian models

Keynesian approach

- Recessions are caused by market failure:
  - Not enough demand to buy all of the output that the economy could produce at full employment
  - Prices and wages do not adjust quickly enough to bring quantity demand into line with quantity supplied
  - Firms see accumulation of inventories and adjust flow of output (and employment) rather than responding fully with price changes
- Recessions involve actual output below natural output
- Existence of market failure implies that government intervention to stabilize economy can be beneficial

Real business cycle approach

- To what extent can *all* business cycles be explained as “supply shocks”
  - We know that oil-market disruptions caused major cyclical fluctuations in the 1970s (and perhaps at other times)
  - Can other recessions be explained by shocks to productivity?

Endogenous cycles vs. impulse-propagation mechanisms

- Are cycles endogenous?

- Does a boom carry the seeds of the next recession automatically?
- Or must there be some external stimulus to send the economy downward?
- Many early models examined endogenous mechanisms:
  - Boom → optimism → disappointment → recession → eventual shortage of capital → high investment → boom → etc.
- Recent business cycles emphasize the propagation of exogenous shocks
  - Where do shocks come from?
    - Random fluctuations in productivity growth
    - Random changes in spending by consumers, investors, governments, foreigners
    - Random shocks to markets: floods, earthquakes, droughts, political disruptions (home or abroad), etc.
  - A business-cycle model consists of a set of rules about how the economy responds to shocks
    - If it is realistic, then the correlations among variables should match those of actual fluctuations
    - **Correlations** are associations in the co-movements of different variables
      - A variable is **procyclical** if it tends to move in the same direction as GDP over the cycle, and **countercyclical** if it moves in the opposite direction
    - **Autocorrelations** are associations between today's movement in a variable with those of earlier periods
  - Stock and Watson paper (optional) on reading list gives very detailed description of how variables move in U.S. business cycles
    - Employment is strongly procyclical with a lag
    - Unemployment is strongly countercyclical with a longer lag
    - Inflation tends to be procyclical with a lag
    - Interest rates are not strongly cyclical
    - Real wages are not strongly cyclical, might be slightly procyclical

## A Real-Business-Cycle Model

- Romer provides a benchmark RBC model that is typical of the early generations of these models
  - The core sections of this chapter have hardly changed since 1998
  - The literature has largely moved on to include more sophisticated effects
- The RBC model can be thought of as a “stochastic growth model”
  - It is based on the Ramsey model but with  $g$  being a random variable rather than a constant
  - We must model labor supply behavior in this model because fluctuations in employment are a critical part of business cycles
- Model is in discrete time with Cobb-Douglas production function and log-utility
  - $Y_t = K_t^\alpha (A_t L_t)^{1-\alpha}$ 
    - Production function determines  $Y$  given  $K, A, L$
  - $\left. \begin{array}{l} K_{t+1} = K_t + I_t - \delta K_t \\ Y_t = C_t + I_t + G_t \end{array} \right\} \Rightarrow K_{t+1} = K_t + Y_t - C_t - G_t - \delta K_t$ 
    - Capital stock adjustment equation determines dynamics of  $K$  over time
    - Note that investment made during  $t$  does not contribute to production until  $t + 1$
  - $w_t = MPL = (1 - \alpha) \left( \frac{K_t}{A_t L_t} \right)^\alpha A_t$ 
    - Wage is marginal product of labor
  - $r_t + \delta = MPK = \alpha \left( \frac{A_t L_t}{K_t} \right)^{1-\alpha}$ 
    - Interest rate plus depreciation rate = user cost of capital = marginal product of capital
  - $N_t = e^{\bar{n}t}$ 
    - Population grows at continuously compounded rate  $\bar{n}$  from initial value  $\bar{N}$
  - $L_t = l_t N_t$ 
    - Share of potential population working is  $l$
    - $l$  has dimension of fraction of total household time devoted to work
    - Can be thought of as either share of household members working and hours worked per household member
  - $C_t = c_t N_t$ 
    - Total consumption ( $C$ ) is consumption per person  $c$  times number of people
    - Note that  $C$  and  $c$  are defined differently here than in Ramsey model

- $U = \sum_{t=0}^{\infty} e^{-\rho t} \left[ \ln c_t + b \ln(1-l_t) \right] \frac{N_t}{H}$ 
  - Log utility in consumption and leisure, multiplied by number of members of household at time  $t$
  - We will need to perform utility maximization problem to get consumption demand functions and labor supply functions for this utility function subject to the appropriate budget constraint
- $A_t = e^{\bar{A} + g t + \tilde{A}_t}$   
 $\tilde{A}_t = \rho_A \tilde{A}_{t-1} + \varepsilon_{A,t}$ 
  - Can rewrite as  $\ln A_t = \bar{A} + g t + \tilde{A}_t$
  - $A$  is a trend-stationary process: the deviation from trend ( $\tilde{A}$ ) follows a stationary, first-order autoregressive process
  - $\varepsilon_{A,t}$  is a “white-noise” shock to productivity
  - We assume that  $0 \leq \rho_A < 1$ , which means that part, but not all, of last period’s deviation from trend survives to this period
  - If  $\rho_A$  is near one, then productivity is highly persistent: most of the deviation carries over and it takes a long time for the effects of a shock to dissipate
  - If  $\rho_A$  is near zero, then shocks go away quickly and series will be less persistent
  - Show graphical representation of exponential return to trend after shock
- $G_t = e^{\bar{G} + (n+g)t + \tilde{G}_t}$   
 $\tilde{G}_t = \rho_G \tilde{G}_{t-1} + \varepsilon_{G,t}$ 
  - Similar process for government spending with white-noise shock  $\varepsilon_{G,t}$
  - $G$  is assumed to grow at  $n + g$  on its trend path because that is the growth rate of  $Y$ , so we assume a constant steady-state  $G/Y$
- Behavioral equations for households
  - We must solve the utility-maximization problem of the household to get
    - Consumption demand equations
    - Labor supply equations
  - Formal problem
    - $\max_{c_t, l_t} \sum_{t=0}^{\infty} e^{-\rho t} u \left[ c_t, 1-l_t \right] \frac{N_t}{H}$
    - subject to  $\sum_{t=0}^{\infty} \frac{c_t}{(1+r)^t} = \sum_{t=0}^{\infty} \frac{w_t l_t}{(1+r)^t}$  (assuming no initial assets)
  - In two-period model, this involves four choice variables:  $c_1, c_2, l_1, l_2$

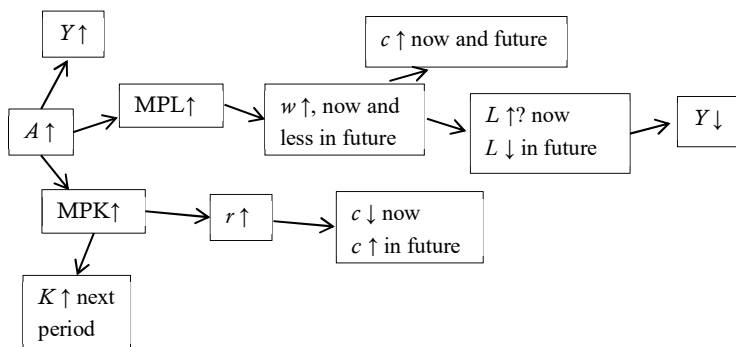
- Romer grapples with analytical solution, but we will try to get intuition of the tradeoffs involved
- **Leisure/goods choice at a particular time**
  - Tradeoff between leisure at  $t$  and consumption at  $t$  (ignoring other times)
  - Each unit of leisure forgone allows  $w_t$  additional goods to be consumed
  - Substitution and wealth effects of  $w \uparrow$  tend to offset
    - Substitution means work more: substitute labor/consumption for leisure because each hour of leisure forgone allows more goods
    - Wealth effect means work less because with higher wealth we want more of both consumption and leisure
- **Intertemporal consumption choice**
  - This is just the Ramsey model consumption decision again.
  - Trade off  $c_1$  against  $c_2$  with budget constraint slope of  $-(1+r)$
  - As before, a permanent change in wage has greater consumption effect than a temporary one because it shifts lifetime income by much more
- **Intertemporal labor choice**
  - Similar in principle to intertemporal consumption choice
  - Should I work now or in future?
  - Depends on interest rate and relative wage rates
  - Budget constraint between  $1 - l_1$  and  $1 - l_2$  has slope of  $-(1+r) \frac{w_1}{w_2}$
  - Temporary change in wage has much larger substitution effect because we substitute not just current labor/goods for current leisure but also future leisure for current leisure
  - Permanent change in wage has small substitution effect and large wealth effect because higher wage is earned for many years
- Final outcome of choice in all three dimensions:

$$l_t = l \left[ \begin{array}{ccccccc} w_t, w_{t+1}^e, w_{t+2}^e, \dots, r_t, \text{wealth} \\ +? & - & - & \dots & +? & - & - \end{array} \right]$$

$$c_t = c \left[ \begin{array}{ccccccc} w_t, w_{t+1}^e, w_{t+2}^e, \dots, r_t, \text{wealth} \\ + & + & + & \dots & -? & + & + \end{array} \right]$$

- These two equations complete the model
  - Endogenous variables:  $Y, w, r, l, L, c, K_{t+1}$
- What is a solution: Describe how paths of endogenous variables are affected by shocks to  $A, G$
- How do we solve?

- Algebraic solution is impossible for several reasons
- These models are solved in practice by numerical simulation
  - Deterministic simulation: Can assume given time path for  $A$  and  $G$ 
    - Perhaps no shocks to get steady state or one-time permanent or temporary shock to get multipliers
    - For deterministic simulations, people are generally assumed to have perfect foresight because there are no future shocks
  - Stochastic simulation: Can generate random shocks for  $\varepsilon$  and run the simulation for hundreds or thousands of periods
    - In this case, we can calculate over time the autocorrelations and cross-correlations of the variables and compare them (or calibrate them) to those observed in actual data
    - For stochastic simulation, people are assumed to expect  $\varepsilon$  to be zero in future periods because that is its mathematical expectation conditional on what is known at the present
      - This is the concept of “rational expectations,” which was central to many developments in modern macroeconomics
- In order to simulate numerically, we usually have to approximate the model with a log-linear approximation using Taylor-series methods
  - You will get to do this in a project soon!
- We can get an eyeball sense of the effects of a shock to  $A$  by thinking about the channels through which it would affect the variables of the model:



- All of these effects then build on (or offset) one another making the ultimate effect complex.
- Can do the same for a change in  $G$
- Romer presents impulse response functions for shocks to  $A$  and  $G$  (Figures 5.2–5.7 in 4<sup>th</sup> edition)

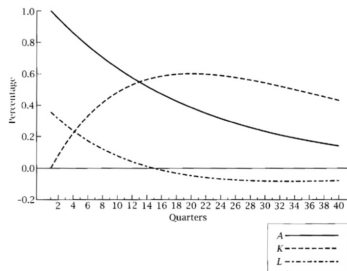


FIGURE 4.2 The effects of a 1 percent technology shock on the paths of technology, capital, and labor

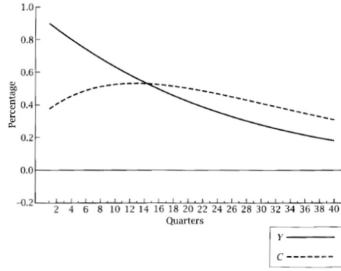


FIGURE 4.3 The effects of a 1 percent technology shock on the paths of output and consumption

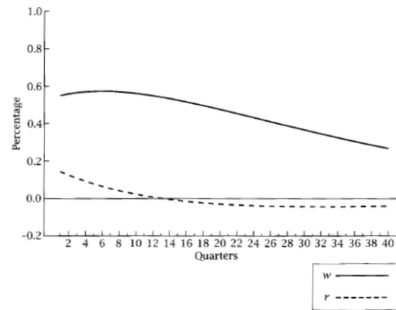


FIGURE 4.4 The effects of a 1 percent technology shock on the paths of the wage and the interest rate

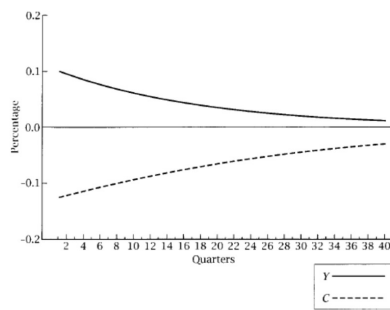


FIGURE 4.6 The effects of a 1 percent government-purchases shock on the paths of output and consumption

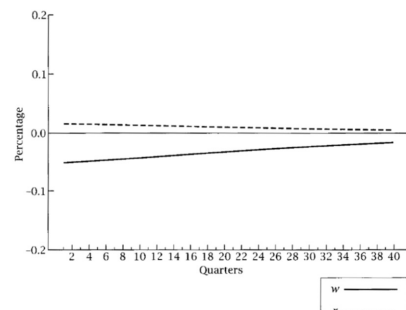


FIGURE 4.7 The effects of a 1 percent government-purchases shock on the paths of the wage and the interest rate

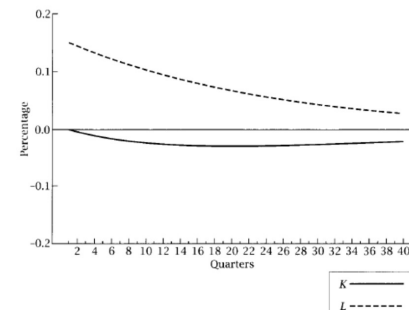


FIGURE 4.5 The effects of a 1 percent government-purchases shock on the paths of capital and labor

## Assessing RBC Models

- How would we decide if a simulated RBC model matched the real world?
  - Are the relative amounts of cyclical variation in the variables correct?
    - For example, does investment vary more than consumption over the cycle? Are real wages relatively acyclical with employment fluctuating a lot?
    - Look at standard deviations of each variable in simulation and actual data
  - Does the degree of persistence in each variable match its actual persistence?
    - Are the autocorrelations of the variables in the simulation similar to the real world?
  - Are the co-movements across variables realistic?
    - Look at correlations (at various lags) between each variable and GDP and compare to actual data.

- **Plosser's evidence**

*Table 1*

**Summary Statistics 1954–1985**

| Variable           | Mean  | Standard<br>Deviation | Autocorrelation <sup>a</sup> |          |          | Correlation<br>With Output | Correlation<br>With Actual |
|--------------------|-------|-----------------------|------------------------------|----------|----------|----------------------------|----------------------------|
|                    |       |                       | $\rho_1$                     | $\rho_2$ | $\rho_3$ |                            |                            |
| Panel A: Actual    |       |                       |                              |          |          |                            |                            |
| $\Delta \log(Y)$   | 1.55  | 2.71                  | .13                          | -.17     | -.16     | 1.00                       | 1.00                       |
| $\Delta \log(C)$   | 1.56  | 1.27                  | .39                          | .08      | .05      | .78                        | 1.00                       |
| $\Delta \log(I)$   | 2.59  | 6.09                  | .14                          | -.28     | -.19     | .92                        | 1.00                       |
| $\Delta \log(N)$   | -0.09 | 2.18                  | .17                          | -.32     | -.24     | .81                        | 1.00                       |
| $\Delta \log(w)$   | 0.98  | 1.80                  | .44                          | -.16     | -.08     | .59                        | 1.00                       |
| Panel B: Predicted |       |                       |                              |          |          |                            |                            |
| $\Delta \log(Y)$   | 1.56  | 2.48                  | .30                          | .18      | .14      | 1.00                       | .87                        |
| $\Delta \log(C)$   | 1.65  | 1.68                  | .55                          | .44      | .37      | .96                        | .76                        |
| $\Delta \log(I)$   | 1.37  | 4.65                  | .14                          | .00      | -.02     | .97                        | .72                        |
| $\Delta \log(N)$   | -0.08 | .89                   | .07                          | -.09     | -.12     | .87                        | .52                        |
| $\Delta \log(w)$   | 1.64  | 1.76                  | .51                          | .40      | .33      | .97                        | .65                        |

<sup>a</sup>The approximate standard error of the estimated autocorrelations is .18.

- Noteworthy problems:
  - Consumption and wages are too highly correlated with GDP
  - Consumption, wages, and output are too persistent
  - Much too little variation in employment
    - Why?



- RBC model explains employment fluctuations within market-clearing model
  - $\Delta L$  must be on labor-supply curve
  - If labor-supply is very elastic, then can have large  $\Delta L$  with small  $\Delta w$
  - But micro evidence is very strong that labor supply is quite inelastic, so simple RBC model can't reconcile large  $\Delta L$  with small  $\Delta w$  as seen in actual data
- Even if RBC model doesn't seem to work for *all* cycles, it might be appropriate for some
  - Hamilton's evidence in paper of week.
- **Mankiw's criticisms of RBC models**
  - Some of these have been addressed in later research
  - It's not plausible that the Great Depression was productivity shock
  - Solow residuals are not exogenous productivity shocks
    - Labor hoarding and effect of AD shocks on Solow residual
    - Varying capital utilization and effect of AD shocks on Solow residual
  - Evidence suggests that intertemporal labor substitution (on which RBC theory of employment fluctuations is based) is very weak
  - No role for money or prices, and we sometimes get wrong predictions when we add them to model
  - Calibration vs. estimation: this has been rectified with Bayesian estimation procedure in simulation models
- **Keane and Rogerson's 2012 assessment of labor-supply elasticities**
  - Traditional approaches have assumed that the micro and macro labor-supply elasticities are identical, and estimates suggest that they are small.
  - New approaches:
    - If workers accumulate human capital by working, then the wage understates the return to working (opportunity cost of time, or OCT) when young, and workers might be more responsive to OCT than to  $w$ . Micro studies might underestimate labor-supply elasticities because OCT is flatter over work life than  $w$ , so there is less variation in cross-section sample.
    - Extensive and intensive margins: Set up minimum hours of work  $\bar{h}$  that is lowest productive amount of work. Jumping into the labor force will cause macro elasticities to be higher than micro (for those who change hours but don't jump in or out).