The Real Business Cycle Model

Economics 3307 - Intermediate Macroeconomics

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Baylor University

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Business Cycles

- Business cycles are fluctuations of the economy about a trend.

- Different ways to compute trends: linear regression, Kalman filter, Hodrick-Prescott filter, etc.

- The H-P filter divides a time series $y_t$ into cyclical and growth components, $y_t = y_t^c + y_t^g$, where $y_t^g$ is chosen to solve, for a given $\lambda$,

$$\min \left\{ y_t^g \right\} \sum_{t=1}^{T} (y_t^c)^2 + \lambda \sum_{t=1}^{T} [ (y_{t+1}^g - y_t^g) - (y_t^g - y_{t-1}^g) ]^2$$

- Periods of below-trend growth (negative cyclical component) differ from periods of recession as defined by the NBER.
Business Cycles

- Business cycle analysis studies the properties of the cyclical components of different time series and their co-movements.

- Objects of interest:
  1. Volatilities (both absolute and relative to GDP).
  2. Whether a series is procyclical, countercyclical, or acyclical.
  3. Whether a series is a leading or lagging indicator.
Business Cycles

The Real Business Cycle Model

[Graphs showing percentage deviations of GDP, Imports, Consumption, and Investment from trend over the years 1940 to 2010]
Business Cycles

- Price Level
- GDP
- Money Supply
- Employment
- Productivity
- GDP

Year:
- 1940
- 1950
- 1960
- 1970
- 1980
- 1990
- 2000
- 2010

Percentage Deviation from Trend:
- 0
- 1
- 2
- 3
- 4
- 5
- 6
- 7

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### Correlations and Standard Deviations of Cyclical Components

<table>
<thead>
<tr>
<th></th>
<th>Correlation</th>
<th>Standard Deviation (% of S.D. of GDP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumption</td>
<td>0.76</td>
<td>75.6%</td>
</tr>
<tr>
<td>Investment</td>
<td>0.83</td>
<td>469.2%</td>
</tr>
<tr>
<td>Price Level</td>
<td>-0.26</td>
<td>57.6%</td>
</tr>
<tr>
<td>Money Supply</td>
<td>0.38</td>
<td>77.9%</td>
</tr>
<tr>
<td>Employment</td>
<td>0.81</td>
<td>59.3%</td>
</tr>
<tr>
<td>Average Labor Productivity</td>
<td>0.83</td>
<td>62.8%</td>
</tr>
</tbody>
</table>

### Summary of Business Cycle Facts

<table>
<thead>
<tr>
<th></th>
<th>Cyclicality</th>
<th>Lead/Lag</th>
<th>Variability Relative to GDP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumption</td>
<td>Procyclical</td>
<td>Coincident</td>
<td>Smaller</td>
</tr>
<tr>
<td>Investment</td>
<td>Procyclical</td>
<td>Coincident</td>
<td>Larger</td>
</tr>
<tr>
<td>Price Level</td>
<td>Countercyclical</td>
<td>Coincident</td>
<td>Smaller</td>
</tr>
<tr>
<td>Money Supply</td>
<td>Procyclical</td>
<td>Leading</td>
<td>Smaller</td>
</tr>
<tr>
<td>Employment</td>
<td>Procyclical</td>
<td>Lagging</td>
<td>Smaller</td>
</tr>
<tr>
<td>Real Wage</td>
<td>Procyclical</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Average Labor Productivity</td>
<td>Procyclical</td>
<td>Coincident</td>
<td>Smaller</td>
</tr>
</tbody>
</table>
Questions of Interest

- What causes business cycles? What are the shocks and what are the propagation mechanisms?
  - Shocks: Technology shocks, weather shocks/natural disasters, monetary shocks, political shocks, taste shocks.
  - Propagation mechanisms: intertemporal substitution, sticky prices, financial market frictions.

- What is the optimal policy response of the government?
  - **Fiscal policy:** Changes in taxes and spending, including both discretionary policy and automatic stabilizers.
  - **Monetary policy:** Federal Reserve policies aimed at changing the supply of money. Policy tools include open market operations, changes to the discount rate, quantitative easing, etc.
Two broad categories of business cycle theories:

- **Market-clearing models** regard business cycles as the dynamic equilibrium response to exogenous economic shocks. These models can be either efficient or inefficient.
  - Primary example: Real Business Cycle models.

- **Disequilibrium models** assume that market breakdown is an important aspect of business cycles, either as a cause or propagation mechanism.
  - Primary example: Keynesian models (traditional and New Keynesian).
The **Real Business Cycle** model assumes that exogenous technology (TFP) shocks are the main cause of economic fluctuations. 

\[ Y_t = z_t F(K_t, N_t) \]

where \( z_t = \rho z_{t-1} + \epsilon_t \), with \( \epsilon_t \) being a random shock and \( 0 < \rho < 1 \).

- The two main propagation mechanisms are **intertemporal substitution** and **capital accumulation**.

- The full RBC model is a stochastic, infinite horizon version of the model in chapters 10 and 11.
Real Business Cycles: Two-Period Deterministic Version

- In the two-period model, consider a persistent increase in \( z \), i.e. an initial increase in \( z_1 \) followed by a smaller increase in \( z_2 \).

- Higher \( z_1 \) increases \( MP_N \) *this period*, resulting in higher \( N_1^d \) and thus a shift to the right of \( Y_1^s \).

- Higher \( z_2 \) increases \( MP_N \) and \( MP_K \) *next period*, resulting in higher \( I_1(r) \) and \( C_1(Y_1; r) \) and thus a shift to the right of \( Y_1^d \).

- In equilibrium, \( Y_1 \) increases but \( r \) is ambiguous. However, because \( z_2 \) increases by less than \( z_1 \), consumers smooth consumption by increasing \( S_{1}^p \), driving down \( r \). Also, \( C_1, N_1, \) and \( I_1 \) increase.

- Higher \( Y_1 \) and lower \( r \) increase money demand \( M_1^d = P_1 L(Y_1, r) \), leading to lower \( P_1 \).
Real Business Cycles: Two-Period Deterministic Version

Demand for Period 1 Goods

\[ r = \text{Real Interest Rate} \]
\[ Y_1 = \text{Period 1 Income} \]
\[ Y_1 = \text{Period 1 Income} \]
\[ Y_1(r) \]
\[ d \]

\[ C_1(Y_1; r) + I_1(r) + G_1 \]
\[ C_1(Y_1; r) + I_1(r) + G_1 \]

\[ Y_1 = \text{Period 1 Income} \]

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Real Business Cycles: Two-Period Deterministic Version

\[ \tilde{N}_1(w_1) \]
\[ N'_1(w_1; r) \]
\[ \tilde{w}_1 \]
\[ w_1 \]
\[ \tilde{N}_1 \]
\[ N_1 \]
\[ Y_1 = z_1 F(K_1, N_1) \]
\[ \tilde{Y}_1 \]
\[ Y_1 \]
\[ \tilde{Y}_1 \]
\[ Y_1 = z_1 F(K_1, N_1) \]
\[ \tilde{Y}_1(r) \]
\[ Y_1(r) \]
\[ Y_1 \]
\[ \tilde{Y}_1 \]
\[ r \]
Summary: \( \downarrow r, \uparrow Y_1, \uparrow C_1, \uparrow l_1, \uparrow N_1, \downarrow P_1. \)

- Labor supply shifts to the left, i.e. \( N_1^s(w_1; \tilde{r}) < N_1^s(w_1; r). \)
### Data vs. Predictions of the RBC Model

<table>
<thead>
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<th>Model</th>
</tr>
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<tbody>
<tr>
<td>Consumption</td>
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</tr>
<tr>
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<td>Procyclical</td>
<td>Procyclical</td>
</tr>
<tr>
<td>Price Level</td>
<td>Countercyclical</td>
<td>Countercyclical</td>
</tr>
<tr>
<td>Money Supply</td>
<td>Procyclical</td>
<td>—</td>
</tr>
<tr>
<td>Employment</td>
<td>Procyclical</td>
<td>Procyclical</td>
</tr>
<tr>
<td>Real Wage</td>
<td>Procyclical</td>
<td>Procyclical</td>
</tr>
<tr>
<td>Average Labor Productivity</td>
<td>Procyclical</td>
<td>Procyclical</td>
</tr>
</tbody>
</table>

- Quantitatively, the model does a reasonable job matching relative volatilities and correlations with GDP (not shown above).

- One notable exception is that the model underpredicts the magnitude of employment movements.
Real Business Cycles: Equilibrium Conditions

- **Household optimality:**

  Real variables:
  \[
  \frac{u_l(C_1, h - N_1^s)}{u_C(C_1, h - N_1^s)} = w_1 \quad \text{and} \quad \frac{u_l(C_2, h - N_2^s)}{u_C(C_2, h - N_2^s)} = w_2
  \]
  \[
  \frac{u_C(C_1, h - N_1^s)}{\beta u_C(C_2, h - N_2^s)} = (1 + R) \frac{P_1}{P_2} \equiv 1 + r
  \]

  Nominal variables:
  \[
  \frac{\phi'(M_1^d / P_1)}{u_C(C_1, h - N_1^s)} = \frac{R}{1 + R}
  \]

  \[
  C_1 + \frac{R}{1 + R} m_1 + \frac{C_2}{1 + r} = w_1 (h - l_1) + \pi_1 - T_1 + \frac{w_2 (h - l_2) + \pi_2 - T_2}{1 + r}
  \]

- **Profit maximization:**

  Labor demand: \( z_1 F_N(K_1, N_1^d) = w_1 \) and \( z_2 F_N(K_2, N_2^d) = w_2 \)
  \[
  \text{Investment: } z_2 F_K(K_2, N_2^d) - d = \frac{P_1}{P_2} (1 + R) - 1 = r
  \]

- **Market clearing:** \( N_1^d = N_1^s \) and \( N_2^d = N_2^s \) (labor); \( C_1 + l_1 = z_1 F(K_1, N_1^d) \) and \( C_2 = z_2 F(K_2, N_2^d) + (1 - d)K_2 \) (goods); \( M_1^d \equiv P_1 L(Y_1, r) = M_1^s \) (money).
Real Business Cycles: Equilibrium Conditions

- Imposing market clearing and combining equations allows us to fully characterize equilibrium quantities:

\[
\frac{u_l(C_1, h - N_1)}{u_C(C_1, h - N_1)} = z_1 F_N(K_1, N_1) \quad \text{and} \quad \frac{u_l(C_2, h - N_2)}{u_C(C_2, h - N_2)} = z_2 F_N(K_2, N_2)
\]

\[
u_C(C_1, h - N_1) = \beta (1 + z_2 F_K(K_2, N_2) - d) u_C(C_2, h - N_2)
\]

\[
C_1 + K_2 = z_1 F(K_1, N_1) + (1 - d)K_1
\]

\[
C_2 = z_2 F(K_2, N_2) + (1 - d)K_2
\]

\[
\frac{\phi'(M_1^s/P_1)}{u_C(C_1, h - N_1)} = \frac{R}{1 + R}
\]
Efficiency and Optimal Policy in the RBC Model

- Does the RBC economy respond optimally to TFP shocks?

- We can compare the equilibrium dynamics to what a social planner would choose, subject only to aggregate resource constraints.

- The social planner takes $z_1$ as given and chooses consumption, labor, next period’s capital stock, and real money balances to solve

$$\max_{C_1, N_1, K_2, m_1, C_2, N_2} u(C_1, h - N_1) + \phi(m_1) + \beta U(C_2, h - N_2)$$

subject to

$$C_1 + K_2 - (1 - d)K_1 = z_1 F(K_1, N_1)$$

$$C_2 = z_2 F(K_2, N_2) + (1 - d)K_2$$
The Lagrangian is
\[
L = u(C_1, h - N_1) + \phi(m_1) + \beta u(C_2, h - N_2) + \gamma_1[z_1 F(K_1, N_1) + (1 - d)K_1 - C_1 - K_2] + \gamma_2[z_2 F(K_2, N_2) + (1 - d)K_2 - C_2]
\]

Optimality conditions:
\[
\frac{u_l(C_1, h - N_1)}{u_C(C_1, h - N_1)} = z_1 F_N(K_1, N_1) \quad \text{and} \quad \frac{u_l(C_2, h - N_2)}{u_C(C_2, h - N_2)} = z_2 F_N(K_2, N_2)
\]
\[
u_C(C_1, h - N_1) = \beta (1 + z_2 F_K(K_2, N_2) - d) u_C(C_2, h - N_2)
\]
\[
C_1 + K_2 = z_1 F(K_1, N_1) + (1 - d)K_1
\]
\[
C_2 = z_2 F(K_2, N_2) + (1 - d)K_2
\]
\[
\phi'(m_1) = 0
\]
The first three conditions are the same equations that characterize equilibrium, implying that the equilibrium is efficient.

The optimal policy response to business cycles is to *do nothing*.

Money does not affect real variables, but it shows up in the household utility function. Implementing the social planner solution in equilibrium requires setting \( R = 0 \).

Because \( R \approx r + i \) and \( r \) is unaffected by monetary policy, the government should continually shrink the money supply to cause deflation \( i = -r \). This is the **Friedman rule**.
Contributions of the RBC Model

- **Substantive contributions:**
  - Variations in TFP can account for many facts of U.S. business cycles.
  - Intertemporal substitution and capital accumulation are important channels in the propagation of economic shocks.
  - Business cycles *may be efficient* responses to a changing environment, implying that optimal government policy response is to do nothing.

- **Methodological contributions:**
  - Introduced rational expectations into economic models, thus addressing some of the major failures of macroeconomic models in the 1970s.
  - Simultaneously brought microeconomic theory into macroeconomics while making macroeconomics a more quantitative field.
Criticisms of the RBC Model

- What causes the fluctuations in productivity that drive business cycles? There is little direct evidence.

- The RBC model implies a higher elasticity of labor supply than is found in most microeconomic studies.

- All fluctuations in employment are voluntary in the model, i.e. there is no involuntary unemployment.

- Evidence suggests that money displays short-run non-neutrality.
  - Sharp recession in the early 1980s preceded by tighter monetary policy implemented by Volcker to reduce inflation.
  - In *A Monetary History of the United States (1963)*, Friedman and Schwarz suggest that a sharp monetary contraction helped precipitate the Great Depression.