Dynamic Macroeconomics I
Introduction to Real Business Cycle Theory

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Sant’Anna di Pisa - Spring 2014
Part of these slides are based on my Course of Advanced Macroeconomics II held at UPF and benefit of the work done by Jordi Gali in preparing his course of Macroeconomia Avanzada II at UPF.
Outline

- Business Cycle Definition and Facts
- Measuring Business Cycle
- Introduction: Lucas’ methodological proposal
- The Real Business Cycle Theory
  1. Data: measuring the business cycle
  2. The Basic Real business cycle model
  3. The solution of DSGE models: the Blanchard-Khan method
  4. Matching moments: Simulations with dynare codes
- Evaluation of the RBC approach: the debate over RBC theory
Evidence - US

U.S. GDP (Billions of 2005 dollars)
Evidence - US

U.S. GDP: Growth Rate

Evidence - US

U.S. CPI Inflation

Graph showing the U.S. CPI Inflation from 1950 to 2010.
Evidence - Euro Area

Euro Area GDP: Growth Rate

Evidence - Euro Area

Euro Area Unemployment Rate


Unemployment Rate

0.0 2.5 5.0 7.5 10.0 12.5
Evidence - Euro Area

Euro Area Inflation

[Graph showing Euro Area Inflation from 1970 to 2010]
Definition of Business Cycle

Burns and Mitchel Definition (1946) - "Measuring Business Cycle"

NBER

“Business cycles are a type of fluctuation found in the aggregate economic activity of nations that organize their work mainly in business enterprises: a cycle consists of expansions occurring at the same time in many economic activities, followed by similarly general recessions, contractions and revivals which merge into the expansion phase of the next cycle; this sequence of changes is recurrent but not periodic; in duration, business cycles vary from more than one year to ten or twelve years; they are not divisible into shorter cycles of similar character with amplitudes approximating their own.”
Definition of Business Cycle

- Economy-wide fluctuations in economic activity around its long-term growth trend.
- Expansions and contractions
- Economic variables show comovements
- Important to take into account possible leads and lags in timing wrt. real GDP
- The business cycle is recurrent, but not periodic: it doesn’t occur at regular, predictable intervals
- The business cycle is persistent
- Since BC is persistent is important to study what causes BC and the possible policies (fiscal or monetary) useful to stabilize the economy
Two key features

1. The comovement among individual economic variables (GDP, industrial production, unemployment, hours...).
2. The division of business cycles into separate phases: **Expansions** and **Contractions**
Business Cycle: Expansions and Contractions

REAL GDP

Expansion

Contraction

Expansion

PEACK

THROUGH

TREND
Business Cycle Expansions and Contractions

- After a trough, activity increases in an expansion or boom until it reaches a peak.
- Business cycle: the sequence from one peak to the next, or from one trough to the next.
- Peaks and troughs are turning points.
- NBER for US and CEPR for EU are responsible for dating turning points and business cycle.
All business cycles are characterized by common features, as for example the cyclical behavior of economic variables in terms of direction and timing with respect to aggregate economic activity $Y$.

- **Direction:**
  - Procyclical: in the same direction of $Y$
  - Countercyclical: in the opposite direction of $Y$
  - Acyclical: with no clear pattern

- **Timing:**
  - Leading
  - Lagging
  - Coincident
A recession is a significant decline in economic activity spread across the economy, lasting more than a few months, normally visible in real gross domestic product (GDP), real income, employment, industrial production, and wholesale-retail sales.

A recession begins just after the economy reaches a peak and ends as the economy reaches its trough. Between trough and peak: an expansion. Expansion is the normal state; most recessions are brief and they have been rare in recent decades.

Because a recession influences the economy broadly and is not confined to one sector, the committee emphasizes economy-wide measures of economic activity.

The committee views real GDP as the single best measure of aggregate economic activity.

The committee therefore places considerable weight on the estimates of real GDP issued by the Bureau of Economic Analysis of the U.S. Department of Commerce.
The traditional role of the committee is to maintain a monthly chronology, however, and the BEA’s real GDP estimates are only available quarterly. For this reason, the committee refers to a variety of monthly indicators to choose the exact months of peaks and troughs.

It places particular emphasis on two monthly measures of activity across the entire economy: (1) personal income less transfer payments, in real terms and (2) employment. Also: (3) industrial production and (4) the volume of sales of the manufacturing and wholesale-retail sectors adjusted for price changes.

The committee also looks at monthly estimates of real GDP such as those prepared by Macroeconomic Advisers (see http://www.macroadvisers.com). Nevertheless, there is no fixed rule about which other measures contribute information to the process.
Turning points are officially designated by the NBER

<table>
<thead>
<tr>
<th>Business Cycle Reference Dates</th>
<th>Duration in Months</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak</td>
<td>Trough</td>
</tr>
<tr>
<td><strong>Quarterly dates are in parentheses</strong></td>
<td>Peak to</td>
</tr>
<tr>
<td>December 1854 (IV)</td>
<td>--</td>
</tr>
<tr>
<td>June 1857 (II)</td>
<td>December 1858 (IV)</td>
</tr>
<tr>
<td>October 1860 (III)</td>
<td>June 1861 (III)</td>
</tr>
<tr>
<td>April 1865 (I)</td>
<td>December 1867 (I)</td>
</tr>
<tr>
<td>June 1869 (II)</td>
<td>December 1870 (IV)</td>
</tr>
<tr>
<td>October 1873 (I)</td>
<td>March 1879 (I)</td>
</tr>
<tr>
<td>March 1882 (I)</td>
<td>May 1885 (II)</td>
</tr>
<tr>
<td>March 1887 (II)</td>
<td>April 1888 (I)</td>
</tr>
<tr>
<td>July 1890 (III)</td>
<td>May 1891 (II)</td>
</tr>
<tr>
<td>January 1893 (I)</td>
<td>June 1894 (II)</td>
</tr>
<tr>
<td>December 1895 (IV)</td>
<td>June 1897 (III)</td>
</tr>
<tr>
<td>June 1899 (III)</td>
<td>December 1900 (IV)</td>
</tr>
<tr>
<td>September 1902 (IV)</td>
<td>August 1904 (III)</td>
</tr>
<tr>
<td>May 1907 (II)</td>
<td>June 1908 (III)</td>
</tr>
<tr>
<td>January 1910 (I)</td>
<td>January 1912 (IV)</td>
</tr>
<tr>
<td>January 1913 (I)</td>
<td>December 1914 (IV)</td>
</tr>
<tr>
<td>August 1918 (III)</td>
<td>March 1919 (I)</td>
</tr>
<tr>
<td>January 1920 (I)</td>
<td>July 1921 (III)</td>
</tr>
<tr>
<td>May 1923 (II)</td>
<td>July 1924 (III)</td>
</tr>
<tr>
<td>October 1926 (III)</td>
<td>November 1927 (IV)</td>
</tr>
<tr>
<td>August 1929 (III)</td>
<td>March 1933 (I)</td>
</tr>
</tbody>
</table>
### Business Cycle Cronology - US

<table>
<thead>
<tr>
<th>Date</th>
<th>Date</th>
<th>Peak 1</th>
<th>Peak 2</th>
<th>Peak 3</th>
<th>Peak 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 1937 (II)</td>
<td>June 1938 (II)</td>
<td>13</td>
<td>50</td>
<td>63</td>
<td>93</td>
</tr>
<tr>
<td>February 1945 (I)</td>
<td>October 1945 (IV)</td>
<td>8</td>
<td>80</td>
<td>88</td>
<td>93</td>
</tr>
<tr>
<td>November 1948 (IV)</td>
<td>October 1949 (IV)</td>
<td>11</td>
<td>37</td>
<td>48</td>
<td>45</td>
</tr>
<tr>
<td>July 1953 (II)</td>
<td>May 1954 (II)</td>
<td>10</td>
<td>45</td>
<td>55</td>
<td>56</td>
</tr>
<tr>
<td>August 1957 (III)</td>
<td>April 1958 (II)</td>
<td>8</td>
<td>39</td>
<td>47</td>
<td>49</td>
</tr>
<tr>
<td>April 1960 (II)</td>
<td>February 1961 (I)</td>
<td>10</td>
<td>24</td>
<td>34</td>
<td>32</td>
</tr>
<tr>
<td>December 1969 (IV)</td>
<td>November 1970 (IV)</td>
<td>11</td>
<td>106</td>
<td>117</td>
<td>116</td>
</tr>
<tr>
<td>November 1973 (IV)</td>
<td>March 1975 (I)</td>
<td>16</td>
<td>36</td>
<td>52</td>
<td>47</td>
</tr>
<tr>
<td>January 1980 (I)</td>
<td>July 1980 (III)</td>
<td>6</td>
<td>58</td>
<td>64</td>
<td>74</td>
</tr>
<tr>
<td>July 1981 (III)</td>
<td>November 1982 (IV)</td>
<td>16</td>
<td>12</td>
<td>28</td>
<td>18</td>
</tr>
<tr>
<td>July 1990 (III)</td>
<td>March 1991 (I)</td>
<td>8</td>
<td>92</td>
<td>100</td>
<td>108</td>
</tr>
<tr>
<td>March 2001 (I)</td>
<td>November 2001 (IV)</td>
<td>8</td>
<td>120</td>
<td>128</td>
<td>128</td>
</tr>
<tr>
<td>December 2007 (IV)</td>
<td>June 2009 (II)</td>
<td>18</td>
<td>73</td>
<td>91</td>
<td>81</td>
</tr>
</tbody>
</table>

**Average, all cycles:**

- 1854-2009 (33 cycles)  
  - Average: 17.5  
  - Average: 38.7  
  - Average: 56.2  
  - Average: 56.4
- 1854-1919 (16 cycles)  
  - Average: 21.6  
  - Average: 26.6  
  - Average: 48.2  
  - Average: 48.9
- 1919-1945 (6 cycles)  
  - Average: 18.2  
  - Average: 35.0  
  - Average: 53.2  
  - Average: 53.0
- 1945-2009 (11 cycles)  
  - Average: 11.1  
  - Average: 58.4  
  - Average: 69.5  
  - Average: 68.5
**Centre for Economic Policy Research (CEPR)**

- www.cepr.org/data/da
- quarterly chronology Euro Area
- recession: significant decline in the level of economic activities in the Euro Area. Two or three consecutive months in which GDP, employment etc decrease in the EU area, and showing a similar pattern in most countries
- Four cycles since 1970
- Last cycle: "peak": 2008Q1, "trough": 2009Q2,
- Actual recession: "peak" 2011Q3 ("trough"?)
- EuroCoin Indicator (CEPR): monthly coincident indicator of the euro area business cycle available in real time
EuroCoin - Centre for Economic Policy Research (CEPR)

- **EuroCoin Indicator** (CEPR): monthly coincident indicator of the euro area business cycle available in real time.

  The indicator provides an estimate of the monthly growth of euro area GDP – after the removal of:

  - measurement errors;
  - seasonal and other short-run fluctuations.
  - idiosyncratic components. The indicator aims to capture only common components of EU area BC

- The indicator is available very quickly, before the GDP numbers are released.
What data was used to produce EuroCOIN?

- The database used to construct EuroCOIN is organized into eleven blocks: industrial production, producer prices, consumer prices, monetary aggregates, interest rates, financial variables, exchange rates, surveys by the European Commission, surveys by national institutes, external trade, labour markets.

- More information:
  http://dev3.cepr.org/data/eurocoin/indepth/#indicator_constructed

- SLIDES on EuroCoin prepared by Cepr:
  http://dev3.cepr.org/data/eurocoin/
Important Questions

- Which are the main features, or stylized facts, of business cycle?
- Are business cycle alike across time and countries?
- Which sources?
- Which propagation mechanisms?
- Which is the role played by macroeconomic policies: monetary and fiscal policies? Are they stabilizing?
- Is it important to stabilize the business cycle? Which are the implication of the stabilization policies in terms of welfare?
- Is there a macro-economic model able to reproduce the main features of the business cycle?
Measuring Business Cycle

- Given a time series $y_1, y_2, y_3, \ldots, y_T \iff \{y_t\}$
- Each series can be decomposed in two parts: trend and cycle

$$y_t = z_t + x_t$$

- $z_t$: long-run trend
- $x_t$: cyclical component
- The cyclical component is stationary.
- To get the cyclical component we need to transform data into mean-zero covariance stationary stochastic processes

$$E\{x_t\} = \mu \quad \text{(usually with } \mu = 0)$$
$$E\{(x_t - \mu)(x_{t-k} - \mu)\} = \gamma(k) < +\infty \ldots \forall t, \text{ per } k = 1, 2, 3\ldots$$
Measuring Business Cycle: Traditional decomposition

- **Traditional Business Cycle Theory:** Output trend $z_t$ evolves smoothly over time,
  $$z_t = \alpha_0 + \alpha_1 t$$
  or
  $$z_t = \alpha_0 + \alpha_1 t + \alpha_2 t^2 + \alpha_3 t^3 + \ldots + \alpha_q t^q$$

- **Estimation**
  $$\min_{\{\alpha_0, \alpha_1\}} \sum_{t=1}^{T} [y_t - (\alpha_0 + \alpha_1 t)]^2$$

- Cycles are viewed as deviation from trends, i.e.
  $$\hat{x}_t = y_t - \hat{z}_t$$

- Where $\hat{z}_t$ is the estimated value of $z_t$.

- **Limits:** eliminating a deterministic trend is not sufficient to stationarize the series if the series has a unit root.
Measuring Business Cycle: Linear Trend

Cyclical Component of US GDP: Linear Trend

Nelson and Plosser (JME 1982): many macroeconomic variables have a unit root.

RBC Theory: cycles can be explained also assuming that $z_t$ evolves according to a random walk, i.e.,

$$z_t = b + z_{t-1} + u_t.$$

In this case much of the movements in $y_t$ are due to movements in $z_t$ and rather then to trend deviations $y_t - z_t$

Notice that

$$\Delta (z_t) = z_t - z_{t-1} = b + u_t$$

is stationary: we say it is difference stationary (DS).

Limits: to much weight is attached to high frequencies (quarter to quarter) that are not related to cycles
Hodrick-Prescott and Band Pass Filter

- **Starting point**: the trend $z_t$ must follow the observed data $y_t$ closely. → The trend should not fluctuate widely from quarter to quarter.

- They infer the trend from the following minimisation problem:

$$\min_{\{z_t\}_{t=1}^T} \sum_{t=1}^T (y_t - z_t)^2 + \lambda \sum_{t=2}^{T-1} [(z_{t+1} - z_t) - (z_t - z_{t-1})]^2$$

- The first part ensures that the trend component tracks the data fairly well.
- The constraint prevents the change in the trend being too volatile.
- The larger $\lambda$ the smoother the changes in the growth of the trend have to be.
Hodrick-Prescott and Band Pass Filter

\[
\min_{\{z_t\}_{t=1}^T} \sum_{t=1}^T (y_t - z_t)^2 + \lambda \sum_{t=2}^{T-1} [(z_{t+1} - z_t) - (z_t - z_{t-1})]^2
\]

- The larger \( \lambda \) the smoother the changes in the growth of the trend have to be.
- \( \lambda \to \infty \to z_t = \alpha_0 + \alpha_1 t \)
- \( \lambda \to 0 \to z_t = y_t \)
- HP suggest a value of \( \lambda = 1600 \) for quarterly data.
- **Advantages:** flexibility to capture changes in trend
- **Critics:** the choice of \( \lambda \) should vary from variable to variable.
Hodrick-Prescott Filter

Trend Component of US GDP: HP Filter

50 100 150 200 250 300 350
Hodrick-Prescott Filter

Cyclical Component of US GDP: HP Filter

This filter allows to choose the frequency range associated with the cyclical component.

Conventional Range: between 6 and 32 quarters.
Macroeconomic series reflect different components - an underlying trend, the business cycle component, seasonality, as well as purely random fluctuations.

One can use hundreds of different filtering methods

Unfortunately we can never with complete certainty claim that one filter is better than another.

Ideally, the cyclical component extracted from any dataset should not vary greatly between different filters.

However, this is not the case.
Comparing Alternative Filters

<table>
<thead>
<tr>
<th>Output</th>
<th>Consumption</th>
<th>Investment</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Graph of Output" /></td>
<td><img src="image2" alt="Graph of Consumption" /></td>
<td><img src="image3" alt="Graph of Investment" /></td>
</tr>
</tbody>
</table>

Legend:
- Red: Differences
- Blue: Linear Trend
- Black: H-P Filter
Comparing Alternative Filters

Cyclical Component of US GDP: HP vs. BP Filter

- YGDPXHP
- YGDPXBP
\{x_t\}: stationary and with zero mean:

- **Volatility**

  \[ \sigma(x_t) \equiv \sqrt{\frac{1}{T} \sum x_t^2} \]

- **Persistence**

  \[ \rho(x_t, x_{t-1}) \equiv \frac{\text{cov}(x_t, x_{t-1})}{\sigma^2(x_t)} \text{ on } \text{cov}(x_t, x_{t-1}) \equiv \frac{1}{T} \sum x_t x_{t-1} \]

- **Cyclicality**

  \[ \rho(x_t, y_t) \equiv \frac{\text{cov}(x_t, y_t)}{\sigma(x_t)\sigma(y_t)} \]
  or \[ \text{cov}(x_t, y_t) \equiv \frac{1}{T} \sum x_t y_t \]

  the variable can be: procyclical (+), countercyclical (−), or acyclical (\(\sim 0\))
Table 1: Statistical Properties of the U.S. Business Cycle
HP-Filtered (1600), 1948Q1-2013Q3

<table>
<thead>
<tr>
<th></th>
<th>$\sigma(\hat{x}_t)$</th>
<th>$\frac{\sigma(\hat{x}_t)}{\sigma(\hat{y}_t)}$</th>
<th>$\rho(\hat{x}<em>t, \hat{x}</em>{t-1})$</th>
<th>$\rho(\hat{x}_t, \hat{y}_t)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP</td>
<td>1.69</td>
<td>1.0</td>
<td>0.85</td>
<td>1.00</td>
</tr>
<tr>
<td>Consumption</td>
<td>1.26</td>
<td>0.7</td>
<td>0.81</td>
<td>0.79</td>
</tr>
<tr>
<td>Investment</td>
<td>4.95</td>
<td>2.9</td>
<td>0.89</td>
<td>0.80</td>
</tr>
<tr>
<td>Gov.Purchases</td>
<td>3.41</td>
<td>2.0</td>
<td>0.90</td>
<td>0.20</td>
</tr>
<tr>
<td>Hours Worked</td>
<td>1.98</td>
<td>1.2</td>
<td>0.91</td>
<td>0.88</td>
</tr>
<tr>
<td>Labor Prod.</td>
<td>1.10</td>
<td>0.6</td>
<td>0.72</td>
<td>0.39</td>
</tr>
<tr>
<td>TFP</td>
<td>1.32</td>
<td>0.8</td>
<td>0.77</td>
<td>0.76</td>
</tr>
<tr>
<td>Real Wage</td>
<td>0.92</td>
<td>0.5</td>
<td>0.71</td>
<td>0.20</td>
</tr>
<tr>
<td>Real Int. Rate</td>
<td>1.22</td>
<td>0.7</td>
<td>0.78</td>
<td>0.07</td>
</tr>
</tbody>
</table>

(1)
Comovements

Aggregate Comovements (HP-Filtered)

- GDP
- Consumption

- GDP
- Investment

- GDP
- Hours
## Table 2: Statistical Properties of the Euro Area Business Cycle

**HP-Filtered (1600), 1970Q1-2012Q4**

<table>
<thead>
<tr>
<th></th>
<th>$\sigma(\hat{x}_t)$</th>
<th>$\frac{\sigma(\hat{x}_t)}{\sigma(\hat{y}_t)}$</th>
<th>$\rho(\hat{x}<em>t, \hat{x}</em>{t-1})$</th>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>GDP</strong></td>
<td>1.17</td>
<td>1.0</td>
<td>0.88</td>
<td>1.00</td>
</tr>
<tr>
<td><strong>Consumption</strong></td>
<td>0.82</td>
<td>0.7</td>
<td>0.89</td>
<td>0.77</td>
</tr>
<tr>
<td><strong>Investment</strong></td>
<td>2.92</td>
<td>2.5</td>
<td>0.89</td>
<td>0.92</td>
</tr>
<tr>
<td><strong>Gov. Purchases</strong></td>
<td>0.58</td>
<td>0.5</td>
<td>0.73</td>
<td>-0.16</td>
</tr>
<tr>
<td><strong>Employment</strong></td>
<td>0.68</td>
<td>0.6</td>
<td>0.96</td>
<td>0.77</td>
</tr>
<tr>
<td><strong>Labor Productivity</strong></td>
<td>0.77</td>
<td>0.7</td>
<td>0.79</td>
<td>0.83</td>
</tr>
<tr>
<td><strong>TFP</strong></td>
<td>0.86</td>
<td>0.7</td>
<td>0.82</td>
<td>0.94</td>
</tr>
<tr>
<td><strong>Real Wage</strong></td>
<td>0.53</td>
<td>0.5</td>
<td>0.74</td>
<td>0.27</td>
</tr>
<tr>
<td><strong>Real Int. Rate</strong></td>
<td>0.91</td>
<td>0.8</td>
<td>0.77</td>
<td>0.57</td>
</tr>
</tbody>
</table>
### Table 3: Statistical Properties of the U.S. Business Cycle
BP-Filtered (6,32), 1948Q1-2012Q3

<table>
<thead>
<tr>
<th></th>
<th>$\sigma(\hat{x}_t)$</th>
<th>$\frac{\sigma(\hat{x}_t)}{\sigma(\hat{y}_t)}$</th>
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<td><strong>Investment</strong></td>
<td>4.69</td>
<td>2.8</td>
<td>0.93</td>
<td>0.81</td>
</tr>
<tr>
<td><strong>Gov. Spend.</strong></td>
<td>3.40</td>
<td>2.1</td>
<td>0.94</td>
<td>0.24</td>
</tr>
<tr>
<td><strong>Hours</strong></td>
<td>1.92</td>
<td>1.2</td>
<td>0.93</td>
<td>0.89</td>
</tr>
<tr>
<td><strong>Labor Prod.</strong></td>
<td>1.04</td>
<td>0.6</td>
<td>0.89</td>
<td>0.40</td>
</tr>
<tr>
<td><strong>TFP</strong></td>
<td>1.25</td>
<td>0.8</td>
<td>0.90</td>
<td>0.76</td>
</tr>
<tr>
<td><strong>Real Wage</strong></td>
<td>0.85</td>
<td>0.5</td>
<td>0.91</td>
<td>0.23</td>
</tr>
<tr>
<td><strong>Real Int. Rate</strong></td>
<td>1.16</td>
<td>0.7</td>
<td>0.89</td>
<td>0.02</td>
</tr>
</tbody>
</table>
### Table 4: Statistical Properties of the Euro Area Business Cycle
BP-Filtered (6,32), 1970Q1-2012Q4

<table>
<thead>
<tr>
<th></th>
<th>$\sigma(\hat{x}_t)$</th>
<th>$\frac{\sigma(\hat{x}_t)}{\sigma(\hat{y}_t)}$</th>
<th>$\rho(\hat{x}<em>t, \hat{x}</em>{t-1})$</th>
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<td>1.16</td>
<td>1.0</td>
<td>0.88</td>
<td>1.00</td>
</tr>
<tr>
<td><strong>Consumption</strong></td>
<td>0.82</td>
<td>0.7</td>
<td>0.84</td>
<td>0.77</td>
</tr>
<tr>
<td><strong>Investment</strong></td>
<td>2.92</td>
<td>2.5</td>
<td>0.89</td>
<td>0.92</td>
</tr>
<tr>
<td><strong>Gov. Purchases</strong></td>
<td>0.58</td>
<td>0.5</td>
<td>0.73</td>
<td>-0.16</td>
</tr>
<tr>
<td><strong>Employment</strong></td>
<td>0.68</td>
<td>0.6</td>
<td>0.96</td>
<td>0.77</td>
</tr>
<tr>
<td><strong>Labor Prod.</strong></td>
<td>0.77</td>
<td>0.7</td>
<td>0.79</td>
<td>0.83</td>
</tr>
<tr>
<td><strong>TFP</strong></td>
<td>0.86</td>
<td>0.7</td>
<td>0.82</td>
<td>0.94</td>
</tr>
<tr>
<td><strong>Real Wage</strong></td>
<td>0.53</td>
<td>0.5</td>
<td>0.74</td>
<td>0.27</td>
</tr>
<tr>
<td><strong>Real Int. Rate</strong></td>
<td>0.91</td>
<td>0.8</td>
<td>0.77</td>
<td>0.57</td>
</tr>
</tbody>
</table>
Stylized Facts

1. Consumption is procyclical and less volatile than output
2. Durable goods consumption is more volatile than non-durable goods consumption
3. Investment are more volatile than output
4. Hours and employment are almost as volatile as output
5. Wages are slightly procyclical or acyclical
6. Productivity: procyclical and less volatile than output
International Business Cycle?

Chart 1. Global GDP Growth

Percent, Year/Year


-8 -6 -4 -2 0 2 4 6 8 10

World (2013 Q3 = 3.2)
Advanced Economies (ex. U.S.) (2013 Q3 = 1.1)
Emerging Economies (2013 Q3 = 5.6)
U.S. (2013 Q4 = 2.5)

NOTE: The advanced economies (ex. U.S.) aggregate includes the Euro Area, Japan, the U.K., Canada, Australia, South Korea, Switzerland and Sweden. The emerging economies aggregate includes China, Brazil, Russia, India, Mexico, Indonesia, Turkey, Argentina, South Africa and Colombia. The world aggregate includes these countries, which make up approximately 80 percent of world GDP computed using purchasing power parity (PPP) adjusted GDP weights.

Sources: National Statistical Offices, International Monetary Fund, HAVER Analytics

Globalization & Monetary Policy Institute
Federal Reserve Bank of Dallas
Common factors at play

Common factors account for a sizable fraction of business cycle fluctuations, confirming the existence of a world business cycle.

(average share of business cycle fluctuations, percent)

Integration matters

The global factor matters most for explaining output growth in industrial countries.

(average share of fluctuations in output growth, percent)

International Business Cycle?

A mixed bag
The global factor has become less important in explaining fluctuations in business cycles...

(average output variance explained by global factor, percent)

- Industrial countries
- Emerging markets
- Other developing countries

International Business Cycle?

...but factors specific to each group of countries have become more important.

(average output variance explained by group-specific factors, percent)

Note: Variance shares for industrial countries are on the left scale, and those for emerging markets and other developing countries are on the right one.
International Business Cycle: Euro Area versus US

Euro Area - U.S. GDP Comovement (HP-Filter)

\[
corr(y_t^{emu}, y_t^{us}) = 0.55 \quad corr(y_t^{emu}, y_{t-1}^{us}) = 0.62
\]
## Table 1: Volatility of Growth of Selected Series

<table>
<thead>
<tr>
<th></th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>GDP</td>
<td>4.43</td>
<td>-2.16</td>
<td>100</td>
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<tr>
<td>Consumption</td>
<td>3.41</td>
<td>-1.37</td>
<td>67.6</td>
</tr>
<tr>
<td>Investment</td>
<td>22.02</td>
<td>-7.97</td>
<td>17.5</td>
</tr>
<tr>
<td>Government</td>
<td>4.50</td>
<td>-.73</td>
<td>6.2</td>
</tr>
<tr>
<td>Exports</td>
<td>21.65</td>
<td>-12.82</td>
<td>10.8</td>
</tr>
<tr>
<td>Imports</td>
<td>20.04</td>
<td>-11.26</td>
<td>13.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Product Components</th>
<th>Standard Deviation</th>
<th>Difference (II-I)</th>
<th>Share in Nominal GDP (pct.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goods</td>
<td>8.00</td>
<td>-3.23</td>
<td>37.6</td>
</tr>
<tr>
<td>Structures</td>
<td>11.80</td>
<td>-5.03</td>
<td>9.1</td>
</tr>
<tr>
<td>Services</td>
<td>1.76</td>
<td>-0.36</td>
<td>53.3</td>
</tr>
</tbody>
</table>

Ahmed et al. 2004
### Table 5: Changes in the U.S. Business Cycle (HP-Filter)

<table>
<thead>
<tr>
<th></th>
<th>1948-1983 (1)</th>
<th>1984-2007 (2)</th>
<th>Ratio (2)/(1)</th>
<th>1984-2013 (3)</th>
<th>Ratio (3)/(1)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GDP</strong></td>
<td>2.05</td>
<td>0.93</td>
<td>0.45</td>
<td>1.07</td>
<td>0.52</td>
</tr>
<tr>
<td><strong>Consumption</strong></td>
<td>1.47</td>
<td>0.75</td>
<td>0.51</td>
<td>0.91</td>
<td>0.61</td>
</tr>
<tr>
<td><strong>Invest</strong></td>
<td>5.68</td>
<td>3.68</td>
<td>0.64</td>
<td>4.46</td>
<td>0.78</td>
</tr>
<tr>
<td><strong>Gov.Purchases</strong></td>
<td>4.57</td>
<td>1.08</td>
<td>0.23</td>
<td>1.13</td>
<td>0.24</td>
</tr>
<tr>
<td><strong>Hours</strong></td>
<td>2.11</td>
<td>1.44</td>
<td>0.68</td>
<td>1.70</td>
<td>0.80</td>
</tr>
<tr>
<td><strong>Aver.Lab Prod.</strong></td>
<td>1.25</td>
<td>0.79</td>
<td>0.63</td>
<td>0.83</td>
<td>0.66</td>
</tr>
<tr>
<td><strong>TFP</strong></td>
<td>1.60</td>
<td>0.73</td>
<td>0.47</td>
<td>0.79</td>
<td>0.49</td>
</tr>
<tr>
<td><strong>Real Wage</strong></td>
<td>0.74</td>
<td>1.03</td>
<td>1.30</td>
<td>1.13</td>
<td>1.52</td>
</tr>
<tr>
<td><strong>Real Int. Rate</strong></td>
<td>1.48</td>
<td>0.89</td>
<td>0.60</td>
<td>0.86</td>
<td>0.58</td>
</tr>
</tbody>
</table>
## Business Cycle Changes over time

**Table 6: Changes in the Euro Area Business Cycle (HP-Filter)**

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>GDP</td>
<td>1.14</td>
<td>1.00</td>
<td>0.87</td>
<td>1.21</td>
<td>1.06</td>
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<tr>
<td>Consumption</td>
<td>0.94</td>
<td>0.73</td>
<td>0.77</td>
<td>0.64</td>
<td>0.68</td>
</tr>
<tr>
<td>Investment</td>
<td>2.76</td>
<td>2.68</td>
<td>0.97</td>
<td>3.10</td>
<td>1.12</td>
</tr>
<tr>
<td>Gov. Purchases</td>
<td>0.57</td>
<td>0.44</td>
<td>0.77</td>
<td>0.56</td>
<td>0.98</td>
</tr>
<tr>
<td>Employment</td>
<td>0.69</td>
<td>0.65</td>
<td>0.94</td>
<td>0.64</td>
<td>0.92</td>
</tr>
<tr>
<td>Ave. Lab. Prod.</td>
<td>0.76</td>
<td>0.53</td>
<td>0.69</td>
<td>0.79</td>
<td>1.03</td>
</tr>
<tr>
<td>TFP</td>
<td>0.84</td>
<td>0.65</td>
<td>0.77</td>
<td>0.90</td>
<td>1.07</td>
</tr>
<tr>
<td>Real Wage</td>
<td>0.62</td>
<td>0.42</td>
<td>0.67</td>
<td>0.34</td>
<td>0.54</td>
</tr>
<tr>
<td>Real Int. Rate</td>
<td>1.09</td>
<td>0.60</td>
<td>0.55</td>
<td>1.06</td>
<td>0.97</td>
</tr>
</tbody>
</table>

*University of Pavia (*)

Some of these slides are based on my course of Advanced Macroeconomics II held at UPF and benefit of the work done by Jordi Gali in preparing his course of Macroeconomia Avanzada II at UPF.
Possible explanations of the Great Moderation

a) sectoral composition: manufacturing versus services
b) Role played by the Government:
   - aggregate demand
   - automatic stabilizers
   - countercyclical policies
c) more flexible labor market
d) role of financial market and crisis (deposits insurance, the LLR)
g) "Good Policies, Good Practices or Good Luck?"
**TRADITIONAL BUSINESS CYCLE THEORY:** output trend $\bar{Y}_t$ evolves smoothly over time, $\bar{Y}_t = a + bt$. Cycles are viewed as deviation from trends, i.e. $Y_t - \bar{Y}_t$

**RBC THEORY:** cycles can be explained also assuming that $\bar{Y}_t$ evolves according to a random walk, i.e., $\bar{Y}_t = b + \bar{Y}_{t-1} + u_t$. In this case much of the movements in $Y_t$ are due to movements in $\bar{Y}_t$ and rather then to trend deviations $Y_t - \bar{Y}_t$
The Lucas Research Program and Methodological Proposal

- Lucas (’76,’77,’80,’87). Two important references:

- The Lucas’ critique: Macroeconomists should build so-called structural models, i.e. models that are based on microeconomics foundations, maximizing households and firms, flexible prices/wages, market clearing, etc.
  1. Microeconomic foundations
  2. General Equilibrium
  3. Rational Expectations
  4. No distinction between micro and macro: Economic theory
CONCLUSIONS

- Modern macroeconomics should employ dynamic general equilibrium models (DSGE), that is, a macroeconomic model should be the results of the solution of dynamic optimization problems under uncertainty by optimizing agents populating the model economy.

- Build a "laboratory economy": much more difficult task than old Keynesian theorizing.

- Kydland & Prescott (1982) accepted the challenge posed by Lucas: they built the first Real Business Cycle (RBC) model.
Basic RBC model

- Outline of the RBC methodology:

a discrete-time stochastic model of the economy populated by maximizing households and firms

MAIN SOURCE OF FLUCTUATIONS:

- The erratic nature of technological progress
MAIN RESULT AND FIRST INTUITION

- There is only one final good in the economy which is produced according to a constant return to scale (CRS) production function

\[ Y_t = A_t F (K_{t-1}, N_t) \]

where \( \ln(A_t/A) = \hat{a}_t \) is an exogenous process of technological progress (or total factor productivity TFP), which evolves according to:

\[ \ln(A_t/A) = \rho_a \ln(A_t/A) + \varepsilon_{a,t}, \quad \varepsilon_{a,t} \sim WN \left( 0, \sigma_a^2 \right) \text{ i.i.d.} \]

- A positive shock to the TFP shifts firms’ labor demand and the AS curve

- Movements in employment and economic activity are seen as the efficient responses of a perfectly competitive economy to a productivity shock. \( \implies \) Movements from a Walrasian equilibrium to another one.
POSITIVE TECHNOLOGY SHOCK

Labor Demand

Production Function

\[ L^S(W/P) \]

\[ L = L^d(W/P) \]

\[ W/P \]

\[ W/P_1 \]

\[ W/P_2 \]

\[ L_1 \]

\[ L_2 \]

\[ \bar{Y}_1 \]

\[ \bar{Y}_2 \]

\[ Y = F(L) \]

\[ Y \]

\[ L \]
MAIN RESULTS OF RBC THEORY

- Money short-run and long run neutrality $\Rightarrow$ classical dichotomy

- Fluctuations of all variable (output, consumption, employment, investment...) are the optimal responses to exogenous changes in the economic environment (technology shocks, government spending shocks)

- Shocks are not always desirable. But once they occur, fluctuations in output, employment, consumption and other variables are the optimal responses to them!!

- Stabilization Policies are not necessary