Examining the Growth Data
The Growth Experience
Linearity in levels or logs: France
Linearity in levels or logs: Ireland
Cycle Turning Points for USA

[Graph showing cycle turning points for USA with labeled peaks and troughs]
Compounding and Growth Rate Formulas

Measuring Growth Rates
### Trend and average growth rates

<table>
<thead>
<tr>
<th>Country</th>
<th>Trend growth</th>
<th>Average growth</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Annualy comp</td>
<td>Continuously comp</td>
<td></td>
</tr>
<tr>
<td>Australia</td>
<td>3.51%</td>
<td>3.46%</td>
<td>3.36%</td>
<td></td>
</tr>
<tr>
<td>Italy</td>
<td>4.00%</td>
<td>3.99%</td>
<td>3.85%</td>
<td></td>
</tr>
<tr>
<td>Japan</td>
<td>5.81%</td>
<td>5.74%</td>
<td>5.43%</td>
<td></td>
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<tr>
<td>Korea</td>
<td>8.25%</td>
<td>7.81%</td>
<td>7.37%</td>
<td></td>
</tr>
<tr>
<td>Norway</td>
<td>2.35%</td>
<td>2.73%</td>
<td>2.35%</td>
<td></td>
</tr>
<tr>
<td>Peru</td>
<td>3.90%</td>
<td>4.73%</td>
<td>4.50%</td>
<td></td>
</tr>
<tr>
<td>Sweden</td>
<td>2.68%</td>
<td>2.80%</td>
<td>2.73%</td>
<td></td>
</tr>
<tr>
<td>United States</td>
<td>3.21%</td>
<td>3.18%</td>
<td>3.10%</td>
<td></td>
</tr>
</tbody>
</table>

- Trend rate can be greater than or less than average growth rates
- Annually compounded rate is always greater than continuously compounded.
Trend growth vs. average growth

- Trend rate is slope of best-fit line
- What is average growth rate?
  From period 0 to 2:

\[
\bar{g} = \frac{(\ln GDP_2 - \ln GDP_1) + (\ln GDP_1 - \ln GDP_0)}{2}
\]

\[
= \frac{\ln GDP_2 - \ln GDP_0}{2}.
\]
Trend growth vs. average growth

- Trend rate is slope of best-fit line
- What is average growth rate?
  From period 0 to T:

\[
\bar{g} = \frac{(\ln GDP_T - \ln GDP_{T-1}) + \ldots + (\ln GDP_1 - \ln GDP_0)}{T}
\]

\[
= \frac{\ln GDP_T - \ln GDP_0}{T}.
\]
Trend growth vs. average growth: Peru

- Trend growth rate (1950-2011) = 3.90%
- Average continuously compounded rate = 4.50%
- Why are they so different?
Trend growth vs. average growth: Peru
Trend growth vs. average growth: Peru

Slope = average growth rate

lnGDPT – lnGDP<sub>0</sub>
Is Trend Growth Stable?

Examining the Record
Is the trend stable?

Single Trend for Japan

- **lgdp**
- **Fitted values**
Is the trend stable?

**Stability Test for Japan**

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>Number of obs = 58</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>42.0122524</td>
<td>3</td>
<td>14.0040841</td>
<td>F( 3, 54) = 3803.57</td>
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<tr>
<td>Residual</td>
<td>0.198818807</td>
<td>54</td>
<td>0.00368183</td>
<td>Prob &gt; F = 0.0000</td>
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<tr>
<td>Total</td>
<td>42.2110712</td>
<td>57</td>
<td>0.740545109</td>
<td>R-squared = 0.9953</td>
</tr>
</tbody>
</table>

| Variable   | Coef.    | Std. Err. | t     | P>|t|   | [95% Conf. Interval] |
|------------|----------|-----------|-------|-------|----------------------|
| lgdp       | 0.0848916 | 0.0017893 | 47.44 | 0.000 | 0.0813043 to 0.0884789 |
| d          | 117.6017  | 4.095852  | 28.71 | 0.000 | 109.39 to 125.8133   |
| dyear      | -0.059565 | 0.0020801 | -28.64| 0.000 | -0.0637353 to -0.0553948 |
| _cons      | -153.1541 | 3.509732  | -43.64| 0.000 | -160.1907 to -146.1175 |
Is the trend stable?

Two-Piece Trend for Japan

- Blue line: lgdp
- Red line: Fitted values
Cyclical series with unstable trend

Cyclical GDP with single trend

Year

Clgdp

1940 1960 1980 2000 2020
Cyclical GDP: Split trend

Japan Cyclical GDP with 2 Trends


clgdp: -1, -0.5, 0, 0.5, 1, 1.5
Are there two breaks?

Three-Piece Trend for Japan

- lgdp
- Fitted values

Year range: 1940 to 2020

Values range: 12.5 to 15
Cyclical series with two breaks

Japan Cyclical GDP with Three-Piece Trend
## Pre- and post-1973 trend growth rates

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Australia</td>
<td>3.51%</td>
<td>3.60%</td>
<td>+0.09%</td>
<td>4.66%</td>
<td>3.28%</td>
<td>-1.38%</td>
</tr>
<tr>
<td>Italy</td>
<td>4.00%</td>
<td>4.22%</td>
<td>+0.22%</td>
<td>5.66%</td>
<td>2.55%</td>
<td>-3.11%</td>
</tr>
<tr>
<td>Japan</td>
<td>5.81%</td>
<td>6.23%</td>
<td>+0.42%</td>
<td>9.31%</td>
<td>3.12%</td>
<td>-6.19%</td>
</tr>
<tr>
<td>Korea</td>
<td>8.24%</td>
<td>8.53%</td>
<td>-0.29%</td>
<td>7.42%</td>
<td>7.00%</td>
<td>-0.42%</td>
</tr>
<tr>
<td>Norway</td>
<td>2.35%</td>
<td>2.32%</td>
<td>-0.03%</td>
<td>2.85%</td>
<td>3.34%</td>
<td>+0.49%</td>
</tr>
<tr>
<td>Peru</td>
<td>3.90%</td>
<td>3.78%</td>
<td>-0.12%</td>
<td>5.37%</td>
<td>3.84%</td>
<td>-1.53%</td>
</tr>
<tr>
<td>Sweden</td>
<td>2.68%</td>
<td>2.73%</td>
<td>+0.05%</td>
<td>3.81%</td>
<td>2.45%</td>
<td>-1.36%</td>
</tr>
<tr>
<td>USA</td>
<td>3.21%</td>
<td>3.30%</td>
<td>+0.09%</td>
<td>3.90%</td>
<td>2.89%</td>
<td>-1.01%</td>
</tr>
<tr>
<td>Greece</td>
<td>4.25%</td>
<td>4.41%</td>
<td>+0.16%</td>
<td>6.92%</td>
<td>3.09%</td>
<td>-3.83%</td>
</tr>
</tbody>
</table>
Hodrick-Prescott filter: Japan

HP Filter (lambda=100) for Japan
Hodrick-Prescott filter: Ireland

HP Filter for Ireland

year

lgdp H_lgdp_sm_1
Separating trend and cyclical components

- No “correct” way to do it
  - Obvious changes in underlying growth rate should be tracked in the trend component
  - Obviously temporary deviations from the trend should be left in the cyclical component
- Piecewise linear trends
  - Assume discrete changes in trend rate
  - Appropriate where discrete event (revolution?) can be assumed to cause change
- HP filter and other, similar methods
  - Trend rate can change continuously
  - HP trend will, to some extent, follow all changes in series
Conclusions

- Most economies grow
  - Growth explains most of the variation in GDP
- Underlying growth rates vary over time
  - Changes in growth rates may result from specific event at specific date
  - Or may be gradual slowdowns or speedups
- GDP fluctuates considerably around its trend
  - Fluctuations are called “cycles” even if they aren’t
  - Traditional “business cycle” has a period of 3-8 years
- Most countries have slowed down after 1973
- Most countries experienced downturn after 2007