The High Correlations of Prices and Interest Rates across Nations

Espen Henriksen       Finn Kydland       Roman Šustek

University of Oslo    UCSB             Bank of England

Econometric Society, June 21, 2008
We document: Fluctuations in aggregate price levels and short-term nominal interest rates are substantially more synchronized across countries over the business cycle than fluctuations in output.

This might seem surprising: Domestic nominal environment can be controlled by domestic monetary policy, thus less subject to external factors than output.

Rationalizing this empirical regularity can enhance our understanding of the channels through which foreign shocks affect domestic nominal variables.

We ask: Can we account for this empirical regularity in a prototypical international business cycle model?
International Business Cycle


<table>
<thead>
<tr>
<th></th>
<th>aus</th>
<th>can</th>
<th>ger</th>
<th>jap</th>
<th>uk</th>
<th>us</th>
</tr>
</thead>
<tbody>
<tr>
<td>aus</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>can</td>
<td>0.53</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ger</td>
<td>-0.02</td>
<td>0.16</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>jap</td>
<td>-0.12</td>
<td>-0.06</td>
<td>0.39</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>uk</td>
<td>0.19</td>
<td>0.45</td>
<td>0.21</td>
<td>0.18</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>us</td>
<td>0.23</td>
<td>0.72</td>
<td>0.42</td>
<td>0.21</td>
<td>0.56</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Whole sample: Mean = 0.27, Rel. std. = 0.89
Excl. Bretton Woods: Mean = 0.25, Rel. std. = 1.21

<table>
<thead>
<tr>
<th></th>
<th>aus</th>
<th>can</th>
<th>ger</th>
<th>jap</th>
<th>uk</th>
<th>us</th>
</tr>
</thead>
<tbody>
<tr>
<td>aus</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>can</td>
<td>0.61</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ger</td>
<td>0.52</td>
<td>0.62</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>jap</td>
<td>0.39</td>
<td>0.39</td>
<td>0.47</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>uk</td>
<td>0.58</td>
<td>0.56</td>
<td>0.63</td>
<td>0.63</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>us</td>
<td>0.55</td>
<td>0.84</td>
<td>0.72</td>
<td>0.43</td>
<td>0.57</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Whole sample: Mean = 0.57, Rel. std. = 0.22
Excl. Bretton Woods: Mean = 0.57, Rel. std. = 0.26

<table>
<thead>
<tr>
<th></th>
<th>aus</th>
<th>can</th>
<th>ger</th>
<th>jap</th>
<th>uk</th>
<th>us</th>
</tr>
</thead>
<tbody>
<tr>
<td>aus</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>can</td>
<td>0.68</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ger</td>
<td>0.25</td>
<td>0.43</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>jap</td>
<td>0.33</td>
<td>0.63</td>
<td>0.41</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>uk</td>
<td>0.50</td>
<td>0.52</td>
<td>0.42</td>
<td>0.58</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>us</td>
<td>0.47</td>
<td>0.71</td>
<td>0.51</td>
<td>0.76</td>
<td>0.61</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Whole sample: \(\text{Mean} = 0.52\), \(\text{Rel. std.} = 0.28\)

Excl. Bretton Woods: \(\text{Mean} = 0.50\), \(\text{Rel. std.} = 0.29\)
Comovement of Nominal Variables vs Comovement of Real GDP – 1970.Q1-2006.Q4
Summary of the Empirical Findings

- Key finding:

\[
\text{corr}(R_i, R_j) \approx \text{corr}(p_i, p_j) > \text{corr}(y_i, y_j)
\]

- Robust to:

  - Adding more countries as data become available (Austria and France from 1970.Q1)
  - Different exchange rate regimes
  - “Great Moderation” – period of stable output growth and low and stable inflation after 1984
Model Economy

- Two-good international business cycle model of Backus, Kehoe, and Kydland (AER, 1994)

- Augmented to include
  - Nominal assets (money and bonds)
  - Taylor rule – a ‘standard’ approximation of a central bank’s behavior;
Preferences

- **Utility function**

\[
E_0 \sum_{t=0}^{\infty} \beta^t U(c_{it}, 1 - n_{it} - s_{it})
\]

\[
U(c, 1 - n - s) = \left[ c^\mu \left( 1 - n - s \right)^{1-\mu} \right]^{1-\gamma} - 1
\]

- **“Shopping time”**

\[
s_{it} = \kappa_1 \left( \frac{p_{it}c_{it}}{m_{it}} \right)^{\kappa_2}
\]
Production

- Country 1 produces good $a$, country 2 produces good $b$
- Production in country $i$

$$y_{it} = z_{it} k_{it}^{\alpha} n_{it}^{1-\alpha}$$

- Expenditures: composites of foreign and domestic goods

$$c_{1t} + x_{1t} = \left( \omega_1 a_{1t}^{-\rho} + \omega_2 b_{1t}^{-\rho} \right)^{-1/\rho}$$
$$c_{2t} + x_{2t} = \left( \omega_1 b_{2t}^{-\rho} + \omega_2 a_{2t}^{-\rho} \right)^{-1/\rho}$$

- Clearing the world market for goods

$$a_{1t} + a_{2t} = y_{1t}$$
$$b_{1t} + b_{2t} = y_{2t}$$
Budget Constraint and Asset Markets

- Consumer’s budget constraint
\[
\frac{q_{it}^a f_{it}}{1 + r_t^f} + \frac{d_{it}}{p_{it} (1 + R_{it})} + \frac{m_{it}}{p_{it}} + c_{it} + x_{it} =
\]
\[
q_{it}^c (r_{it}^k k_{it} + w_{it} n_{it}) + q_{it}^a f_{i,t-1} + \frac{d_{i,t-1}}{p_{it}} + \frac{m_{i,t-1}}{p_{it}} + v_{it}
\]

- Law of motion for capital
\[
k_{i,t+1} = (1 - \delta) k_{it} + x_{it}
\]

- Money and asset market clearing conditions
\[
m_{it} = m_{i,t-1} + p_{it} v_{it}
\]
\[
d_{it} = 0
\]
\[
f_{1t} + f_{2t} = 0
\]
Monetary Policy

Taylor rule

\[ R_{it} = (1 - \phi) \left[ R + \nu_y (\ln GDP_{it} - \ln GDP) + \nu_\pi (\pi_{it} - \pi) \right] + \phi R_{i,t-1} \]

where

\[ \pi_{it} = \ln p_{it} - \ln p_{i,t-1} \]
## Baseline Calibration

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative risk aversion</td>
<td>$\gamma$</td>
<td>2.0</td>
</tr>
<tr>
<td>Consumption share in utility</td>
<td>$\mu$</td>
<td>0.34</td>
</tr>
<tr>
<td>Discount factor</td>
<td>$\beta$</td>
<td>0.989</td>
</tr>
<tr>
<td>Depreciation rate</td>
<td>$\delta$</td>
<td>0.025</td>
</tr>
<tr>
<td>Capital’s share of output</td>
<td>$\alpha$</td>
<td>0.36</td>
</tr>
<tr>
<td>Weight on domestic good</td>
<td>$\omega_1$</td>
<td>0.761</td>
</tr>
<tr>
<td>Weight on foreign good</td>
<td>$\omega_2$</td>
<td>0.239</td>
</tr>
<tr>
<td>Elasticity of substitution</td>
<td>$\sigma$</td>
<td>1.5</td>
</tr>
<tr>
<td>Shopping time level parameter</td>
<td>$\kappa_1$</td>
<td>0.0054</td>
</tr>
<tr>
<td>Shopping time curvature param.</td>
<td>$\kappa_2$</td>
<td>1.0</td>
</tr>
<tr>
<td>Steady-state inflation rate</td>
<td>$\pi$</td>
<td>0.0091</td>
</tr>
<tr>
<td>Weight on GDP</td>
<td>$\nu_y$</td>
<td>0.125</td>
</tr>
<tr>
<td>Weight on inflation</td>
<td>$\nu_\pi$</td>
<td>1.5</td>
</tr>
<tr>
<td>Smoothing parameter</td>
<td>$\phi$</td>
<td>0.75</td>
</tr>
</tbody>
</table>
Baseline Stochastic Process for Technology

\[
\begin{bmatrix}
\ln z_{1,t+1} \\
\ln z_{2,t+1}
\end{bmatrix} =
\begin{bmatrix}
0.00072 \\
0.00072
\end{bmatrix} +
\begin{bmatrix}
0.906 & 0.088 \\
0.088 & 0.906
\end{bmatrix}
\begin{bmatrix}
\ln z_{1t} \\
\ln z_{2t}
\end{bmatrix} + \varepsilon_{t+1}
\]

\[\varepsilon_{t+1} \sim N(0, \Sigma)\]

\[
\Sigma = 0.00852 \cdot 
\begin{bmatrix}
1 & 0.258 \\
0.258 & 1
\end{bmatrix}
\]
Findings
## Findings

<table>
<thead>
<tr>
<th></th>
<th>Data, six-country sample, 60.Q1-06.Q4</th>
<th>Model economy</th>
</tr>
</thead>
<tbody>
<tr>
<td>$(GDP_1, GDP_2)$</td>
<td>$(p_1, p_2)$</td>
<td>$(R_1, R_2)$</td>
</tr>
<tr>
<td>corr</td>
<td>0.27</td>
<td>0.23</td>
</tr>
<tr>
<td></td>
<td>0.52</td>
<td>0.69</td>
</tr>
<tr>
<td></td>
<td>0.57</td>
<td>0.69</td>
</tr>
</tbody>
</table>
The Mechanism

- No arbitrage between domestic real and nominal assets

\[ E_t \hat{r}_{i,t+1}^k = \hat{R}_{it} - E_t \hat{\pi}_{i,t+1} \]

- Taylor rule

\[ \hat{R}_{it} = \tilde{\nu}_\pi \hat{\pi}_{it} + \tilde{\nu}_y \hat{Y}_{it} \]
The Mechanism

- Equilibrium price level and nominal interest rate

\[ \hat{p}_{it} = \hat{p}_{i,t-1} + E_t \left[ \sum_{j=1}^{\infty} \left( \frac{1}{\tilde{\nu}_\pi} \right)^j \hat{r}_{i,t+j}^k \right] - \tilde{\nu}_y E_t \left[ \sum_{j=1}^{\infty} \left( \frac{1}{\tilde{\nu}_\pi} \right)^j \hat{Y}_{i,t+j-1} \right] \]

\[ \hat{R}_{it} = E_t \left[ \sum_{j=1}^{\infty} \left( \frac{1}{\tilde{\nu}_\pi} \right)^{j-1} \hat{r}_{i,t+j}^k \right] - \tilde{\nu}_y E_t \left[ \sum_{j=1}^{\infty} \left( \frac{1}{\tilde{\nu}_\pi} \right)^j \hat{Y}_{i,t+j} \right] \]

where \( \tilde{\nu}_\pi > 1 \)
Responses to a 1% Positive Technology Shock in Country 1
Sensitivity Analysis

- Elasticity of substitution – no effect
- Steady-state import share of GDP – no effect
- Parameters of the monetary policy rule
- Spillovers
- Domestic nominal business cycle
Weight on inflation in the Taylor Rule

\[ \nu_y = 0 \]

\[ \nu_y = 0.125 \]

- \( \text{std}(p)/\text{std}(GDP) \) and \( \text{std}(R)/\text{std}(GDP) \) are minimized by setting \( \nu_y = 0 \) and increasing \( \nu_\pi \)
Spillovers

\[ \nu_y = 0 \]

\[ \nu_y = 0.125 \]
Domestic Nominal Business Cycle

- We document the similarity across countries of the domestic business cycle properties of the nominal interest rate and prices
  1. Price level – countercyclical
  2. Nom. interest rate – procyclical
  3. Both strongly negatively correlated with future output

- Baseline model does not account for 2 and 3
- Introduce a wedge that distorts the Euler equation for nominal bonds
- Choose the parameters of its stochastic process so as to generate the dynamics of the nominal interest rate as in the data

Finding:
  - Dynamics of the price level similar to that in the data
  - Cross-country corr. of nominal variables higher than that of output
Conclusion

- At business cycle frequencies nominal variables are substantially more correlated across countries than output.

- Our model economy can to a large extent account for this empirical regularity.

- The mechanism:
  - Interaction between asset markets and monetary policy
    \[ \Rightarrow \text{Current prices and interest rates reflect expected future states of the economy} \]
  - Spillovers of technology shocks
    \[ \Rightarrow \text{Future states are similar across economies} \]
  - Hence current prices and interest rates are similar across economies.
The Mechanism

- No arbitrage between domestic real and nominal assets
  \[ E_t \hat{r}_{i,t+1}^k = \hat{R}_{it} - E_t \hat{\pi}_{i,t+1} \]

- Taylor rule
  \[ \hat{R}_{it} = \tilde{\nu}_\pi \hat{\pi}_{it} + \tilde{\nu}_y \hat{Y}_{it} \]

- No arbitrage between real domestic and international assets
  \[ E_t \hat{r}_{i,t+1}^k = \hat{r}_t + E_t \hat{q}_{i,t+1}^a - \hat{q}_{it}^a \]

No arbitrage in international capital flows
\[ E_t \hat{r}_{1,t+1}^k + \left[ E_t \left( \hat{q}_{2,t+1}^a - \hat{q}_{1,t+1}^a \right) - (\hat{q}_{2t}^a - \hat{q}_{1t}^a) \right] = E_t \hat{r}_{2,t+1}^k \]
The Mechanism

- Equilibrium price level and nominal interest rate

\[ \hat{p}_{it} = \hat{p}_{i,t-1} + E_t \left[ \sum_{j=1}^{\infty} \left( \frac{1}{\tilde{\nu}_\pi} \right)^j \hat{r}_{i,t+j}^k \right] - \tilde{\nu}_y E_t \left[ \sum_{j=1}^{\infty} \left( \frac{1}{\tilde{\nu}_\pi} \right)^j \hat{Y}_{i,t+j-1} \right] \]

\[ \hat{R}_{it} = E_t \left[ \sum_{j=1}^{\infty} \left( \frac{1}{\tilde{\nu}_\pi} \right)^{j-1} \hat{r}_{i,t+j}^k \right] - \tilde{\nu}_y E_t \left[ \sum_{j=1}^{\infty} \left( \frac{1}{\tilde{\nu}_\pi} \right)^j \hat{Y}_{i,t+j} \right] \]

- No arbitrage between real domestic and international assets

\[ E_t \hat{r}_{i,t+1}^k = \hat{r}_t + E_t \hat{q}_{i,t+1}^a - \hat{q}_{it}^a \]

No arbitrage in international capital flows

\[ E_t \hat{r}_{1,t+1}^k + \left[ E_t (\hat{q}_{2,t+1}^a - \hat{q}_{1,t+1}^a) - (\hat{q}_{2t}^a - \hat{q}_{1t}^a) \right] = E_t \hat{r}_{2,t+1}^k \]
Responses for Different Weights on GDP in the Taylor Rule

\[ \nu_y = 0.125 \quad \nu_y = 0 \quad \nu_y = 0.03 \]

Nominal interest rate

\[ \nu_y = 0.125 \quad \nu_y = 0 \quad \nu_y = 0.03 \]
Domestic Nominal Business Cycle

Nominal interest rate

Price level