International Business Cycles and Financial Frictions

Wen Yao

Bank of Canada
Motivation

- Output, investment and employment move together across countries in the data.

<table>
<thead>
<tr>
<th>Cross-country Correlations</th>
</tr>
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<tbody>
<tr>
<td>Output</td>
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<tr>
<td>0.61</td>
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</table>

- However, standard models cannot generate these strong positive business cycle correlations.

- Given the recent global financial crisis and the global recession, my focus is on how financial frictions can produce a positive transmission of business cycles across countries.
Story of Financial Frictions

Leverage constraints increase the business cycle correlations.

- Negative shock hits the US.
- Asset (mortgage-backed security) price in the US falls.
- In both countries, investors’ leverage constraints are tightened.
- Borrowing is reduced globally.
- Investment declines. Asset price in Europe also falls.
- Another round of decline in investment and output is triggered.
- A feedback loop is established.
What Do I Do?

• Basic model structure
  • Two-country model with financial frictions in the debt market
  • Business cycles are driven by technology shocks
  • Investors hold capital in both countries
  • Investors face leverage constraints on debt
  • Endogenous labor supply
  • Capital accumulation

• Calibrate the model to the US and the rest of the world.

• Financial frictions help the model to match the positive business cycle co-movements in the data.
Summary of Results
What do I find?

- With financial frictions the model can account for the positive and sizable business cycle correlations.
  - The model produces more than half of the output correlation.
  - The model produces most of the investment correlation.
  - The model produces a positive employment correlation.
- Business cycles are more synchronized when the investor has more foreign capital exposure.
What have others done?

- Open economy model with financial frictions: no foreign capital exposure
  - Gertler, Gilchrist and Natalucci (2007)
  - Faia (2007)

- Theoretical open economy model with portfolio choice: no endogenous labor and investment
  - Devereux and Yetmann (2010)

- Computation of portfolio choice in general equilibrium model
  - Heathcote and Perri (2009)
Two-country open economy model with financial frictions

- Countries are symmetric
- One good
- Two types of agents
- Labor is internationally immobile
- Capital in each country can be owned by domestic and foreign investors
- Financial frictions exist in the debt market
Investors

- Buy capital installed in both home and foreign countries
- Receive risky returns from capital
- Borrow from domestic savers to finance capital holdings
- Work at the market production firm

Savers

- Only buy capital from the domestic market
- Engaged in home production
- Lend to investor at risk free rate
- Savers are more patient than investors
- Work at the market production firm
Financial Frictions


- Leverage constraint limits his debt to be less than a fraction of the total value of his capital.
Model

Firms and Capital Producer

Market production firms

- Cobb-Douglas production technology
- Rent capital from domestic and foreign investors
- Rent labor from domestic investors and savers

Capital producer

- Production input: capital and final goods
- Production output: new capital
- Investment adjustment cost
Investor

- Country 1 investor chooses \(c_{1t}, l_{1t}, k_{11,t+1}, k_{12,t+1}, B_{1,t+1}\) to solve

\[
\max \ E_t \sum_{t=0}^{\infty} \beta_t^t U(c_{1t}, l_{1t})
\]

\[
c_{1t} + q_{1t} k_{11,t+1} + q_{2t} k_{12,t+1} = w_{1t} l_{1t} + q_{1t} B_{1,t+1} - B_{1,t}
\]

\[+ (1 - \delta)q_{1t}^k + R_{1t}^k) k_{11,t} + (1 - \delta)q_{2t}^k + R_{2t}^k) k_{12,t}\]

- \(k_{i,j,t}\) : capital in country j held by country i’s investor
- \(q_{1t}^k (q_{2t}^k)\) : price of capital in country 1 (country 2)
- \(q_{1t}^b\) : price of bond in country 1
Investor

- Greenwood-Hercowitz-Huffman (GHH) Preferences

\[ U(c_t^I, l_t^I) = \frac{1}{1 - \gamma} \left( c_t^I - \psi_t^I \frac{(l_t^I)^{1+\theta}}{1 + \theta} \right)^{1-\gamma} \]

- Endogenous discount factor \( \beta(C_{it}^I, L_{it}^I) \)

- Total debt is restricted to be smaller than \( \kappa \) times the market value of capital holdings, where \( \kappa < 1 \).

\[ B_{1t+1}^I \leq \kappa(q_{1t}k_{11,t+1}^I + q_{2t}k_{12,t+1}^I) \]
Saver

- Saver chooses $c_{1t}^{SM}, c_{1t}^{SH}, l_{1t}^{SM}, l_{1t}^{SH}, k_{11t+1}, B_{1t+1}^{S}$ to maximize

$$\max E_t \sum_{t=0}^{\infty} \beta^t_S U(c_{1t}^{SM}, c_{1t}^{SH}, l_{1t}^{SM}, l_{1t}^{SH})$$

$$c_{1t}^{SM} + q_{1t}^k k_{11,t+1}^{S} = w_{1t} l_{1t}^{SM} + (1 - \delta) q_{1t}^k k_{11,t}^{S} + q_{1t}^b B_{1t+1}^{S} - B_{1t}^{S}$$

$$c_{1t}^{SH} = G(k_{11t}^{S}, l_{1t}^{SH})$$

- Endogenous discount factor $\beta(C_{it}^{S}, L_{it}^{S})$
Saver

- Saver also has GHH preference

\[
u \left( c_{it}^{SM}, c_{it}^{SH}, l_{it}^{SM}, l_{it}^{SH} \right) = \frac{1}{1 - \gamma} \left( c_{it}^{S} - \psi^{S} \frac{(l_{it}^{S})^{1+\theta}}{1 + \theta} \right)^{1-\gamma}\]

- Elasticity of substitution between \( c_{it}^{SM} \) and \( c_{it}^{SH} \) is \( 1/(1 - e) \)

\[
c_{it}^{S} = \left( \lambda \left( c_{it}^{SM} \right)^{e} + (1 - \lambda) \left( c_{it}^{SH} \right)^{e} \right)^{1/e}\]

- Perfect substitution between market and home labor

\[
l_{it}^{S} = l_{it}^{SM} + l_{it}^{SH}\]
Capital Producer

- Capital producer produces new capital using final good and currently installed capital

\[ \Pi_{i,t} = q_{i,t}^k k_{i,t+1} - q_{i,t}^k (1 - \delta) k_{i,t} - i_{i,t} \]

- Capital producer uses CRTS technology with adjustment cost

\[ k_{i,t+1} = (1 - \delta) k_{i,t} + \phi \left( \frac{i_{i,t}}{k_{i,t}} \right) k_{i,t} \quad i = 1, 2 \]

where

\[ \phi \left( \frac{i_{i,t}}{k_{i,t}} \right) = \frac{g_1}{1 - \pi} \left( \frac{i_{i,t}}{k_{i,t}} \right)^{1-\pi} + g_2 \]

- Price of new capital is

\[ q_{i,t}^k = \frac{1}{\phi'(i_{i,t} / k_{i,t})} \]
Market Production and Home Production

- Market production firms only live for one period

\[ F(z_{1t}, k_{1t}^M, l_{1t}^M) = e^{z_{1t}} \left( k_{1t}^M \right)^{\alpha_1} \left( l_{1t}^M \right)^{1-\alpha_1} \]

- Capital and labor used in the market production are

\[ k_{1t}^M = n(k_{11t}^I + k_{21t}^I) \]
\[ l_{1t}^M = nl_{1t}^I + (1 - n)l_{1t}^{SM} \]

- Home Production

\[ G(k_{11,t}^S, l_{1t}^{SH}) = (k_{11,t}^S)^{\alpha_2}(l_{1t}^{SH})^{1-\alpha_2} \]

- Total capital in country \( i \)

\[ k_{1t} = nk_{11t}^I + nk_{21t}^I + (1 - n)k_{11t}^S \]
\[ k_{2t} = nk_{12t}^I + nk_{22t}^I + (1 - n)k_{22t}^S \]
Technology

- Technology Process

\[
\begin{bmatrix}
z_{1t} \\
z_{2t}
\end{bmatrix} =
\begin{bmatrix}
\rho_1 & \rho_2 \\
\rho_2 & \rho_1
\end{bmatrix}
\begin{bmatrix}
z_{1t-1} \\
z_{2t-1}
\end{bmatrix} +
\begin{bmatrix}
\epsilon_{1t} \\
\epsilon_{2t}
\end{bmatrix}
\]

- Covariance

\[
\begin{bmatrix}
\epsilon_{1t} \\
\epsilon_{2t}
\end{bmatrix} \sim \mathcal{N}(0, \Sigma) \text{ with correlation matrix } \begin{bmatrix}
\sigma_1 & \phi \\
\phi & \sigma_2
\end{bmatrix}
\]
Market Clearing

• Good Market

\[ nc_{1t}^I + (1 - n)c_{1t}^{SM} + nc_{2t}^I + (1 - n)c_{2t}^{SM} + i_1t + i_2t = F(k_{1t}^M, l_{1t}^M) + F(k_{2t}^M, l_{2t}^M) \]

• Bond Market

\[ nB_{1t+1}^I + (1 - n)B_{1t+1}^S = 0 \]

\[ nB_{2t+1}^I + (1 - n)B_{2t+1}^S = 0 \]
Leverage constraints increase the business cycle correlations.

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• Calibration
• Simulation Results
• Impulse Response Functions
• Sensitivity Analysis
### Exogenously Chosen

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<th>Value</th>
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<tbody>
<tr>
<td>(\gamma)</td>
<td>2</td>
<td>inverse of IES</td>
<td>convention</td>
</tr>
<tr>
<td>(\theta)</td>
<td>0.6</td>
<td>controls elasticity of labor supply</td>
<td>Greenwood et al. (1988)</td>
</tr>
<tr>
<td>(e)</td>
<td>0.9</td>
<td>ES between goods</td>
<td>Benhabib et al. (1991)</td>
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### Calibrated to Observations

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</thead>
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<tr>
<td>(\omega^I)</td>
<td>0.112</td>
<td>controls investor’s discount factor</td>
<td>risk free rate: 4%</td>
</tr>
<tr>
<td>(\omega^S)</td>
<td>0.039</td>
<td>controls saver’s discount factor</td>
<td>interest premium: 2%</td>
</tr>
<tr>
<td>(\psi^I)</td>
<td>3.08</td>
<td>controls level of investor’s labor</td>
<td>investor’s market hour: 0.33</td>
</tr>
<tr>
<td>(\psi^S)</td>
<td>1.32</td>
<td>controls level of saver’s labor</td>
<td>saver’s market hour: 0.33</td>
</tr>
<tr>
<td>(\lambda)</td>
<td>0.57</td>
<td>share of market good consumption</td>
<td>saver’s home hour: 0.25</td>
</tr>
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- endogenous discount factor
Calibration

- Production and other parameters

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<tr>
<td>$\alpha_1$</td>
<td>0.29</td>
<td>capital share of market production</td>
<td>market capital to output ratio: 7</td>
</tr>
<tr>
<td>$\alpha_2$</td>
<td>0.40</td>
<td>capital share of home production</td>
<td>home capital to output ratio: 5</td>
</tr>
<tr>
<td>$\delta$</td>
<td>0.025</td>
<td>depreciation</td>
<td>annual depreciation: 10%</td>
</tr>
<tr>
<td>$\tau$</td>
<td>0.091</td>
<td>iceberg cost</td>
<td>home bias: 75%</td>
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<td>$\pi$</td>
<td>0.25</td>
<td>investment adjustment cost</td>
<td>Bernanke et al. (1999)</td>
</tr>
<tr>
<td>$\kappa$</td>
<td>2/3</td>
<td>controls leverage ratio</td>
<td>Dedola et al. (2010)</td>
</tr>
<tr>
<td>$n$</td>
<td>0.5</td>
<td>measure of investors</td>
<td>SCF (2007)</td>
</tr>
</tbody>
</table>
Calibration

- Technology Process

\[
\begin{bmatrix}
  z_{1t} \\
  z_{2t}
\end{bmatrix} =
\begin{bmatrix}
  0.91 & 0 \\
  0 & 0.91
\end{bmatrix}
\begin{bmatrix}
  z_{1t-1} \\
  z_{2t-1}
\end{bmatrix} +
\begin{bmatrix}
  \epsilon_{1t} \\
  \epsilon_{2t}
\end{bmatrix}
\]

- Covariance

\[
\begin{bmatrix}
  \epsilon_{1t} \\
  \epsilon_{2t}
\end{bmatrix} \sim N(0, \Sigma) \text{ with correlation matrix }
\begin{bmatrix}
  0.006 & 0.25 \\
  0.25 & 0.006
\end{bmatrix}
\]

- Parameters are taken from Heathcote and Perri (2004).
Simulation Results

Benchmark

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<thead>
<tr>
<th></th>
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<td>(A) Standard Deviation in %</td>
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<tr>
<td>Output</td>
<td>2.06</td>
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<tr>
<td>Net Export</td>
<td>0.39</td>
<td>0.28</td>
<td>0.21</td>
<td>0.16</td>
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<td>(B) Standard Deviation relative to Output</td>
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<td>1.07</td>
<td>1.01</td>
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<td>0.55</td>
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<td>(D) Cross-Country Correlations</td>
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## (A) Standard Deviation in %

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## (B) Standard Deviation relative to Output

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## (C) Cross Correlation with Output

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Impulse Response Functions
Benchmark

Country 1: Investment

Country 1: Price

Country 1: Debt

Country 2: Investment

Country 2: Price

Country 2: Debt
Impulse Response Functions

Benchmark

Country 1: output

Country 1: consumption

Country 1: market labor

Country 2: output

Country 2: consumption

Country 2: market labor
With financial frictions the model can account for the positive and sizable business cycle correlations.

- The model produces more than half of the output correlation.
- The model produces most of the investment correlation.
- The model produces a positive employment correlation.

Business cycles are more synchronized when the investor has more foreign capital exposure.
Sensitivity Analysis

I explore the robustness of the result by changing some key parameters of the model

- Model 1: Higher leverage ratio
- Model 2: Different elasticity between two goods
- Model 3: Different investment adjustment cost
# Simulation Results

## Sensitivity Analysis - Leverage

<table>
<thead>
<tr>
<th></th>
<th>Data</th>
<th>Benchmark Model</th>
<th>Sensitivity Test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td>High Leverage</td>
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<tr>
<td><strong>(A) Standard Deviation in %</strong></td>
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<tr>
<td>Output</td>
<td>2.06</td>
<td>1.84</td>
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<tr>
<td>Net Export</td>
<td>0.39</td>
<td>0.21</td>
<td>0.24</td>
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<tr>
<td><strong>(B) Standard Deviation relative to Output</strong></td>
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<tr>
<td>Consumption</td>
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<td>1.01</td>
<td>1.09</td>
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<tr>
<td>Investment</td>
<td>2.82</td>
<td>0.67</td>
<td>0.53</td>
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<tr>
<td>Labor</td>
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<td>0.72</td>
</tr>
<tr>
<td><strong>(C) Cross Correlation with Output</strong></td>
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<td></td>
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<tr>
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<td>0.82</td>
<td>0.99</td>
<td>0.99</td>
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<tr>
<td>Labor</td>
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<td>1</td>
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<tr>
<td>Investment</td>
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<td>0.94</td>
<td>0.92</td>
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<tr>
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<td>0.54</td>
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<tr>
<td><strong>(D) Cross-Country Correlations</strong></td>
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<tr>
<td>Consumption</td>
<td>0.44</td>
<td>0.45</td>
<td>0.52</td>
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<tr>
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<tr>
<td>Investment</td>
<td>0.46</td>
<td>0.46</td>
<td>0.61</td>
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<tr>
<td>Labor</td>
<td>0.43</td>
<td>0.34</td>
<td>0.41</td>
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## Simulation Results

### Sensitivity Analysis - Elasticity of Substitution between Goods

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<th>Sensitivity Test $e = 0.5$</th>
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<tr>
<td>Output</td>
<td>2.06</td>
<td>1.84</td>
<td>1.51</td>
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<tr>
<td>Net Export</td>
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<td>0.21</td>
<td>0.22</td>
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<tr>
<td><strong>(B) Standard Deviation relative to Output</strong></td>
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<tr>
<td>Consumption</td>
<td>0.63</td>
<td>1.01</td>
<td>0.86</td>
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<tr>
<td>Investment</td>
<td>2.82</td>
<td>0.67</td>
<td>0.86</td>
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<tr>
<td>Labor</td>
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<td>0.71</td>
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<td><strong>(C) Cross Correlation with Output</strong></td>
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<td>0.82</td>
<td>0.99</td>
<td>0.99</td>
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<td>Labor</td>
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<td>1</td>
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<tr>
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<td>0.97</td>
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<td>Net Export</td>
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<td>0.59</td>
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<td><strong>(D) Cross-Country Correlations</strong></td>
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<td>Consumption</td>
<td>0.44</td>
<td>0.45</td>
<td>0.46</td>
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<td>Output</td>
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<td>0.31</td>
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<td>Labor</td>
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<td>0.34</td>
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## Simulation Results

### Sensitivity Analysis - Investment Adjustment Cost

<table>
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<td>$\pi = 0.5$ $\pi = 100$</td>
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<tr>
<td><strong>(A) Standard Deviation in %</strong></td>
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<tr>
<td>Output</td>
<td>2.06</td>
<td>1.94</td>
</tr>
<tr>
<td>Net Export</td>
<td>0.39</td>
<td>0.26</td>
</tr>
<tr>
<td></td>
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<tr>
<td><strong>(B) Standard Deviation relative to Output</strong></td>
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<td></td>
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<tr>
<td>Consumption</td>
<td>0.63</td>
<td>1.06</td>
</tr>
<tr>
<td>Investment</td>
<td>2.82</td>
<td>0.45</td>
</tr>
<tr>
<td>Labor</td>
<td>0.67</td>
<td>0.72</td>
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<tr>
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<tr>
<td><strong>(C) Cross Correlation with Output</strong></td>
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<tr>
<td>Consumption</td>
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<td>0.99</td>
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<tr>
<td>Labor</td>
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<tr>
<td>Investment</td>
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<td>0.94</td>
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<tr>
<td>Net Export</td>
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<td>0.53</td>
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<td>0.46</td>
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<td>Labor</td>
<td>0.43</td>
<td>0.34</td>
</tr>
</tbody>
</table>
Conclusions

- I studied a two-country international business cycle model with financial frictions.
  - The technology shock is amplified and spilled over to another country through leverage constraint.

- Financial frictions have an important role in shaping the business cycle comovements.
  - Output comovement increases in the presence of financial frictions.
  - Investment and employment comovements are improved.