International Business Cycles and Financial Frictions

Wen Yao

Bank of Canada

Motivation

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

Cross-country Correlations

Output	Investment	Labor
0.61	0.46	0.43

- However, standard models can not 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.

result

Literature

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)

Model

Environment

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

Model

Agents

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

Model

Financial Markets

Financial Frictions

- Investor faces leverage constraint of Kiyotaki and Moore (1997) type.
- 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 $c^{\mathcal{I}}_{1t}, l^{\mathcal{I}}_{1t}, k^{\mathcal{I}}_{11,t+1}, k^{\mathcal{I}}_{12,t+1}, B^{\mathcal{I}}_{1,t+1}$ to solve

$$\max E_t \sum_{t=0}^{\infty} \beta^t_{\mathcal{I}} U(c^{\mathcal{I}}_{1t}, l^{\mathcal{I}}_{1t})$$

$$c^{\mathcal{I}}_{1t} + q^k_{1t} k^{\mathcal{I}}_{11,t+1} + q^k_{2t} k^{\mathcal{I}}_{12,t+1} = w_{1t} l^{\mathcal{I}}_{1t} + q^b_{1t} B^{\mathcal{I}}_{1t+1} - B^{\mathcal{I}}_{1t}$$

$$+((1-\delta) q^k_{1t} + R^k_{1t}) k^{\mathcal{I}}_{11,t} + ((1-\delta) q^k_{2t} + R^k_{2t}) k^{\mathcal{I}}_{12,t}$$

- $k^{\mathcal{I}}_{i,j,t}$: capital in country j held by country i's investor
- q^k_{1t} (q^k_{2t}) : price of capital in country 1 (country 2)
- q^b_{1t} : price of bond in country 1

Investor

- Greenwood-Hercowitz-Huffman (GHH) Preferences

$$U(c_t^{\mathcal{I}}, l_t^{\mathcal{I}}) = \frac{1}{1-\gamma}\left(c_t^{\mathcal{I}} - \psi^{\mathcal{I}}\frac{(l_t^{\mathcal{I}})^{1+\theta}}{1+\theta}\right)^{1-\gamma}$$

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

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

$$B_{1t+1}^{\mathcal{I}} \leq \kappa(q_{1t}k_{11,t+1}^{\mathcal{I}} + q_{2t}k_{12,t+1}^{\mathcal{I}})$$

Saver

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

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

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

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

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

Saver

- Saver also has GHH preference

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

- 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

$$I_{it}^{S} = I_{it}^{SM} + I_{it}^{SH}$$

Capital Producer

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

$$\Pi_{i,t} = q^k_{i,t} k_{i,t+1} - q^k_{i,t}(1-\delta)k_{i,t} - i_{i,t}$$

- Capital producer uses CRTS technology with adjustment cost

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

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

$$q^k_{i,t} = \frac{1}{\phi'\left(i_{i,t}/k_{i,t}\right)}$$

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

$$k_{1t}^M = n(k_{11t}^{\mathcal{I}} + k_{21t}^{\mathcal{I}})$$

$$l_{1t}^M = n l_{1t}^{\mathcal{I}} + (1-n) l_{1t}^{SM}$$

- 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

$$k_{1t} = n k_{11t}^{\mathcal{I}} + n k_{21t}^{\mathcal{I}} + (1-n) k_{11t}^S$$

$$k_{2t} = n k_{12t}^{\mathcal{I}} + n k_{22t}^{\mathcal{I}} + (1-n) k_{22t}^S$$

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

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

Market Clearing

- Good Market

$$\begin{aligned} & nc_{1t}^{\mathcal{I}} + (1-n)c_{1t}^{SM} + nc_{2t}^{\mathcal{I}} + (1-n)c_{2t}^{SM} + i_{1t} + i_{2t} \\ = \quad & F(k_{1t}^{M}, l_{1t}^{M}) + F(k_{2t}^{M}, l_{2t}^{M}) \end{aligned}$$

- Bond Market

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

$$nB_{2t+1}^{\mathcal{I}} + (1-n)B_{2t+1}^{S} = 0$$

Main Mechanism - Recap

Leverage constraints increase the business cycle correlations.

- Negative technology shock hits the US.
- Asset 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.
- A feedback loop is established.

Roadmap from here on ...

- Calibration
- Simulation Results
- Impulse Response Functions
- Sensitivity Analysis

Calibration

- Preference parameters

Exogenously Choosen

Parameter	Value	Description	Source
γ	2	inverse of IES	convention
θ	0.6	controls elasticity of labor supply	Greenwood et al. (1988)
e	0.9	ES between goods	Benhabib et al. (1991)

Calibrated to Observations

Parameter	Value	Description	Target
ω^I	0.112	controls investor's discount factor	risk free rate: 4%
ω^S	0.039	controls saver's discount factor	interest premium: 2%
ψ^I	3.08	controls level of investor's labor	investor's market hour: 0.33
ψ^S	1.32	controls level of saver's labor	saver's market hour: 0.33
λ	0.57	share of market good consumption	saver's home hour: 0.25

▸ endogenous discount factor

Calibration

- Production and other parameters

Calibrated to Observations

Parameter	Value	Description	Target
α_1	0.29	capital share of market production	market capital to output ratio: 7
α_2	0.40	capital share of home production	home capital to output ratio: 5
δ	0.025	depreciation	annual depreciation: 10%
τ	0.091	iceberg cost	home bias: 75%

Exogenously Choosen

Parameter	Value	Description	Source
π	0.25	investment adjustment cost	Bernanke et al. (1999)
κ	2/3	controls leverage ratio	Dedola et al. (2010)
n	0.5	measure of investors	SCF (2007)

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

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

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

Simulation Results

Benchmark

	Data	Model 1 Unconstrained	Model 2 Constrained 25% Foreign Exposure	Model 3 Constrained 86% Foreign Exposure
(A) Standard Deviation in %				
Output	2.06	2.52	1.84	1.78
Net Export	0.39	0.28	0.21	0.16
(B) Standard Deviation relative to Ouput				
Consumption	0.63	1.07	1.01	0.99
Investment	2.82	0.55	0.67	0.77
Labor	0.67	0.73	0.71	0.71
(C) Cross Correlation with Output				
Consumption	0.82	0.99	0.99	0.98
Labor	0.86	1	1	1
Investment	0.95	0.91	0.94	0.96
Net Export	-0.45	0.54	0.53	0.46
(D) Cross-Country Correlations				
Consumption	0.44	0.28	0.45	0.75
Output	0.61	0.23	0.34	0.52
Investment	0.46	0.76	0.46	0.29
Labor	0.43	0.23	0.34	0.54

back

Simulation Results

Benchmark

	Data	Model 1 Unconstrained	Model 2 Constrained 25% Foreign Exposure	Model 3 Constrained 86% Foreign Exposure
(A) Standard Deviation in %				
Output	2.06	2.52	1.84	1.78
Net Export	0.39	0.28	0.21	0.16
(B) Standard Deviation relative to Ouput				
Consumption	0.63	1.07	1.01	0.99
Investment	2.82	0.55	0.67	0.77
Labor	0.67	0.73	0.71	0.71
(C) Cross Correlation with Output				
Consumption	0.82	0.99	0.99	0.98
Labor	0.86	1	1	1
Investment	0.95	0.91	0.94	0.96
Net Export	-0.45	0.54	0.53	0.46
(D) Cross-Country Correlations				
Consumption	0.44	0.28	0.45	0.75
Output	0.61	0.23	0.34	0.52
Investment	0.46	0.76	0.46	0.29
Labor	0.43	0.23	0.34	0.54

back

Simulation Results

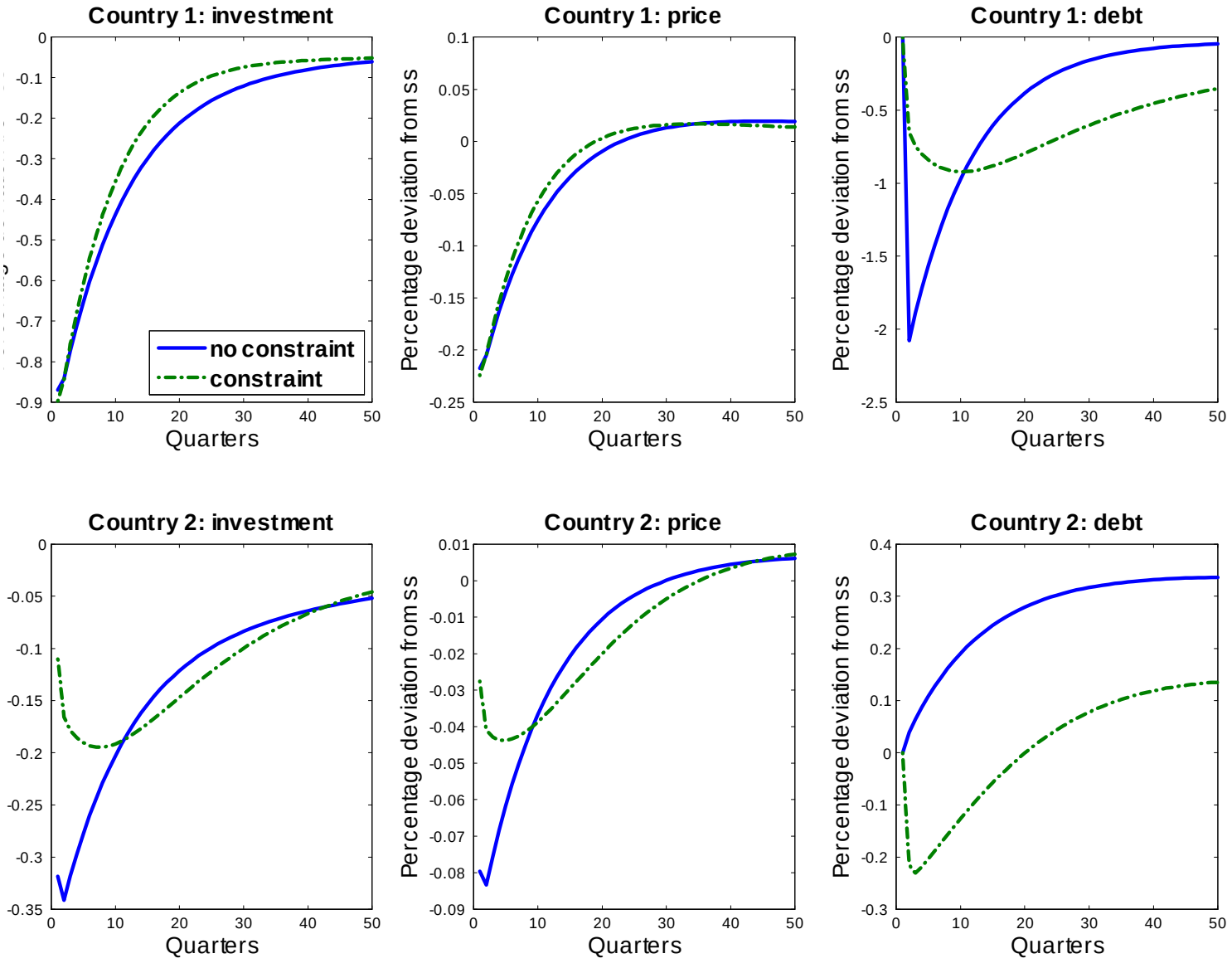
Benchmark

	Data	Model 1 Unconstrained	Model 2 Constrained 25% Foreign Exposure	Model 3 Constrained 86% Foreign Exposure
(A) Standard Deviation in %				
Output	2.06	2.52	1.84	1.78
Net Export	0.39	0.28	0.21	0.16
(B) Standard Deviation relative to Ouput				
Consumption	0.63	1.07	1.01	0.99
Investment	2.82	0.55	0.67	0.77
Labor	0.67	0.73	0.71	0.71
(C) Cross Correlation with Output				
Consumption	0.82	0.99	0.99	0.98
Labor	0.86	1	1	1
Investment	0.95	0.91	0.94	0.96
Net Export	-0.45	0.54	0.53	0.46
(D) Cross-Country Correlations				
Consumption	0.44	0.28	0.45	0.75
Output	0.61	0.23	0.34	0.52
Investment	0.46	0.76	0.46	0.29
Labor	0.43	0.23	0.34	0.54

back

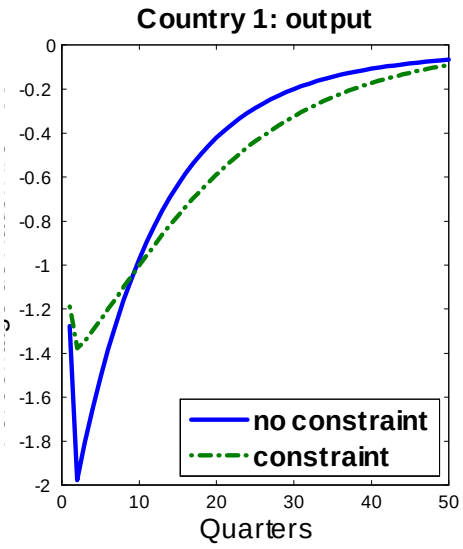
Impulse Response Functions

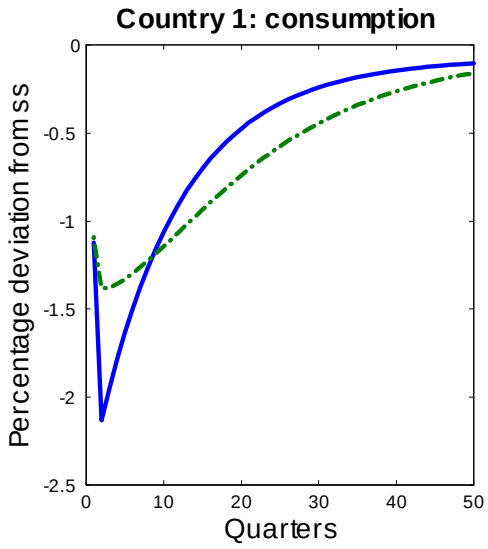
Benchmark

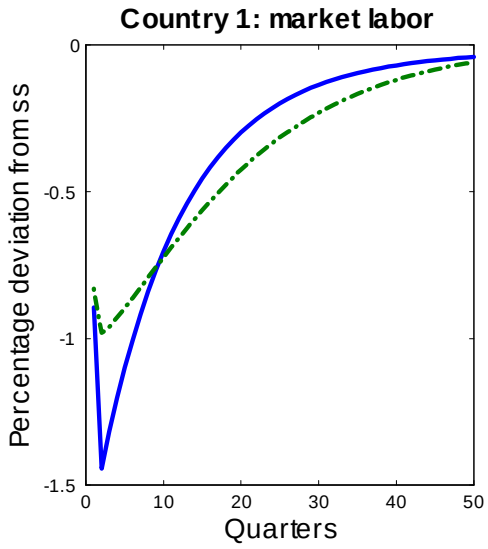


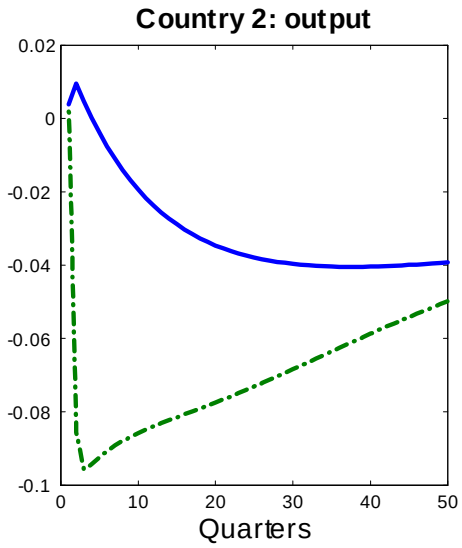
Impulse Response Functions

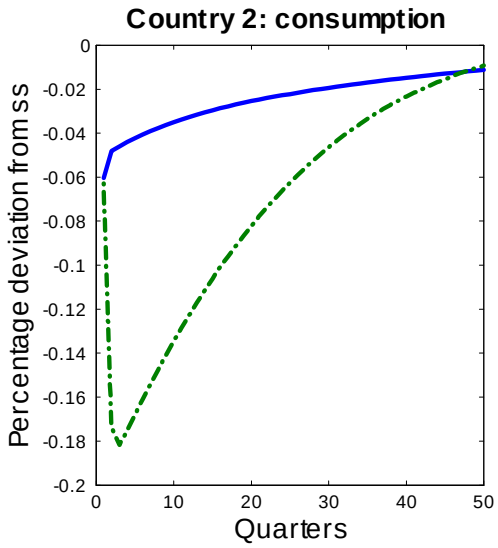
Benchmark

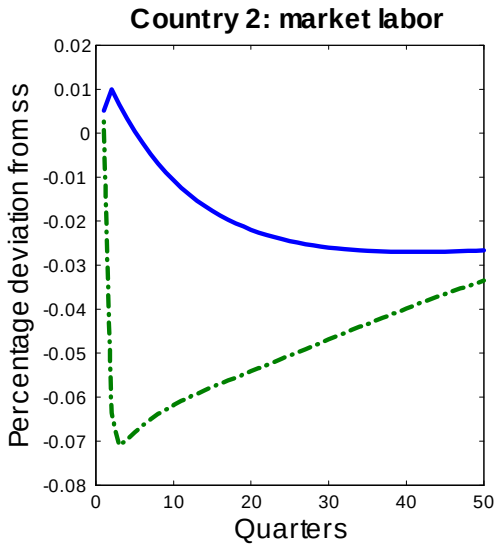






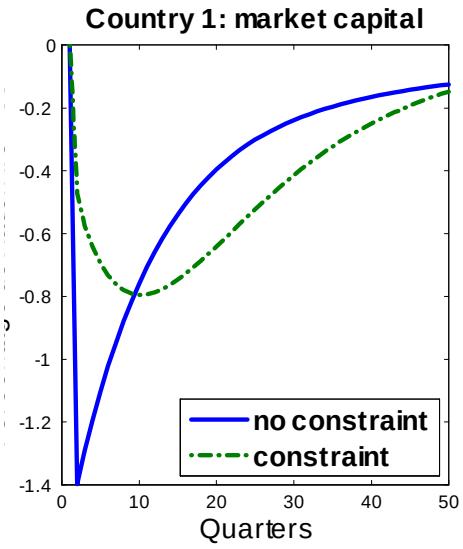


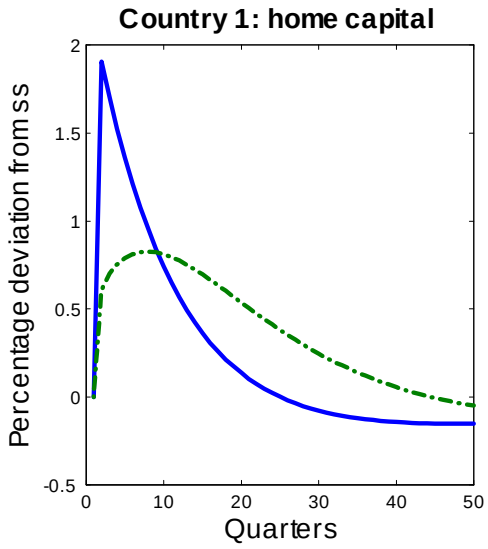


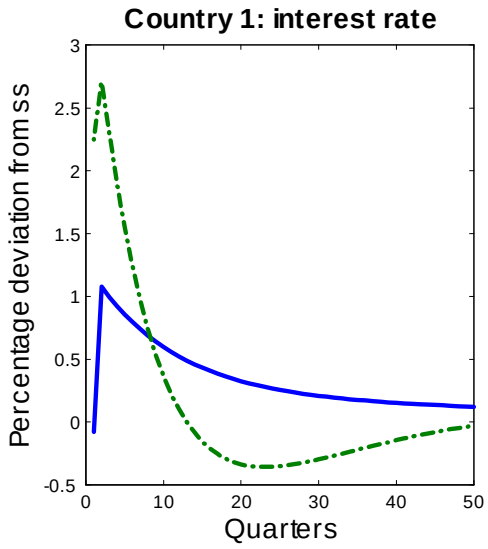


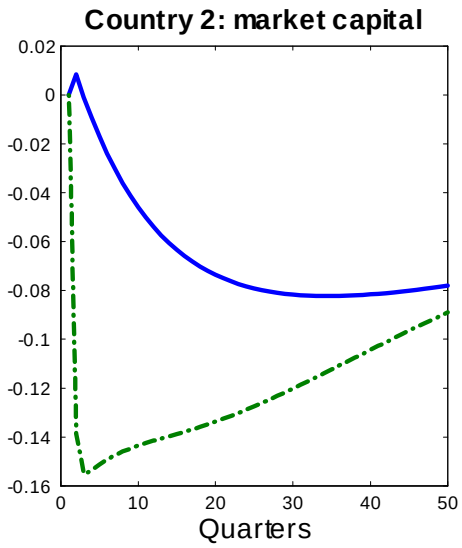
Impulse Response Functions

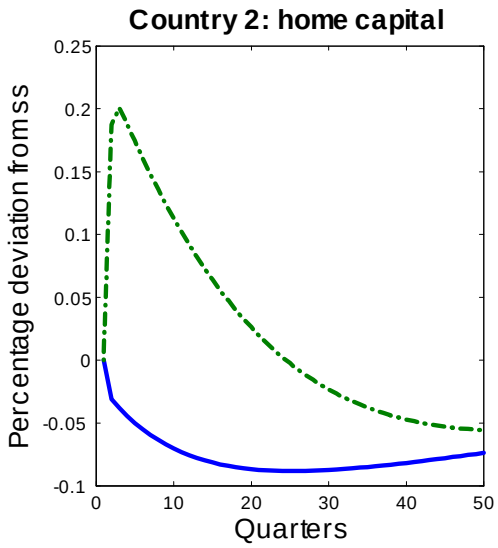
Benchmark

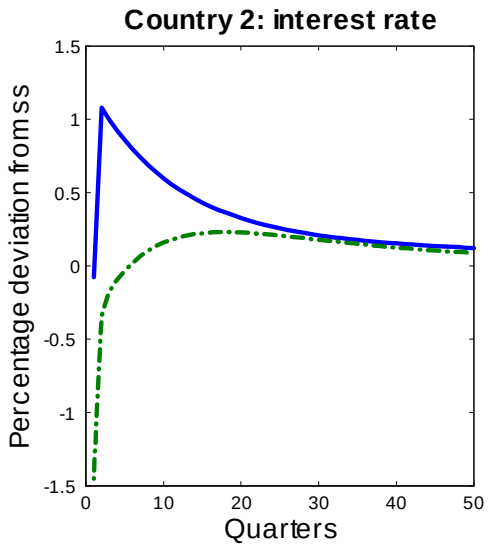






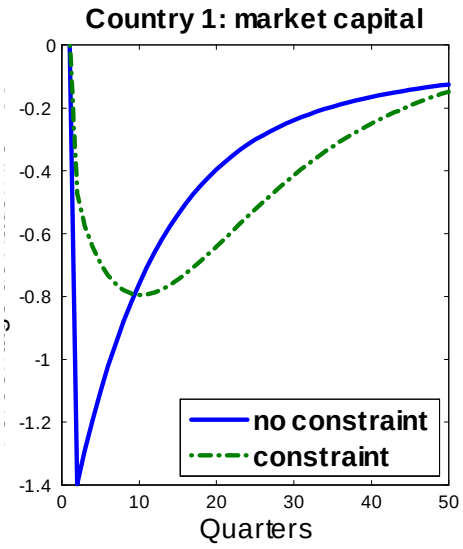


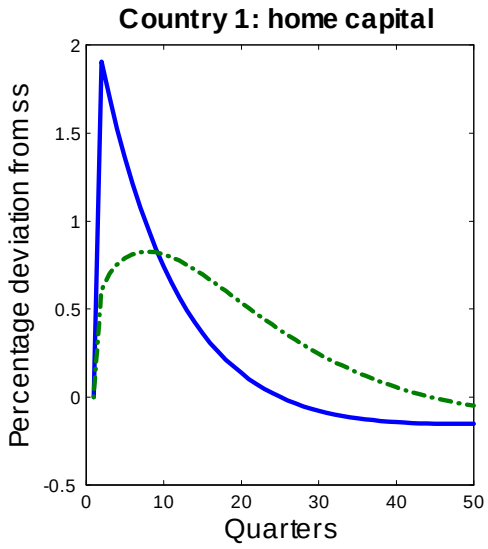


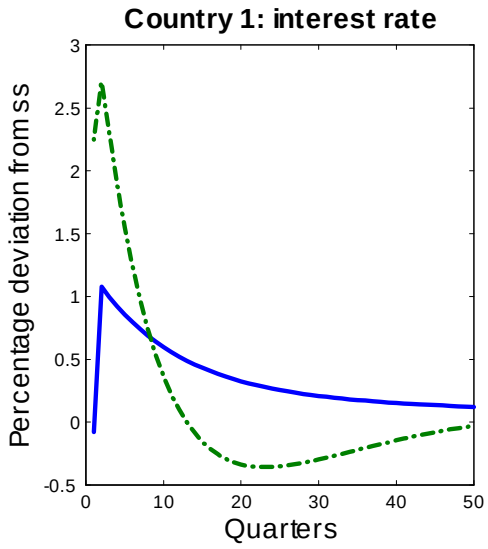


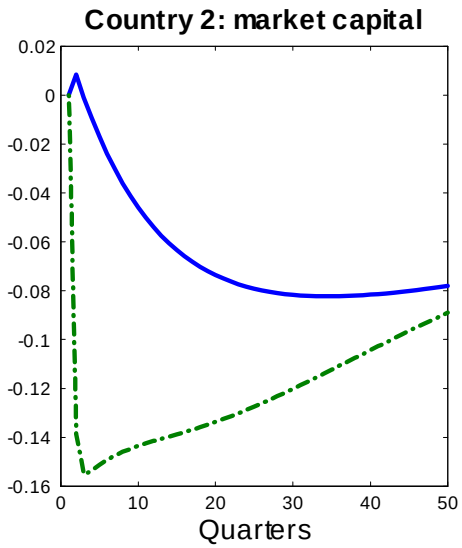
Impulse Response Functions

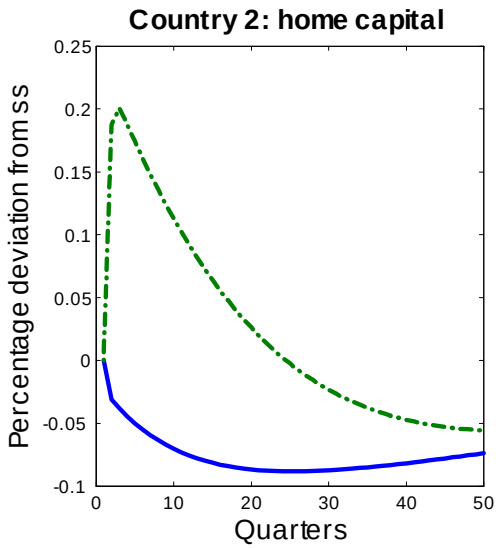
Benchmark

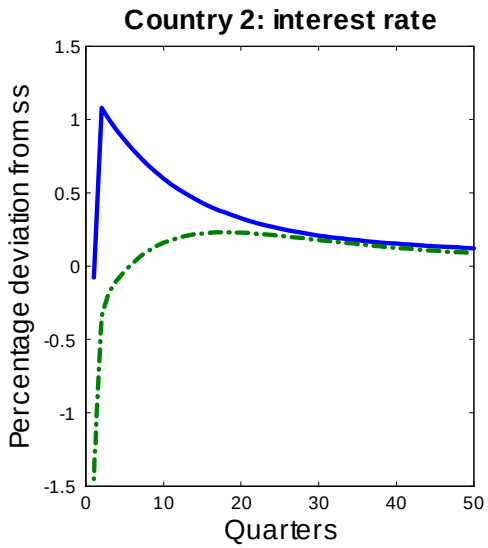












Contribution Recap...

- 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

	Data	Benchmark Model	Sensitivity Test
			High Leverage
(A) Standard Deviation in %			
Output	2.06	1.84	2.18
Net Export	0.39	0.21	0.24
(B) Standard Deviation relative to Ouput			
Consumption	0.63	1.01	1.09
Investment	2.82	0.67	0.53
Labor	0.67	0.71	0.72
(C) Cross Correlation with Output			
Consumption	0.82	0.99	0.99
Labor	0.86	1	1
Investment	0.95	0.94	0.92
Net Export	-0.45	0.53	0.54
(D) Cross-Country Correlations			
Consumption	0.44	0.45	0.52
Output	0.61	0.34	0.41
Investment	0.46	0.46	0.61
Labor	0.43	0.34	0.41

Simulation Results

Sensitivity Analysis - Elasticity of Substitution between Goods

	Data	Benchmark Model $e = 0.9$	Sensitivity Test $e = 0.5$
(A) Standard Deviation in %			
Output	2.06	1.84	1.51
Net Export	0.39	0.21	0.22
(B) Standard Deviation relative to Ouput			
Consumption	0.63	1.01	0.86
Investment	2.82	0.67	0.86
Labor	0.67	0.71	0.57
(C) Cross Correlation with Output			
Consumption	0.82	0.99	0.99
Labor	0.86	1	1
Investment	0.95	0.94	0.97
Net Export	-0.45	0.53	0.59
(D) Cross-Country Correlations			
Consumption	0.44	0.45	0.46
Output	0.61	0.34	0.31
Investment	0.46	0.46	0.62
Labor	0.43	0.34	0.27

▸ Saver's FOC

Simulation Results

Sensitivity Analysis - Investment Adjustment Cost

	Data	Benchmark Model $\pi = 0.25$	Sensitivity Test $\pi = 0.5$	Sensitivity Test $\pi = 100$
(A) Standard Deviation in %				
Output	2.06	1.84	1.94	2.22
Net Export	0.39	0.21	0.26	0.34
(B) Standard Deviation relative to Ouput				
Consumption	0.63	1.01	1.06	1.18
Investment	2.82	0.67	0.45	0.00
Labor	0.67	0.71	0.72	0.72
(C) Cross Correlation with Output				
Consumption	0.82	0.99	0.99	0.99
Labor	0.86	1	1	1
Investment	0.95	0.94	0.95	0.93
Net Export	-0.45	0.53	0.55	0.48
(D) Cross-Country Correlations				
Consumption	0.44	0.45	0.56	0.70
Output	0.61	0.34	0.41	0.53
Investment	0.46	0.46	0.70	0.91
Labor	0.43	0.34	0.42	0.54

Conclusions

- I studied a two-country international business cycle model with financial fricitions.
  - 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.