International Financial Business Cycles∗

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Abstract

Recent international macroeconomics literature on global imbalances explains the U.S. persistent current account deficit and emerging countries’ surplus, i.e., the U.S. is the borrower. Little research has been done on the banking-sector level, where U.S. banks are lenders to banks in emerging countries. We build a two country framework where banks are explicitly modeled to investigate how lending in the banking sector can affect the international macroeconomy during the recent crisis. In steady state, banks in the developing country borrows from the U.S. banks. When the borrowers in the U.S. pay back less than contractually agreed and damage the balance sheet of the U.S. banks, with the presence of bank capital requirement constraint, U.S. banks raise lending rates and decrease the loans made to U.S. borrowers as well as banks in the developing country. The results are a sharp increase in the lending spread, a reduction in output and a depreciation in the real exchange rate of the developing country. They are the experience of many emerging Asian markets following the U.S. financial crisis starting in late 2007. Another feature of our model captures an empirical fact, documented by Devereux and Yetman (2010), that across different economies, countries with lower financial rating can suffer more when the lending country deleverages.

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1 Introduction

International macroeconomics literature on global imbalances explains why the U.S. runs a persistent current account deficit. While the U.S. is the net borrower at the country level, at the banking-sector level, this is not necessary the case. U.S. banks, and banks in other developed economies, are net lenders to banks in emerging Asian markets (EAM). At around late 2007, beginning of 2008, when losses in the mortgage market begins to damage U.S. banks’ balance sheets (Figure 1 and 2), U.S. banks deleverage and reduce deposits and credits (Figure 3). Not only do they contract loans made to U.S. borrowers, they contract loans made to foreign borrowing banks as well. Figure 4 documents external (cross-border) assets of banks in developed economies and Figure 5 documents external liabilities of banks in EAM. With the exception of Japan, who was little exposed to U.S. Mortgage Backed Securities (MBS), all major developed economies show significant contractions in banks’ external assets, which result in significant contractions in EAM banks’ external liabilities\(^1\). The documented contraction in international inter-bank lending was followed by the worldwide drop in GDP growth, both among the developed world (Figure 6) and the developing world (Figure 7). These empirical evidence highlight the importance of the banking system in international transmission of shocks.

The recent financial crisis in the U.S. was characterized by decline in asset prices, disruption in the loan market, sharp increase in interest rate spread and a large drop in GDP. One thing many scholars have agreed is the banking system plays a vital role in this crisis. There is a number of recent working papers that include bank in a closed economy DSGE model to model the recent crisis in the U.S.: Kiyotaki and Gertler (2010), Iacoviello (2010), a series of papers by Ali Dib (2010) and others. Recent development in international macroeconomics literature investigates the effect of the financial linkage that spread the U.S. mortgage crisis worldwide. Devereux and Yetman (2010), van Wincoop (2011) build international portfolio models where leveraged investor in one country holds the financial asset in the other country. Consequently, any shock that affects the domestic country asset prices will affect the foreign investor’s balance sheet and spread to the foreign economy. Kollman (2011), Ueda (2010) and Kalemli-Ozcan, Papaioannou and Perri (2011) build international business cycles model with banks. In these papers, entrepreneurs in two countries share a common lender(s). Any shock that hits one

\(^{1}\text{Kamin and DeMarco 2010 document that the majority of foreign exposure to U.S. MBS are of European Banking Centers.}\)
economy will affect the common lender(s) and thus, its (their) borrowers. While both of these features can be true among the developed world, i.e., U.S. and the Euro Area, they are not the best to describe the recent crisis for the EAM. Contrary to the large portfolio position of European banks in U.S. MBS, banks in EAM have no or very little exposure to the U.S. MBS and firms in these countries have little direct access to foreign bank credits.

We would like to build a two country model with the banking system that plays an important role in international transmission of shock, which has been largely agreed to be the main cause of the recent crisis. Our model is built upon the closed economy version in Iacoviello (2010). In steady state, banks in the developing country (EAM/domestic country) borrow from banks in the developed country (the U.S./foreign country). When some borrowers in the U.S. pay back less than contractually agreed, with the presence of capital requirement constraint, U.S. banks cut back on lending to U.S. borrowers as well as EAM banks and raise the inter-bank lending rate. Domestic banks now face more expensive and less availability of foreign credit, and will reduce loans made to domestic borrowers. The financial (repayment) shock in the U.S. is transmitted across country via the banking system.

In another exercise, we investigate the behavior of the model under permanent and temporary shocks to the weight of domestic bank loan in the foreign bank’s capital requirement constraint. The permanent shock can be interpreted as a change in bank regulation, such as moving from Basel I to Basel II. A temporary shock can be interpreted as an exogenous drop in domestic banks’ credit ratings. The results for these shocks are reductions in home output, investment and consumption; and a depreciation of home real exchange rate.

use the data from nationwide and local banks in Japan to test whether banking integration plays an important role in transmitting financial shocks across geographical boundaries. They found that nationwide banks do indeed transmit financial shocks originated from major cities to smaller local economies. The results of our model under different weights of interbank loan in the capital requirement constraint suggests that across countries, lower rated economies will suffer more when U.S. banks deleverage. This is consistent with empirical evidence for the recent crisis, documented by Devereux and Yetman (2010).

2 The Model

1There are two countries: the domestic country (EAM) and the foreign country (U.S.). In each country, there are five types of agents: patient households, impatient households, entrepreneurs, firms and banks. There are two sectors in the economy: tradable good sector and non-tradable good sector.

Both patient and impatient households (HHs) work for firms in tradable and non-tradable sectors. They earn wage income and consume tradable goods, non-tradable goods and housing. Patient HHs supply deposits for banks and earn a return from the deposits. Impatient HHs, on the other hand, borrow from banks to consume. They can only borrow up to a fraction of the value of their collateral (house).

Domestic bankers take the deposit from domestic depositors and can also borrow in the international inter-bank market. They can only borrow up to a fraction of the value of their capital. They pay a return for the fund they borrow and lend it to domestic borrowers for a higher return. Foreign bankers take the deposit from foreign depositors. They lend out to foreign borrowers and domestic bankers. Domestic and foreign bankers face capital requirement constraint.

Entrepreneurs accumulate physical capital used in both tradable and nontradable sectors. They finance their investment with income from capital rental and bank loan, which is subject to a collateral debt constraint.

1Much of the model’s features are similar to those of Iacoviello 2010 closed economy model.
Firms in tradable and nontradable sectors use capital and labor to produce goods. They pay wages to HHs.

2.1 Consumption Basket

Consumers’ consumption aggregate is given by: $c_t = \left[ (c_T^N)^\omega + (c_T^T)^\omega \right]^{\frac{1}{\omega}}$, where $c^T$ and $c^N$ are tradable and non-tradable consumptions. The corresponding price index is $P_t = \left[ (P_T^N)^{1-\omega} + (P_T^T)^{1-\omega} \right]^{\frac{1}{1-\omega}}$, where $P^T$ and $P^N$ are tradable and non-tradable price indices. The consumption aggregate and price indices for the foreign economy are identical. We denote the price of non-tradable (tradable) relative to the price of consumption baskets as $p_t^N$ ($p_t^T$).

2.2 Patient HHs

A continuum of domestic patient HHs deposit $d_t$, consume composite good $c_{p,t}$ and housing $h_{p,t}$, and supply labor to tradable, $n_{p,t}^T$, and nontradable, $n_{p,t}^N$, sectors. They earn wage income and return from their deposits. They maximize the infinite sum of utilities:

$$\max_{c_{p,t}, h_{p,t}, n_{p,t}^N, n_{p,t}^T, d_t} E_0 \sum_{t=0}^{\infty} \beta^t_p \left[ \ln c_{p,t} + \nu \ln h_{p,t} + \tau_p \ln (1 - n_{p,t}^N - n_{p,t}^T) \right]$$

subject to budget constraint:

$$c_{p,t} + d_t + q_t \Delta h_{p,t} = R_{d,t} d_{t-1} + w_{p,t}^N n_{p,t}^N + w_{p,t}^T n_{p,t}^T.$$ (1)

$R_{d,t}$ is the return from the deposits and $q_t$ is the price of house. $w_{p,t}^N$ and $w_{p,t}^T$ are wages from nontradable and tradable sectors respectively. Their first order conditions are:
\[
\frac{1}{c_{p,t}} = \beta_p E_t \left( \frac{R_{d,t+1}}{c_{p,t+1}} \right) \tag{2}
\]
\[
\frac{q_t}{c_{p,t}} = \frac{\nu}{h_{p,t}} + \beta_p E_t \left( \frac{q_{t+1}}{c_{p,t+1}} \right) \tag{3}
\]
\[
\frac{w_{N,t}^p}{c_{p,t}} = \frac{\tau_p}{1 - n_{N,t}^p - n_{N,t}} \tag{4}
\]
\[
\frac{w_{T,t}^p}{c_{p,t}} = \frac{\tau_p}{1 - n_{T,t}^p - n_{T,t}} \tag{5}
\]

Foreign patient HHs optimization problem are identical and indexed with *.

2.3 Impatient HHs

Domestic impatient HHs also consume goods and housing, and supply labor. \( c_{i,t}, h_{i,t}, n_{i,t}^N, n_{i,t}^T \) are impatient HHs’ consumptions, houses, labor supply to nontradable and tradable sectors. Unlike patient HHs, however, they borrow money from banks, \( l_{i,t}, \) to finance consumption. They pay interest \( R_{i,t} \) on the loan and can only borrow up to the value of their house. Their maximization problem is:

\[
\max_{c_{i,t}, h_{i,t}, n_{i,t}^N, n_{i,t}^T, l_{i,t}} \sum_{t=0}^{\infty} \beta_i^t \left[ \ln c_{i,t} + \nu \ln h_{i,t} + \tau_i \ln (1 - n_{i,t}^N - n_{i,t}^T) \right]
\]

subject to budget constraint:
\[
c_{i,t} + q_{i} \Delta h_{i,t} + R_{i,t} l_{i,t-1} = l_{i,t} + w_{i,t}^N n_{i,t}^N + w_{i,t}^T n_{i,t}^T, \tag{6}
\]

and borrowing constraint:
\[
l_{i,t} \leq m_i E_t \left( \frac{q_{t+1} h_{i,t}}{R_{i,t}} \right). \tag{7}
\]

Foreign impatient HHs problem is equivalent, except that in their budget constraint, there is a repayment shock. Their budget constraint is:
\[
c_{i,t}^* + q_t^* \Delta h_{i,t}^* + R_{i,t}^* l_{i,t-1}^* - \epsilon_t \\
= l_{i,t}^* + w_{i,t}^N n_{i,t}^N + w_{i,t}^T n_{i,t}^T
\]

As in Iacoviello 2010, \( \epsilon_t \) is a mean zero, AR(1) shock that captures the exogenous repayment shock in the U.S.. When \( \epsilon_t \) is greater than 0, U.S. impatient HHs pays back less than their debt obligation.

First order conditions of impatient HHs are:

\[
\frac{1}{c_{i,t}} = \lambda_{i,t} \frac{R_{i,t}}{c_{i,t} + 1} + \beta_t E_t \left( \frac{R_{i,t+1}}{c_{i,t+1}} \right) \tag{8}
\]

\[
\frac{q_t}{c_{i,t}} = \frac{\nu}{h_{i,t}} + \lambda_{i,t} m_i E_t (q_{t+1}) + \beta_t E_t \left( \frac{q_{t+1}}{c_{i,t+1}} \right) \tag{9}
\]

\[
\frac{w_{i,t}^N}{c_{i,t}} = \frac{\tau_i}{1 - \frac{n_{i,t}^N}{1 - n_{i,t}^N}} \tag{10}
\]

\[
\frac{w_{i,t}^T}{c_{i,t}} = \frac{\tau_i}{1 - \frac{n_{i,t}^T}{1 - n_{i,t}^T}} \tag{11}
\]

\( \lambda_{i,t} \) is the Lagrangian multiplier of impatient HHs borrowing constraint.
2.4 Entrepreneurs

Entrepreneurs’ optimization problem is:

$$\max_{c_{e,t},k_{t}^{N},k_{t}^{T},l_{e,t}} \mathbb{E}_{0} \sum_{t=0}^{\infty} \beta_{t} \ln c_{e,t}$$

subject to budget constraint:

$$c_{e,t} + k_{t}^{N} + k_{t}^{T} + R_{e,t}l_{e,t-1} + \frac{\phi_{k}}{2} (\Delta k_{t}^{N})^{2} + \frac{\phi_{k}}{2} (\Delta k_{t}^{T})^{2} = l_{e,t} + (r_{k,t}^{N} + 1 - \delta)k_{t-1}^{N} + (r_{k,t}^{T} + 1 - \delta)k_{t-1}^{T}$$

and borrowing constraint:

$$l_{e,t} \leq m_{e}(k_{t}^{N} + k_{t}^{T})$$

$c_{e,t}$ is entrepreneurs’ consumption. $k_{t}^{N}, k_{t}^{T}$ are entrepreneurs’ capital in the tradable and nontradable sectors. They finance investment with income from capital rental in the two sectors $r_{k,t}^{N} + 1, r_{k,t}^{T} + 1$ and bank loan $l_{e,t}$. The bank loan cannot exceed the value of their capital. Entrepreneurs pay banks a return $R_{e,t}$ on the loan. Similar to Backus, Kehoe and Kydland (1994), we assume that investment uses the same goods composite as the consumption basket. $\frac{\phi_{k}}{2} (\Delta k_{t}^{N})^{2}$ and $\frac{\phi_{k}}{2} (\Delta k_{t}^{T})^{2}$ are convex capital adjustment cost that entrepreneurs face when they change their stock of capital in the tradable and non-tradable sectors. Entrepreneurs’ first order conditions are:

$$\frac{1}{c_{e,t}}(1 + \phi_{k}\Delta k_{t}^{N}) = \frac{\lambda'_{e,t}}{c_{e,t}}m_{e} + \beta_{e}E_{t}\left\{ \frac{1}{c_{e,t+1}}[(r_{k,t}^{N} + 1 - \delta) + \phi_{k}\Delta k_{t+1}^{N}] \right\}$$

$$\frac{1}{c_{e,t}}(1 + \phi_{k}\Delta k_{t}^{T}) = \frac{\lambda'_{e,t}}{c_{e,t}}m_{e} + \beta_{e}E_{t}\left\{ \frac{1}{c_{e,t+1}}[(r_{k,t}^{T} + 1 - \delta) + \phi_{k}\Delta k_{t+1}^{T}] \right\}$$

$$\frac{1}{c_{e,t}} = \frac{\lambda'_{e,t}}{c_{e,t}} + \beta_{e}E_{t}\left( \frac{R_{e,t+1}}{c_{e,t+1}} \right)$$

$\frac{\lambda'_{e,t}}{c_{e,t}}$ is the Lagrangian multiplier of entrepreneurs’ borrowing constraint. Foreign en-
entrepreneurs problems and first order conditions are similar.

2.5 Bankers

**Domestic Bankers**: Domestic bankers borrow from domestic depositors and foreign banks, supply loans to impatient HHs and entrepreneurs. The fund they obtain from the foreign bank is in term of tradable good. They pay returns on the fund they borrow, \( R_{d,t} \) and \( R_{f,t} \), to depositors and foreign banks respectively. They charge higher interests to the loans they lend out: \( R_{i,t} \) and \( R_{e,t} \) to impatient HHs and entrepreneurs. They face a capital requirement constraint and a collateral debt constraint. The two constraint together pin down the level of foreign asset in the model. Their optimization problem is:

\[
\begin{align*}
\max_{c_{b,t},d_t,l_{i,t},l_{e,t},l_{f,t}} \quad & E_0 \sum_{t=0}^{\infty} \beta_t^R \ln c_{b,t} \\
\text{subject to budget constraint:} \quad & c_{b,t} + R_{d,t}d_{t-1} + l_{e,t} + l_{i,t} + R_{f,t} p_t^T l_{f,t-1} \\
& = d_t + R_{e,t}l_{e,t-1} + R_{i,t}l_{i,t-1} + p_t^T l_{f,t} - \left\{ \frac{\phi_e}{2} (\Delta l_{e,t})^2 + \frac{\phi_i}{2} (\Delta l_{i,t})^2 + \frac{\phi_d}{2} (\Delta d_t)^2 + \frac{\phi_f}{2} \Delta (p_t^T l_{f,t})^2 \right\} \quad (17)
\end{align*}
\]

capital requirement constraint:

\[
\begin{align*}
& d_t + p_t^T l_{f,t} \leq \gamma_{e} l_{e,t} + \gamma_{i} l_{i,t} \quad (18)
\end{align*}
\]

and foreign debt constraint:

\[
\begin{align*}
& p_t^T l_{f,t} \leq m_f \left( \frac{l_{i,t} + l_{e,t} - d_t}{R_{f,t}} \right) \quad (19)
\end{align*}
\]

The international inter-bank loan \( l_{f,t} \) is denominated in tradable good price. In domestic consumption good unit, its value is \( p_t^T l_{f,t} \). Domestic bankers use their capital as collateral, which is equal to total asset \( l_{i,t} + l_{e,t} \) minus liability \( d_t \). Similar assumption on interbank lending constraint has been made by Ali Dib (2010). \( m_f \) is the loan to value in the international financial market. \( \frac{\phi_e}{2} (\Delta l_{e,t})^2, \frac{\phi_i}{2} (\Delta l_{i,t})^2, \frac{\phi_d}{2} (\Delta d_t)^2, \frac{\phi_f}{2} (\Delta p_t^T l_{f,t})^2 \) are adjustment costs that banks face when they change their loans and deposit. Their first order conditions are:
\[
\frac{1}{c_{b,t}} [1 - \phi_d \Delta d_t] = \frac{\lambda'_{b,t}}{c_{b,t}} + \frac{\lambda'_{f,t}}{c_{b,t}} m_f + \beta_b E_t \left\{ \frac{1}{c_{b,t+1}} [R_{d,t+1} - \phi_d \Delta d_{t+1}] \right\} 
\]
(20)

\[
\frac{1}{c_{b,t}} [1 + \phi_i \Delta l_{i,t}] = \frac{\lambda'_{b,t}}{c_{b,t}} \gamma_i + \frac{\lambda'_{f,t}}{c_{b,t}} m_f + \beta_b E_t \left\{ \frac{1}{c_{b,t+1}} [R_{i,t+1} + \phi_i \Delta l_{i,t+1}] \right\} 
\]
(21)

\[
\frac{1}{c_{b,t}} [1 + \phi_e \Delta l_{e,t}] = \frac{\lambda'_{b,t}}{c_{b,t}} \gamma_e + \frac{\lambda'_{f,t}}{c_{b,t}} m_f + \beta_b E_t \left\{ \frac{1}{c_{b,t+1}} [R_{e,t+1} + \phi_e \Delta l_{e,t+1}] \right\} 
\]
(22)

\[
\frac{1}{c_{b,t}} [1 - \phi_f \Delta (p^T_{f,t} l_{f,t})] = \frac{\lambda'_{b,t}}{c_{b,t}} + \frac{\lambda'_{f,t}}{c_{b,t}} R_{f,t} 
\]
\[+ \beta_b E_t \left\{ \frac{1}{c_{b,t+1}} \left[ R_{f,t+1} \frac{p_{t+1}^T}{p_t^T} - \phi_f \Delta (p_{t+1}^T l_{f,t+1}) \right] \right\}. 
\]
(23)

\(\lambda'_{b,t}\) and \(\lambda'_{f,t}\) are multipliers on the capital requirement and foreign debt constraints, multiplied by banker consumptions. The intuition here is similar to that of Iacoviello 2010, with one exception, the presence of \(\lambda'_{f,t}\). To increase one unit of consumption today, bankers can either increase one unit of today’s deposit or today’s inter-bank loan (today’s liabilities), or reduce one unit of today’s consumers’ loan or business loan (today’s assets). If he, for example, choose to increase \(d_t\), re-arranging the equations gives:

\[
1 - \lambda'_{b,t} - \lambda'_{f,t} m_f - \phi_d \Delta d_t = E_t \left\{ \beta_b \frac{c_{b,t}}{c_{b,t+1}} [R_{d,t+1} - \phi_d \Delta d_{t+1}] \right\}.
\]

The right hand side of the equation is the cost of increasing one unit of deposit this period, which is equal to the additional return tomorrow that bankers has to pay on the deposit, less the lower cost that bankers pay on adjustment cost tomorrow, discounted into today value by bankers’s stochastic discount factor \(\left\{ \beta_b \frac{c_{b,t}}{c_{b,t+1}} \right\}\). The left hand side is the marginal benefit of consuming one more unit today, minus the cost of tightening capital requirement constraint, \(\lambda'_{b,t}\), minus the cost of tightening foreign debt constraint, \(\lambda'_{f,t} m_f\), minus the adjustment cost in changing deposit that bankers face today. Similar argument holds if bankers choose, instead, to increase foreign loan or decrease loans made to domestic borrowers.
Foreign Bankers: Foreign bankers borrow the fund from foreign depositors and supply loan to foreign impatient HHs, entrepreneurs. Foreign banks also lend to domestic banks in the form of tradable goods. They only face budget constraint and capital requirement constraint. They are subject to the endowment shock $\epsilon_t$. Their maximization problem is:

$$
\max_{c_{b,t}^*, d_{t}^*, i_{i,t}, l_{i,t}, l_{e,t}, l_{f,t}} E_0 \sum_{t=0}^{\infty} (\beta_b^*)^t \ln c_{b,t}^* \\
\text{subject to budget constraint:} \\
c_{b,t}^* + R_{d,t}^* d_{t-1}^* + l_{e,t}^* + l_{i,t}^* + p_l^T l_{f,t}^* \\
= d_{t}^* + R_{e,t}^* l_{e,t-1}^* + R_{i,t}^* l_{i,t-1}^* + R_{f,t}^* p_l^T l_{f,t-1}^* - \epsilon_t^* \\
- \left\{ \frac{\phi_e}{2} (\Delta l_{e,t}^*)^2 + \frac{\phi_i}{2} (\Delta l_{i,t}^*)^2 + \frac{\phi_d}{2} (\Delta d_{t}^*)^2 + \frac{\phi_f}{2} (p_l^T l_{f,t}^*)^2 \right\} 
$$

(24)

and capital requirement constraint:

$$
d_{t}^* \leq \gamma_e l_{e,t}^* + \gamma_i l_{i,t}^* + \gamma_f p_l^T l_{f,t}^*. 
$$

(25)

Their first order conditions are similar to those of domestic banks without the multiplier on the foreign debt constraint $\lambda_{f,t}^*$. When foreign banks increase their consumption by increasing deposit or reducing loans, only their capital requirement constraint is tightened.

2.6 Firms

Firms in tradable and nontradable sectors use labor from HHs, capital from entrepreneurs to produce tradable and nontradable goods. They pay wages to HHs and capital rental fees to entrepreneurs.

Non-tradable Sector:
\[
\max_{k_{t-1}^N, n_{p,t}^N, n_{i,t}^N} \pi_t^N = p_t^N y_t^N - r_{k,t}^N k_{t-1}^N - w_{p,t}^N n_{p,t}^N - w_{i,t}^N n_{i,t}^N
\]
subject to \( y_t^N = z_t^N (k_{t-1})^\alpha \left( (n_{p,t}^N)^{1-\sigma} (n_{i,t}^N)^\sigma \right)^{1-\alpha} \).

** Tradable Sector:**

\[
\max \pi_t^T = p_t^T y_t^T - r_{k,t}^T k_{t-1}^T - w_{p,t}^T n_{p,t}^T - w_{i,t}^T n_{i,t}^T
\]
subject to \( y_t^T = z_t^T (k_{t-1})^\alpha \left( (n_{p,t}^T)^{1-\sigma} (n_{i,t}^T)^\sigma \right)^{1-\alpha} \).

The Cobb-Douglas aggregate of labor is to control for the economic size of patient and impatient HHs in the economy, as in Iacoviello (2005, 2010). The higher \( \sigma \) is, the larger the size of impatient HHs vs. patient HHs. The Cobb-Douglas aggregate is used, instead of a simple linear combination, to pin down the steady state labor supply to each sector. In the model with two sectors and two agents, even though total labor demand in each sector and total labor supply of each type of agents are determined, a linear aggregate cannot determine what fraction of labor effort of each agent is allocated to each sector.

### 2.7 Market Clearing Conditions

The housing market clearing conditions are:

\[
\begin{align*}
    h_{p,t}^* + h_{i,t}^* &= 1 \\
    h_{p,t}^* + h_{i,t}^* &= 1
\end{align*}
\]
The good market clearing conditions for tradable good are:

\[
y_t^T + l_{f,t} = (p_t^T)^{-\omega} [c_{p,t} + c_{e,t} + c_{b,t} + k_{t+1}^N + k_{t+1}^T - (1 - \delta) (k_{t+1}^N + k_{t+1}^T) + adj] + R_{f,t}l_{f,t-1}
\]

\[
y_t^{T*,} + R_{f,t}l_{f,t-1} = (p_t^{T*})^{-\omega} [c_{p,t}^* + c_{e,t}^* + c_{b,t}^* + k_{t+1}^N + k_{t+1}^T - (1 - \delta) (k_{t+1}^N + k_{t+1}^T) + adj^*]
\]

Here, \(adj\) (\(adj^*\)) is the sum of all adjustment costs the domestic (foreign) bankers and entrepreneurs face. The market clearing conditions for non-tradable are implied from the budget constraints of all agents and the above four market clearing conditions.

3 Key Assumptions and Calibration

3.1 Key Assumptions

The steady state deposit and lending rates are as followed:

<table>
<thead>
<tr>
<th></th>
<th>Domestic Country</th>
<th>Foreign Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deposit Rates</td>
<td>(R_d = \frac{1}{\beta_p})</td>
<td>(R_d^* = \frac{1}{\beta_p^*})</td>
</tr>
<tr>
<td>Interbank Rate</td>
<td>(R_i = R_d + \frac{1}{\delta_1}(R_d - R_f))</td>
<td>(R_i^* = (1 - \gamma_i)\frac{1}{\beta_p^*} + \gamma_i R_d)</td>
</tr>
<tr>
<td>Loan to IHs</td>
<td>(R_e = R_d + \frac{1}{\delta_2}(R_d - R_f))</td>
<td>(R_e^* = (1 - \gamma_e)\frac{1}{\beta_p^*} + \gamma_e R_d)</td>
</tr>
</tbody>
</table>

where \(\delta_1 = \frac{\lambda_f(R_f - m_f)}{(1 - \beta_b)R_d - \lambda_f m_f)(1 - \gamma_i)}\) and \(\delta_2 = \frac{\lambda_f(R_f - m_f)}{(1 - \beta_b)R_d - \lambda_f m_f)(1 - \gamma_e)}\). Detailed solutions can be found in the Appendix.

In steady state, foreign banks take the deposit from foreign savers (patient HHs) and lend out to foreign impatient HHs, foreign entrepreneurs and domestic banks. In order for foreign banks to accept the deposit, the return on deposits that foreign banks must pay should be "low enough" for foreign banks. Specifically, \(\frac{1}{\beta_p} > R_d^* = \frac{1}{\beta_p^*}\), or foreign bankers are more impatient than foreign depositors. In order for foreign impatient HHs and entrepreneurs to borrow from foreign banks, the interest rates the foreign banks charge must be "low enough" for them, or \(\frac{1}{\beta_p^*} > R_i^* = (1 - \gamma_i)\frac{1}{\beta_p^*} + \gamma_i R_d\) and \(\frac{1}{\beta_p^*} > R_e^* = (1 - \gamma_e)\frac{1}{\beta_p^*} + \gamma_e R_d\). Foreign entrepreneurs and impatient HHs are more impatient than the weighted average of foreign bankers and foreign depositors. The intuition here is similar to that of Iacoviello 2010.

In the interbank market, domestic banks borrow from foreign banks because the fund supplied from foreign banks is cheaper than the fund supplied from domestic depositors. From
the Appendix solution for the multiplier on the interbank borrowing constraint, one can easily verify that the condition $R_f < R_d$ ensures the binding of the constraint in steady state. It is equivalent to: $(1 - \gamma_f)\frac{1}{\beta_p} + \gamma_f \frac{1}{\beta_p^*} < \frac{1}{\beta_p}$, or savers in domestic country are more impatient than the weighted average of savers and bankers in the foreign country. For domestic borrowers to accept these rates the domestic bank charge, they have to be "impatient enough", or $\frac{1}{\beta_e} > R_e$ and $\frac{1}{\beta_i} > R_i$.

Within the large literature on the global imbalance, to generate the observed current account in the U.S. and other developing nations, especially China, the common assumption is the representative agent in the U.S. is more impatient than a representative in the developing country. To generate the flow of fund at the banking sector level from the U.S. to EAM, we only assume that the savers in EAM are more impatient than the weighted average of savers and bankers in the U.S. Other agents in the EAM can be more patient than the U.S. Thus, our assumption does not contradict with the assumption in the global imbalance literature.

### 3.2 Calibration

<table>
<thead>
<tr>
<th>Domestic Agent</th>
<th>Value</th>
<th>Foreign Agent</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta_p$</td>
<td>0.9875</td>
<td>$\beta_{p*}$</td>
<td>0.9925</td>
</tr>
<tr>
<td>$\beta_i$</td>
<td>0.95</td>
<td>$\beta_{i*}$</td>
<td>0.94</td>
</tr>
<tr>
<td>$\beta_e$</td>
<td>0.95</td>
<td>$\beta_{e*}$</td>
<td>0.94</td>
</tr>
<tr>
<td>$\beta_b$</td>
<td>0.96</td>
<td>$\beta_{b*}$</td>
<td>0.975</td>
</tr>
</tbody>
</table>

The discount factors for each agent are given by table 1. All these values are within the range of two standard deviation bands interval (0.91, 0.99) estimated by Carroll and Samwick (1997). They are chosen according to the key assumptions. The fraction of impatient HHs $\sigma$ is 0.5. Campbell and Mankiw (1990) estimated the fraction of liquidity constrained HHs to be 0.5. Iacoviello (2005, 2010) set the fraction of impatient HHs to be 0.36 and 0.3 respectively. Setting $\sigma$ to be 0.5 is at the upperbound of the values used in the literature. It gives the convenience in algebraically solving the model in closed form without changing its fundamentals. Elasticity of substitution between tradable and non-tradable good $\omega$ is 0.44 as estimated by Stockman and Tesar (1995). $\gamma_i, \gamma_e$ are 0.9 as in Iacoviello (2010). We choose $\gamma_f$ to be 0.9. Parameters controlling bankers’ adjustment cost $\phi_d, \phi_i, \phi_e, \phi_f$ are 0.25. Loan to values $m_i, m_e, m_f$ are 0.9, 0.9 and 0.7 respectively. Capital depreciation rate $\delta$ is 0.025. The rest of the model’s parameters
are chosen from the closed economy model by Iacoviello (2010)

Table 2: Calibration

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \alpha )</td>
<td>0.35</td>
<td>( \nu )</td>
<td>0.08</td>
</tr>
<tr>
<td>( \tau_p )</td>
<td>2</td>
<td>( \tau_i )</td>
<td>2</td>
</tr>
<tr>
<td>( \phi_k )</td>
<td>2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4 Results

4.1 Repayment shock

The repayment shock is exogenous. Alternatively, one can endogenize the default shock as function of the underlying state of the economy. For example, in Forlati and Lambertini (2011), borrowers default endogenously, when they find that the value of their collateral is lower than the value of the loan they borrow. Within the context of this paper, we treat the repayment shock as exogenous for simplicity and tractability. A further step, to describe how default can happen endogenously and depend on the fundamental of the lending country, and through banking sector, spread to the borrowing country, is worthwhile for future investigation.

Figure 10 plots the impulse response results of foreign macroeconomic variables for the foreign repayment shocks. Default coming from foreign impatient HHs forces the foreign banks to contract both loans and deposit to maintain their required capital-asset ratio. The results are a fall in output, asset price, investment, employment, loan and an increase in lending interest rates. Similar results have been obtained in Iacoviello (2010) closed economy version.

Figure 11 plots the impulse response of international interbank loan and interest rate. When the lending banks from the developed country contract the loan for all of their borrowers, they do so for the borrowing banks as well.

Figure 12 plots the impulse response results of domestic macroeconomic variables. When foreign banks contract asset by raising lending rates to maintain their capital requirement ratio, domestic banks now face more expensive (as \( R_f \) increases) and less availability credits (international borrowing constraint tighten when \( R_f \) increases), they have to raise domestic lending rates
and reduce the loans made to domestic borrowers. A domestic credit crunch, characterized by a decrease in loan and an increase in borrowing interest rates has occurred following the default from abroad.

Domestic output, investment and asset prices fall, which are the typical results following a credit crunch. What is interesting here is the movement of resources across sector and the dynamics of the real exchange rate. The international loan is denominated in tradable good. When the loan that foreign banks made to domestic banks suddenly decreases, in foreign country, the demand for tradable good decreases and the price of tradable relative to non-tradable decreases. In domestic country, the supply of tradable good suddenly decreases, which increases the price of tradable relative to non-tradable. As a result, the real exchange rate decreases on impact. Over time, in domestic country, labor and investment move from non-tradable to tradable sector to equalize the prices in two sectors, exchange rate appreciate toward its steady state value. Figure 13 plots the impulse responses of real exchange rate and price of tradable and non-tradable in foreign and domestic country. Figure 8 documents the real exchange rate movement of Chinese Taipei, India and Korea. The sharp reduction in the real exchange rate of these country against the U.S. happened around the time when U.S. banks substantially deleveraged their balance sheet with respect to Asia.

Figure 14 plots the impulse responses of repayment shock under different values of $\gamma_f$. A lower value of $\gamma_f$ can be interpreted as banks’ strategy to contract foreign loan and gives priority to long-term domestic borrowers. Peek and Rosengren (1997) documented this behavior among Japanese banks. It can also be interpreted as a lower credit rating of the domestic economy. With a smaller $\gamma_f$, the repayment shock generates much larger volatilities of domestic variables while decreasing the volatilities of foreign variables. In other word, a lower $\gamma_f$, helps mitigate the effects of the financial shock in the developed country where it originates, while amplifying the effects on the developing country. The intuition for this comes from foreign banks’ capital requirement constraint:

$$d_t^e \leq \gamma_e l_{e,t}^* + \gamma_i l_{i,t}^* + \gamma_f p_t^* T_{f,t}$$
Deposit equals asset minus equity:

\[
\begin{align*}
    l_{i,t}^* + l_{e,t}^* + p_t^T l_{f,t} - E^* &\leq \gamma_i l_{i,t}^* + \gamma_e l_{e,t}^* + \gamma_f p_t^T l_{f,t} \\
    (1 - \gamma_e) l_{e,t}^* + (1 - \gamma_i) l_{i,t}^* + (1 - \gamma_f) p_t^T l_{f,t} &\leq E^*
\end{align*}
\] (26)

When default happens and decreases foreign banks’ equity, these banks will have to decrease the left hand side of the above equation. When \( \gamma_f \) is smaller than \( \gamma_i, \gamma_e \), it is more beneficial for the foreign banks to contract international loan. One unit decrease in \( l_{f,t} \) will loosen the capital requirement constraint by \( 1 - \gamma_f \), which is larger than \( 1 - \gamma_e (1 - \gamma_i) \) if banks contract business (consumer) loan. The adjustment costs banks face are convex and together with the \( \gamma \) will determine how banks contract its portfolio. Without the convexity in costs, banks will find it most beneficial to contract foreign loan only when \( \gamma_f \) is lower relative to \( \gamma_i \) and \( \gamma_e \).

Devereux and Yetman (2010), using the data for the recent crisis, found that the magnitude of capital flow from one country to the U.S. depends on the country’s foreign currency credit rating. A lower rating results in a larger capital outflow of the country to the U.S., following the recent U.S. crisis. A lower rating asset will have a higher weight in banks’ risk weighted asset (RWA) portfolio in equation 26, or a lower \( \gamma_f \) in our model. Thus, the empirical evidence is in line with our model prediction, that countries perceived as more risky will suffer more from the U.S. crisis than less risky countries.

4.2 \( \gamma_f \) Shock

Permanent Shock

A permanent shock to \( \gamma_f \) can be interpreted as a change in regulation. A real world example of this is the change from the Basel I Accord to the Basel II Accord. Under the Basel I Accord, banks’ assets were classified into categories such as sovereign, banks, collateral, etc. All debts under the same category will carry the same weight in banks’ RWA and banks were required to hold capital equal to 8% of banks’ total RWA. For example, all corporate debts will
have the weight of 100% and all government debts will have the weight of 0%. The Basel II Accord no longer gives the same weight to all assets in one category if they have different level of risks. Borrowing banks in developing country, if considered risky by Basel II’s new assessment of risk, will have a higher weight in the lending bank’s RWA.

Figure 15 to 18 have impulse response for a 10% permanent negative shock to $\gamma_f$. As the international inter-bank loan have a higher weight in the lending banks’ RWA, lending banks permanently increase the lending rate, $R_f$, and decrease the amount of loan made to borrowing banks in the developing country, $l_f$. The steady state interbank lending rate is:

$$R_f = \frac{1}{\beta_B} - \left[ \frac{1}{\beta_B} - \frac{1}{\beta_H} \right] \gamma_f.$$  

When $\gamma_f$ decreases, $R_f$ converges to a higher steady state. The steady state lending rates to domestic borrowers are weighted average of interbank lending rate and domestic deposit rate. Thus, they converge to a new higher steady state. As a result, domestic consumption, output and investment converge to a lower steady state.

As $\gamma_f$ permanently decreases, from equation 25, we see that foreign banks’ capital requirement constraint tightens, foreign banks can “loosen” the constraint by either deleveraging, reducing the total size of its RWA and deposit, or restructuring its portfolio, hold less asset with high weight and more asset with low weight. The foreign banks’ adjustment cost helps pin the optimal path for their deposit demand and loan supply. Contrary to the repayment shock, when the only option is to deleverage, foreign banks in this case also restructure their portfolio and holds more assets with lower weight in its RWA. As a result, foreign deposit goes down (deleveraging effect) and loans to foreign IHs and entrepreneurs go up (portfolio restructuring effect). The foreign investment, consumption and output go up. New steady state foreign domestic lending rates, which only depends on foreign bank and patient HHs time preference, stay the same.

**Temporary Shock**

Figure 19 to 22 have the impulse responses for the temporary negative shock to $\gamma_f$. The temporary shock can be interpreted as an exogenous temporary drop in domestic banks’ credit rating. A real world example for this is the drop in domestic bank credit rating of South Korean banks during the Asian financial crisis in 1997. Figure 9 has the graph of credit ratings of nationwide South Korean banks and the South Korean Won - US Dollar exchange rate. Credit Ratings of major banks in South Korea drop significantly before and right at the beginning of the crisis. The results of the impulse response shows a drop in domestic gdp, consumption and investment. The foreign loan given to domestic banks contracts and interest rate increases.
real exchange rate also depreciates as a result of tightening foreign credit. These were also the experience of South Korea during the financial crisis.

5 Relation to empirical facts and existing literature

For the foreign repayment shock, our model generates a drop in output, consumption, investment, loans and housing prices and an increase in bank lending rates in both home and foreign countries. The borrowing country’s real exchange rate also depreciates. Qualitatively, our model matches the empirical facts. The lowest drop in the foreign and domestic consumption are $2 \times 10^{-3}$ and $2 \times 10^{-4}$, respectively. The drops of foreign and domestic investment are $5 \times 10^{-3}$ and $5 \times 10^{-4}$. The transmission of shock to the foreign country is just 10%. Quantitatively, our model does not match the magnitude of international transmission observed in data.

Devereux and Yetman (2010) build an international portfolio model to describe the recent crisis. Leveraged investors in each country holds foreign equity in their portfolio. The total value of their portfolio have to be greater than a constant times their equities. When a shock hits the home country and decreases home asset prices, the value of portfolio of home and foreign investors decreases, forcing them to deleverage. Eric van Wincoop (2011) build a model with leveraged financial institutions, who invest in both home and foreign asset. The default shock in his model is similar to the repayment shock in ours. Since foreign financial institutions hold domestic asset, the domestic default shock damages the foreign bank balance sheet and spread the crisis to the foreign country. The main difference between our model and theirs, is in our model, leveraged domestic bank does not hold foreign asset. In our model, shock is transmitted through a credit crunch in the interbank loan market. Their models fit well for the comovement between U.S. and Europe since European Banking Centers were the majority foreign holders of U.S. MBS. Our model fits the story between U.S. and the EAM. EAM were not directly exposed to the U.S. MBS as only 3% of U.S. ABS are held outside of U.S., Europe and Carribean.

Kollmann et.al. (2011), Ueda (2010) and Kalemli-Ozcan et.al. (2011) also build international business cycle model with leveraged bank(s). In their models, borrowers in both countries share a common lender(s). When shock hits one country and damage the balance sheet of the common lender(s), the common lender(s) contract loans in both countries. In their model, borrowers in one country have direct access to the credit of the foreign lenders. The story works in the developed world. For the EAM, this is not the case as few borrowers in EAM have direct
access to U.S. bank credit. In our model, borrowers in EAM only borrow fund from the U.S. through domestic banks. Thus, in steady state, banks in EAM are net borrowers in our model, which is an empirical fact and cannot be generated with a model of two symmetric countries.

Another main difference between our model and previous models with leveraged financial investors (banks) is in our capital requirement (leverage) constraint, we separate the weights of different assets in the lending bank RWA. Thus, we are able to investigate the behavior of international transmission of shock when borrowing banks have different credit rating. We found that when the borrowing economy has lower rating, the magnitude of capital flows back to the U.S. in the crisis is higher. Our result is consistent with the empirical finding in Devereux and Yetman (2010).

6 Conclusion

Recent financial crisis in the U.S. highlights the role that banking sector plays in the global macroeconomy. There has been substantial empirical evidence that suggests financial crisis can be transmitted across border through the contraction in cross-border loan in banking system. The very first empirical paper was by Peek and Rosengren (1997) and later (2000 who study Japanese financial crisis and the effects on the U.S.. More recent empirical paper study the U.S. financial crisis and the effects on lending in other countries. Such paper are Cetorelli and Goldberg (2008, 2009), Popov and Udell (2010). Our model provide a theoretical framework to support the hypothesis. When financial shock hits one country, the cross border inter-bank loan contracts and transmits the shock to another country.

Our paper is also related to a number of papers that study the effects of shocks to international lending rate on a small open economy. These include Faia and Iliopulos (2010), Christensen and others (2009) Buyukkarabacak (2008). These papers treat the source of shock as exogenous. Our paper go one step further and point out the lending country’s financial shock may be what is behind the increase in the international lending rate. Our paper also differ from other recent papers with leveraged banks (investors) in three dimensions. First, the shock from the source country is not directly transmitted by damaging the foreign banks balance sheet, but rather, from contracting the loan in the interbank market. This helps apply our model for the EAM, who was not directly exposed to the U.S. MBS. Second, the borrowers in one country does
not borrow directly from foreign bank, but through domestic bank. Thus, in steady state, at banking level, EAM are net borrowers from the U.S.. Third, we separate the weight of international loans from weights for consumer and business loans in the capital requirement constraint. This helps us investigate the dynamics of the borrowing country when its banks have different credit rating levels and when there is a bank regulation change in the lending country.
References


Figure 1:

New Delinquent Balances by Loan Type

Source: Federal Reserve Bank of New York

Figure 2:

Percent of Mortgage Debt 90+ Days Late by State

Source: Federal Reserve Bank of New York
Figure 3:

U.S. Bank Assets & Liabilities

Source: Board Governors of Federal Reserve System

Figure 4:

External Assets of Banks in Developed Economies

Source: Bank for International Settlement
Figure 5:

External Liabilities Banks in Emerging Asian Markets

Source: Bank for International Settlement

Figure 6:

GDP Growth of Developed Economies

Source: World Bank
Figure 7:

GDP Growth of U.S and Developing Economies

Source: World Bank

Figure 8:

RER movements of Emerging Markets

Source: Bank for International Settlement
Figure 9:

![Graph of S. Korean Won/USD Exchange Rate and Major S. Korean Banks Rating](image)

Source: Moody’s

Figure 10:

![Impulse Response: Foreign repayment shock graphs](image)
Figure 11:

**Impulse Response: Foreign repayment shock**
Figure 12:

Impulse Response: Foreign repayment shock
Figure 13:

Impulse Response: Foreign repayment shock
Figure 14:

Impulse Response: Foreign repayment shock
Figure 15:

Impulse Response: Permanent Shock to $\gamma_f$
Figure 16:

Impulse Response: Permanent Shock to $\gamma_f$

Figure 17:

Impulse Response: Permanent Shock to $\gamma_f$
Figure 18:

Impulse Response: Permanent Shock to $\gamma_f$
Impulse Response: Temporary Shock to $\gamma_f$
Figure 20:

Impulse Response: Temporary Shock to $\gamma_f$
Figure 21:

Impulse Response: Temporary Shock to $\gamma_f$
Figure 22:

Impulse Response: Temporary Shock to $\gamma_f$
Appendices

Solving for Steady State Lending Rates

The steady state equations of domestic and foreign patient HHs’ FOCs for deposits give the deposit rates: \( R_d = \frac{1}{1-p} \) and \( R_d^* = \frac{1}{1-p^*} \). Foreign banks’ steady state FOCS for deposits and loans can be written as:

\[
\begin{align*}
1 - \beta_b^* R_d^* &= \lambda_b^* \\
1 - \beta_b^* R_i^* &= \lambda_b^* \gamma_i^* \\
1 - \beta_b^* R_e^* &= \lambda_b^* \gamma_e^* \\
1 - \beta_b^* R_f &= \lambda_b^* \gamma_f^*
\end{align*}
\]

where \( \lambda_b^* \) is the multiplier on foreign banks capital requirement constraint, multiplied by foreign bankers’ consumption, i.e., \( \lambda_b^* = \lambda_b^* c_{b,t}^* \). Simple algebra, replacing \( \lambda_b^* \) with \( (1 - \beta_b^* R_d^*) \), then yield the foreign banks’ lending rates. Domestic banks steady state FOCS for deposits and loans are:

\[
\begin{align*}
1 - \beta_b R_d &= \lambda_b' + \lambda_f' m_f \\
1 - \beta_b R_i &= \lambda_b' \gamma_i + \lambda_f' m_f \\
1 - \beta_b R_e &= \lambda_b' \gamma_e + \lambda_f' m_f \\
1 - \beta_b R_f &= \lambda_b' + \lambda_f' R_f
\end{align*}
\]

From the first and the last equation of the above system of four equations, one can solve for the value of \( \lambda_f' \):

\[
\lambda_f' = \frac{\beta_b (R_d - R_f)}{R_f - m_f}
\]
The bottom of the equation is greater than 0, since $R_f > 1 > m_f$. Thus, $\lambda_f > 0$ when $R_d > R_f$.

Combine the above system of equations to solve for domestic lending rates, we have

\[
\begin{align*}
\frac{R_f - R_d}{R_i - R_d} &= \frac{\lambda_f'(m_f - R_f)}{\lambda_b'(1 - \gamma_i)} \\
\frac{R_f - R_d}{R_i - R_d} &= \lambda_f'(m_f - R_f) \\
&= \frac{(1 - \beta_b R_d - \lambda_f'm_f)(1 - \gamma_i)}{1 - \beta_b R_d - \lambda_f'm_f} = -\delta_1 \\
R_i &= R_d + \frac{1}{\delta_1}(R_d - R_f) \\
\end{align*}
\]

\[
\begin{align*}
\frac{R_f - R_d}{R_e - R_d} &= \frac{\lambda_f'(m_f - R_f)}{\lambda_b'(1 - \gamma_e)} \\
\frac{R_f - R_d}{R_e - R_d} &= \lambda_f'(m_f - R_f) \\
&= \frac{(1 - \beta_b R_d - \lambda_f'm_f)(1 - \gamma_e)}{1 - \beta_b R_d - \lambda_f'm_f} = -\delta_2 \\
R_e &= R_d + \frac{1}{\delta_2}(R_d - R_f) \\
\end{align*}
\]

All deposit and lending rate in the table are now determined.