Financial intermediation in a global environment

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Abstract

I develop a two country DSGE model with financial intermediation that allows banks to lend to each other across countries. Banks are financially constrained on how much they can borrow. The main goal is to have a framework that can not only capture some aspects of the international transmission of a financial crisis, but can also help explaining the insurance mechanism of the international asset market. I use the model to study the quantitative aspects of a financial crisis and how unconventional monetary policy can help to mitigate the effects of a financial disruption.

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1 Introduction

During the last financial crisis, banks experienced large loan losses. Moreover, banks in United States suffered a decrease in their domestic assets, while European banks experienced a decline in their foreign assets, in particular those denominated in U.S. dollars. In this paper, I develop a two-country model with global financial intermediaries that operate across international borders to explain the global transmission of the recent financial crisis.

Starting in the year 2000, international banks in many countries increased their foreign claims; they augmented from $10 trillion at the beginning of the year 2000, up to $34 trillion by the end of 2007 (**?**). In particular, banks member of the European Union increased not only their intra-euro area lending because of the introduction of the common currency, but also their U.S. dollar position. Swiss, Japanese, and U.K. banks increased predominately their position in U.S. dollar. In this paper, I focus on the Swiss case, where half of the Swiss banks' assets are denominated in foreign currency; and half of the latter are in U.S. dollars.

Figure **??** shows the net asset position in U.S. dollars for the Swiss banking sector, from 1987 until 2012. Starting in 2002, Swiss banks increased their claims in U.S. dollars. This gap can be understood as an increase in the risk exposure to a possible default of the foreign borrowers (**?**).

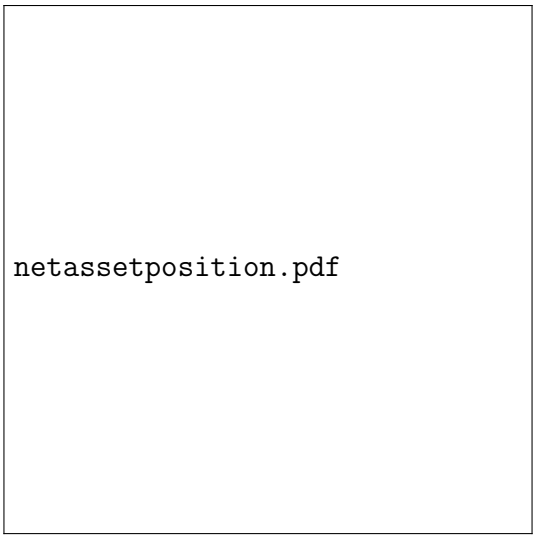

Figure 1: Swiss Banks: Net asset position in U.S. dollars

When the turbulence in the American housing sector hit the financial institutions, many banks were put into distress. This, in addition to the failure of Lehman Brothers in September 2008, triggered a severe liquidity crisis in the interbank market. Assets held by not only U.S. banks, but also by foreign banks and denominated in U.S. dollars started to lose value. The loss in the value of net assets in U.S. dollars for Swiss banks is reflected in Figure **??**. Starting in February 2007, net assets started to decrease; by February 2008, Swiss banks have lost 223 billion of CHF, 7% of total assets in February 2007. This prompted a reduction in the net worth of Swiss banks. Because of the large position that banks held in U.S. dollars, and because of the large size of the Swiss banking system, the crisis in United States spread to the Swiss economy.

As a result of the financial crisis, the Fed and other central banks started to carry out the so called "unconventional" monetary policy. In particular, the Fed started to intervene directly in the credit market, lending to non-financial institutions and reducing the restriction to access to the discount window, among other policies.

Given these events, I propose a two-country model to analyze how frictions in financial intermediation can prompt a crisis that affects real activity. Given global banks (banks that operate across borders) and an international interbank market, I am interested in the transmission mechanism from one country to the other one of a country-specific shock. I also focus on the role of insurance of the interbank market. Furthermore, I look at how unilateral unconventional monetary policy might mitigate the effects of the crisis. In order to answer to these questions, I develop a two-country dynamic stochastic general equilibrium model (henceforth, DSGE) that builds on **?** and **?**.

Figure **??** shows the orthogonalized impulse responses functions from a VAR with two lags that includes: real loans of American banks (lhplo_us), the S&P500 index (lhpsp500), real Swiss domestic demand (lhpfdd), real Swiss loans denominated in U.S. dollars (lhplo_usd), real Swiss net interest payments (hpnip), and the Swiss market index, SMI (lhpsmi), from 1988Q2 to 2012Q2.[1] All data are in log (expect the net interest payments that are demeaned) and detrended using the Hodrick-Prescott filter. The starting point corresponds to the availability of the Swiss data. The Cholesky ordering corresponds to the order of the listed variables.[2]

[1] See Appendix for the definition and the sources of the data.

[2] Given the comments of **?**, I performed different robustness checks. Changing the order for the Cholesky decomposition of the Swiss variables does not alter the behavior of the IRF. Including real interest rate and consumer price index for Switzerland do not alter the results neither. A smallest specification of the VAR also suggests the lag order equal to two and the general behavior is similar.

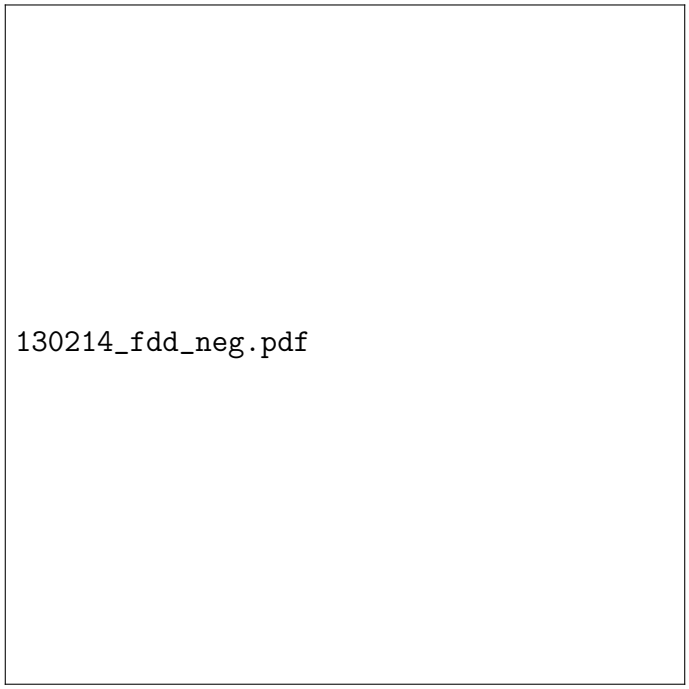

Figure 2: VAR Evidence.
Note: VAR estimated for 1988Q2 to 2012Q2. The dashed lines indicate the 67% confident intervals. The Cholesky ordering is lhplo_usd, lhpsp500, lhpfdd, lhplo_usd, lhpnip, lhpsmi. The vertical axis shows the percent deviation from the baseline.

The VAR evidence shows the response to a one-standard deviation innovation (negative) to the loan and leases in bank credit for all American commercial banks. This shock suggests a decrease in the S&P 500 index. Then, the crisis is transmitted to Switzerland, where the final domestic demand, the loans denominated in U.S. dollars that Swiss banks make, the net interest payment, and the stock market index fall. The variables that react on impact are the Swiss domestic demand and the net interest payments. In particular, the latter one rebounds after the first 4 periods, probably because of the reduction on the loans denominated in U.S. dollars. This evidence points a significant reaction of the Swiss (real and financial) economy to a shock in the loans and leases of the American banks, prompting a decrease in the activity in both countries. Furthermore, the co-movement of the stock indexes suggests a strong inter-country relation of the asset prices. While loans in U.S. go down because of the shock, loans made by Swiss banks and denominated in U.S. dollars also shrink, emphasizing the co-movement across countries. Moreover, net interest

payments decrease for the Swiss economy because the return that banks get from the loans abroad also go down. I aim to build a DSGE model that explains these interactions.

In the model developed in this paper, banks finance their activity through two different sources. Banks have access to a retail market, mainly households through deposits, and to a wholesale international market. I assume that only home banks can have a positive position on foreign banks. Banks face an endogenous borrowing constraint to receive funding from households. On the contrary, foreign banks are not constrained on borrowing from home banks. I assume a central bank per country. Moreover, I abstract from other frictions, including the one of banks lending to non-financial firms.

First, I study how a country-specific quality of capital shock, that simulates part of the financial crisis, is transmitted to the other country. The shock occurs in the foreign economy. I study the transmission mechanism in the context of imperfect substitutable intermediate goods. In particular, I compare a model without financial frictions with a model with financial frictions but without global banks, à la Gertler and Kiyotaki. Countries in these models are in financial autarky. Then, I allow for an international asset, from now on I call it international interbank market. I study the case in which foreign banks are not constrained on how much they can borrow from home banks. When foreign banks are allowed to borrow from home banks, the interbank market works as insurance for the foreign economy. Furthermore, there is integration of the two domestic asset markets.

Next, I turn to policy analysis during a crisis. I analyze how direct lending to non-financial firms in the country hit by the shock can help to mitigate the effects of the crisis domestically and abroad. Additionally, I study if the unilateral policy helps to have a faster recovery from a crisis. Then, I compare the international spillover of the crisis with and without the policy.

What is new in this framework is the analysis of the international transmission mechanism of a financial crisis. In particular, the transmission through the global interbank market in a context where there are financial intermediaries and they are constrained on how much they can borrow to finance their activity. As I show, the introduction of the global interbank market prompts a high level of co-movement between the foreign and the home economy, with similarities to the VAR shown in Figure **??**.

As in the previous literature (**?**, **?**, and **?**), I simulate the model given a quality of capital shock. The purpose of this type of shock is to have a deterioration of the value of intermediaries portfolios. The shock is country specific and I assume that it occurs in the foreign economy. When the shock hits the economy, the level of capital

goes down. The capital is the asset of the banks. Then, when it falls, the balance sheet of the banks shrinks. Moreover, because capital is going down, and given the agency problem of financial intermediaries on obtaining funds from depositors, it takes longer to the economy to recover. Therefore, firms demand fewer loans from the banks because they are reducing how much they borrow; in addition, the supply of loans busts because banks are more financially constrained. A firesale of assets starts that prompts the asset price to go down. This causes a further decrease in the net worth of foreign banks and a tightening of the banks' borrowing constraint.

Foreign banks are more constrained on how much they can borrow. In addition, because of the shock, the return on the foreign and the international assets go up. The latter reduces how much foreign banks borrow from home banks. Less demand prompts a lower price. Then, the asset side of the net worth of home banks goes down because of price and quantities. This tightens home borrowing constraint and depreciates the price of investment at home. Therefore, the price of the asset at home and at foreign fall prompting a decrease in investment and in total demand in both countries.

My analysis is related to three strands of literature. The first one is the international real business cycle one; the second strand is related to the introduction of financial intermediaries in open economies; while the third group is international transmission of financial shocks. Regarding the international business cycle synchronization, **?** build a standard international real business cycle (IRBC) model. They find that to a technology shock, the model predicts a negative international correlation for investment and output. This is because it is efficient to allocate the resources in the more productive country, while reducing them in the less productive one. Several papers afterwards try to improve the results by including frictions in the financial markets to the IRBC model; **?** introduces the **?** model in a two-country model. This literature does not usually model banks explicitly.

Financial intermediaries have been added to international models in the last few years. **?** study financial globalization in a two-country model with banks and a country-specific capital shock. However, they do not study the business cycle properties because production is constant. On the other hand, **?** analyzes the international business cycle in a two-country DSGE model with banks. Although he presents a very complete model, financial frictions arise because there is an asymmetric information problem between the firms and the financial intermediaries. Furthermore, because global banks have deposits from both countries and lend in either of them, there is no gap for the specific relation across banks in different countries. This is also one of the lacks of the work of **?**. In their paper, they look at how much a bank capital requirement affects the international transmission of a shock given

global banks in a two-country model. They find that a very large loan loss induces a decline in both countries.

? points out the relevance of the international transmission of financial shocks to understand how the last crisis, which originated in the U.S. housing sector, transmitted to different countries. Continuing on this strand of literature, **?** develop a two-country DSGE model to highlight how balance sheet constrained agents and portfolio interdependence prompt a large spillover to the other country given a productivity shock. **?** extend the last paper by analyzing how macroeconomic outcomes and welfare behave for different level of financial integration in the bond and equity markets. They find that bond and equity integration is welfare improving with positive co-movement across countries. In a complementary paper, **?** show how equalization of asset prices lead to a higher propagation of an asymmetric shock. Although this literature looks at similar topics to this paper, banks are not modeled explicitly; furthermore, they solve the model using portfolio choice, while in my model I simplify this point by assuming a different discount factor between home and foreign banks.

My paper is very close to the work of **?**. They develop a two country model with banks à la **?**. However, households decide between lending to home or foreign banks. And banks have to decide between providing funds to home or foreign firms. In this sense, households and banks make the decisions and it is not clear which is the initial net foreign asset position. On the contrary, in my paper because home banks are more patient than foreign banks, home banks lend to foreign banks. **?** study the effects of unilateral unconventional monetary policy.

The rest of the paper is organized as follows. In the next section, I describe in the detail the full model. In Section 3, I present the unconventional monetary policy. Section 4 consists on the numerical analysis of a quality of capital shock, including the model with and without policy response. Section 5 concludes.

2 The Model

The model builds on the previous work of **?**. My focus, however, is on the international transmission of a simulated financial crisis. In particular, I introduce a global interbank market, which contributes to the international spillover of the crisis.

I try to keep the framework as simple as possible to analyze the effects of global financial intermediation. As in the previous literature, I focus on a real economy, abstracting from nominal frictions.

2.1 Physical Setup

First, I present the basic setup and then, I add financial frictions. The world consists of two countries, each of which is habited by a continuum of infinitely lived households. In what follows, I describe the home economy; otherwise specified, foreign economy is symmetric. Foreign variables are expressed with a *.

There are a continuum of firms of mass unity. A fraction m corresponds to home country, while a fraction $1-m$ to foreign country. Using an identical Cobb-Douglas production function, each of the firms produces output with local capital and labor. Aggregate home capital, K_t, and aggregate home labor hours, L_t, are combined to produced X_t in the following way,

$$X_t = A_t K_t^{\alpha} L_t^{1-\alpha}, \quad \text{with } 0 < \alpha < 1, \tag{1}$$

where A_t is a home productivity shock. I assume that capital and labor are internationally immobile.

With K_t as the capital stock at the end of period t and S_t as the aggregate capital stock "in process" for period $t+1$, I can define

$$S_t = I_t + (1-\delta)K_t \tag{2}$$

as the sum of investment, I_t, and the undepreciated capital $(1-\delta)K_t$. Capital in process, S_t, is transformed into final capital, K_{t+1}, after taking into account the quality of capital shock, Ψ_{t+1},

$$K_{t+1} = S_t \Psi_{t+1}. \tag{3}$$

Following the previous literature, the quality of capital shock introduces an exogenous variation in the value of capital. It also helps on the asset price dynamics, given that the latter is endogenous. The best way to think about this shock is as an economic obsolesce, in contrast with physical depreciation. The shocks Ψ_t and Ψ_t^* are mutually independent and i.i.d. The shock serves as a trigger for the financial crisis.

As in **?**, I assume that there are local perfectly competitive distributor firms that combine domestic and imported goods to produce final goods. These are used for consumption and investment, and are produced using a constant elasticity of substitution technology

$$Y_t = \left[\nu^{\frac{1}{\eta}} X_t^{H\,\frac{\eta-1}{\eta}} + (1-\nu)^{\frac{1}{\eta}} X_t^{F\,\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}, \tag{4}$$

where η is the elasticity of substitution between domestic and imported goods. There is home bias in production. The parameter ν is a function of the size of the economy and the degree of openness (λ). In particular, $\nu = 1 - (1 - m)\lambda$.

Non-financial firms acquire new capital from capital good producers, who operate at a national level. As in **?**, I assume convex adjustment costs in the gross rate of investment for capital goods producers. Then, the final domestic output is divided into domestic households' consumption, C_t, domestic investment, I_t, and government consumption, G_t,

$$Y_t = C_t + I_t\Big[1 + f\Big(\frac{I_t}{I_{t-1}}\Big)\Big] + G_t.$$

Given that so far this is a frictionless economy in financial autarky, the current account results in the difference between exports and imports,

$$CA_t = 0 = \frac{1-m}{m} X_t^{H*} - \tau_t X_t^F \tag{5}$$

with τ_t as the terms of trade, defined by the price of imports relative to exports for the home economy.

Turning to preferences, households maximize their expected discounted utility

$$U(C_t, L_t) = E_t \sum_{t=0}^{\infty} \beta^t \Big[\ln C_t - \frac{\chi}{1+\gamma} L_t^{1+\gamma} \Big], \tag{6}$$

where E_t is the expectation operator condition on information on date t, and γ is the inverse of Frisch elasticity. I do abstract from many features in the conventional DSGE models, such as habit in consumption, nominal prices, wage rigidity, etc.

In a model without financial frictions, the competitive equilibrium is defined as a solution to the problem that involves choosing aggregate quantities (Y_t, X_t, L_t, C_t, I_t, S_t, X_t^H,X_t^{H*}, Y_t^*, X_t^*, L_t^*, C_t^*, I_t^*, S_t^* X_t^F,X_t^{F*}) as a function of the aggregate state (I_{t-1}, S_{t-1}, A_t, Ψ_t, I_{t-1}^*, S_{t-1}^*, A_t^*, Ψ_t^*) in order to maximize the expected discounted utility of the representative household of home and foreign subject to the resource constraints. This frictionless economy will be the benchmark to compare the different models with financial frictions. It is a standard international real business cycle model in financial autarky with trade in goods.

Next, I introduce banks that intermediate funds between the household and the non-financial firms. The flow of funds will be constrained by the introduction of

financial frictions. A new feature of this model is that home banks can invest in the foreign economy by lending to banks. Then, home and foreign banks will be financially constrained on how much they can borrow from households. Moreover, I assume that foreign banks are not constrained on how much they can borrow from home banks.

2.2 Households

There is a representative household for each of the countries. The household is composed of a continuum of members. A fraction f are bankers, while the rest are workers. Workers supply labor to non-financial firms, and return their wage back to its households. Each of the bankers manages a financial intermediary and transfers non negative profits back to its household subject to its flow of funds constraint. Within the family, there is perfect consumption insurance.

Households deposit funds in a bank, they do not hold capital directly. It might be best to think about households depositing funds in another bank than the one that they own. Deposits are riskless one period securities, and they pay R_t return.

Households choose consumption, deposits, and labor (C_t, D_t^h, and L_t, respectively) by maximizing expected discounted utility, Equation (**??**), subject to the flow of funds constraint,

$$C_t + D_{t+1}^h = W_t L_t + R_t D_t^h + \Pi_t - T_t, \tag{7}$$

where W_t is the wage rate, Π_t are the profits from ownership of banks and non-financial firms, and T_t are lump sum taxes. Then, the first order conditions for the problem of the households are given by

$$L_t : \quad \frac{W_t}{C_t} = \chi L_t^{\gamma} \tag{8}$$

$$D_{t+1}^h : \quad E_t R_{t+1} \beta \frac{C_t}{C_{t+1}} = E_t R_{t+1} \Lambda_{t,t+1} = 1 \tag{9}$$

with $\Lambda_{t,t+1}$ is the stochastic discount factor.

A bank retains earnings to accumulate assets, because she might be finally constraint. While a member continues being a banker, she finds it optimal to save up to the point where the financial constraint that she faces is no longer binding. In order to limit banker's ability to save to overcome being financially constrained, I allow for turnovers between bankers and workers. Then, I assume that with i.i.d. probability σ a banker continues being a banker next period, while with probability $1 - \sigma$ she exits the banking business. If she exits, she transfers retained earnings back to her

household, and becomes a worker. As I explain below, to motivate the global interbank market, I assume that $\sigma^* < \sigma$.

To keep the number of workers and bankers fixed, each period a fraction of workers becomes bankers. A bank needs positive funds to operate, therefore every young banker receives a start-up constant fraction ξ of total assets of the bank. Then, total profits can be defined as net funds transferred to the households from the ownership of the banks plus profits of capital producer firms.

2.3 Non-financial firms

2.3.1 Goods producers

Intermediate competitive goods producers operate at a local level with constant returns to scale technology with capital and labor as inputs, given by Equation (**??**). Labor is mobile inside the same country and the wage is defined by

$$W_t = (1-\alpha)\frac{X_t}{L_t}. \tag{10}$$

The gross profits per unit of capital Z_t are

$$Z_t = \alpha \left[\frac{L_t}{K_t}\right]^{1-\alpha} = \alpha \frac{X_t}{K_t}. \tag{11}$$

To simplify, I assume that non-financial firms do not face any financial frictions when obtaining funds from intermediaries and they can commit to pay all future gross profits to the creditor bank. A good producer will issue new state-contingent securities at price Q_t to obtain funds for buying new capital. Because there is no financial friction, each unit of security is a state-contingent claim to the future returns from one unit of investment. Then, by perfect competition, the price of new capital equals the price of the security and goods producers earn zero profits state-by-state.

The production of these competitive goods is used locally and abroad,

$$X_t = X_t^H + \frac{1-m}{m} X_t^{H*}$$

to produce the final good Y_t following the CES technology explained in Equation (**??**). Then, the demands that the intermediate competitive goods producers face are

$$X_t^H = \nu \left[\frac{P_t^H}{P_t}\right]^{-\eta} Y_t$$

and

$$X_t^{H*} = \nu^* \left[\frac{P_t^{H*}}{P_t^*} \right]^{-\eta} Y_t^*$$

where P_t is the price of the home final good, and P_t^H and P_t^{H*} are the prices of the home good at home and broad, respectively. By the law of one price, $P_t^{H*} S_t = P_t^H$ with S_t as the nominal exchange rate. Rewriting the price of the final good yields

$$\begin{aligned} P_t &= \left[\nu (P_t^H)^{1-\eta} + (1-\nu)(P_t^F)^{1-\eta} \right]^{\frac{1}{1-\eta}} \\ \frac{P_t}{P_t^H} &= \left[\nu + (1-\nu)\tau_t^{1-\eta} \right]^{\frac{1}{1-\eta}}. \end{aligned}$$

Because of the assumption in home bias in the final good production: $P_t \neq P_t^* S_t$; therefore, the real exchange rate is defined by $\varepsilon_t = \frac{P_t^* S_t}{P_t}$.

2.3.2 Capital goods producers

Capital goods producers use final output, Y_t, to make new capital subject to adjustment costs. They sell new capital to goods producers at price Q_t. The objective of non-financial firms is to maximize their expected discounted profits, choosing I_t

$$\max_{I_t} E_t \sum_{\tau=t}^{\infty} \Lambda_{t,\tau} \left\{ Q_\tau I_\tau - \left[1 + f\left(\frac{I_\tau}{I_{\tau-1}} \right) \right] I_\tau \right\}.$$

The first order condition yields the price of capital good, which equals the marginal cost of investment

$$Q_t = 1 + f\left(\frac{I_t}{I_{t-1}} \right) + \frac{I_t}{I_{t-1}} f'\left(\frac{I_t}{I_{t-1}} \right) - E_t \Lambda_{t,t+1} \left[\frac{I_{t+1}}{I_t} \right]^2 f'\left(\frac{I_{t+1}}{I_t} \right). \qquad (12)$$

Profits, which arise only out of the steady state, are redistributed lump sum to households.

2.4 Banks

To finance their lending, banks raise funds from national households and use retained earnings from previous periods. As noted earlier, the survival rate of home banks σ is higher than the one of foreign banks σ^*. Then, home banks can accumulate more net

worth to operate. Moreover, in equilibrium, home banks lend to foreign banks. This interaction between home and foreign banks is what I call global interbank market. Therefore, home banks fund their activity through a retail market (deposits from households) and foreign banks fund their lending through a retail and a wholesale market (where home banks lend to foreign banks).

At the beginning of each period, a bank raises funds from households, i.e. deposits d_t, and, with retained earnings, net worth n_t, she decides how much to lend from available funds to non-financial firms s_t (and, in the case of home banks, to foreign banks b_t, too).

Banks are constrained on how much they can borrow from households. In this sense, financial frictions affect real economy. By assumption, there is no friction on transferring resources to non-financial firms. Hence, firms offer banks a perfect state-contingent security, s_t. The price of the security (or loan) is Q_t, which is also the price of the assets of the bank. In other words, it is the market price of the bank's claim on the future returns from one unit of present capital of non-financial firm at the end of period t, which is in process for period $t+1$.

Next, I describe the characteristics of home and foreign banks.

2.4.1 Home Banks

For an individual home bank, the balance sheet implies that the value of the loans funded in that period, $Q_t s_t$ plus $Q_{bt} b_t$, where Q_{bt} is the price of loans made to foreign banks, has to be equal to the sum of bank's net worth n_t and home deposits d_t,

$$Q_t s_t + Q_{bt} b_t \quad = \quad n_t + d_t.$$

Note that Q_t is not going to be equal to Q_{bt}.

Let R_{bt} be the global asset rate of return from period $t-1$ to period t. The net worth of an individual home bank at period t is the payoff from assets funded at $t-1$, net borrowing costs:

$$n_t \quad = \quad [Z_t + (1-\delta)Q_t]s_{t-1}\Psi_t + R_{b,t}Q_{bt-1}b_{t-1} - R_t d_{t-1},$$

where Z_t is the dividend payment at t on loans funded the previous period, and it is defined by Equation (**??**).

Because the bank is financially constrained, it is optimal to retain earnings until the time she exits the banking business. At the end of period t, the bank maximizes the present value of the future dividends taking into account the probability of continuing being a banker in the next periods; therefore, the value of the bank is defined

by

$$V_t = E_t \sum_{i=1}^{\infty} (1-\sigma)\sigma^{i-1}\Lambda_{t,t+i} n_{t+i},$$

where $\Lambda_{t,t+i}$ is the stochastic discount factor of the households, Equation (**??**).

Following the previous literature, I introduce a simple agency problem to endogenously motivate the ability of the bank to obtain funds. I assume that after the bank obtains funds, the bank may transfer a fraction of assets back to her own household. Because households know this, they limit the funds lent to banks.

Moreover, the funds that the bank might divert are a fraction θ of total assets. If a bank diverts assets, she defaults on her debt and shuts down. Her creditors can re-claim the remained fraction $1-\theta$. Let $V_t(s_t, b_t, d_t)$ be the maximized value of V_t, given an asset and liability configuration at the end of period t. Therefore, the following incentive constraint must hold for each individual bank to ensure that the bank does not divert funds:

$$V_t(s_t, b_t, d_t) \geq \theta(Q_t s_t + Q_{bt} b_t). \tag{13}$$

The borrowing constraint establishes that for households to be willing to supply funds to a bank, the value of the bank must be at least as large as the benefits from diverting funds.

At the end of period $t-1$, the value of the bank satisfies the following Bellman equation

$$V(s_{t-1}, b_{t-1}, d_{t-1}) = E_{t-1}\Lambda_{t-1,t}\Big\{(1-\sigma)n_t + \sigma[\max_{s_t, b_t, d_t} V(s_t, b_t, d_t)]\Big\}. \tag{14}$$

Then, the problem of the bank is to maximize Equation (**??**) subject to the borrowing constraint, Equation (**??**).

I guess and verify that the form of the value function of the Bellman equation is linear in assets and liabilities,

$$V(s_t, b_t, d_t) = \nu_{st} s_t + \nu_{bt} b_t - \nu_t d_t, \tag{15}$$

where ν_{st} is the marginal value of assets at the end of period t, ν_{bt}, the marginal value of global lending, and ν_t, the marginal cost of deposits.

Maximizing the objective function (**??**) with respect to (**??**), with λ_t as the constraint multiplier, yields the following first order conditions:

$$\begin{aligned}
s_t: &\quad \nu_{st} - \lambda_t(\nu_{st} - \theta Q_t) = 0 \\
b_t: &\quad \nu_{bt} - \lambda_t(\nu_{bt} - \theta Q_{bt}) = 0 \\
d_t: &\quad \nu_t - \lambda_t \nu_t = 0 \\
\lambda_t: &\quad \theta(Q_t s_t + Q_{bt} b_t) - \{\nu_{st} s_t + \nu_{bt} b_t - \nu_t d_t\} = 0.
\end{aligned}$$

Rearranging:

$$(\nu_{bt} - \nu_t)(1 + \lambda_t) = \lambda_t \theta Q_{bt} \tag{16}$$

$$\left(\frac{\nu_{st}}{Q_t} - \frac{\nu_{bt}}{Q_{bt}}\right)(1 + \lambda_t) = 0 \tag{17}$$

$$\left[\theta - \left(\frac{\nu_{st}}{Q_t} - \nu_t\right)\right] Q_t s_t + \left[\theta - \left(\frac{\nu_{bt}}{Q_{bt}} - \nu_t\right)\right] Q_{bt} b_t = \nu_t n_t. \tag{18}$$

From Equation (**??**), I can verify that the marginal value of lending in the international asset market is equal to the marginal value of assets in terms of home final good. Let μ_t be the excess value of a unit of assets relative to deposits, Equations (**??**) and (**??**) yield:

$$\mu_t = \frac{\nu_{st}}{Q_t} - \nu_t. \tag{19}$$

Rewriting the incentive constraint (**??**), I can define the leverage ratio net of international borrowing

$$\phi_t = \frac{\nu_t}{\theta - \mu_t}.$$

Therefore, the balance sheet of the individual bank can be written as

$$Q_t s_t + Q_{bt} b_t = \phi_t n_t. \tag{20}$$

The last equation establishes how tightly the constraint is binding. The leverage has positive co-movement with the fraction that banks can divert and negative with the excess value of bank assets.

I verify the conjecture regarding the form of the value function using the Bellman equation (**??**) and the guess (**??**). For the conjecture to be correct, the cost of deposit and the excess value of bank assets have to satisfy:

$$\nu_t = E_t \Lambda_{t,t+1} \Omega_{t+1} R_{t+1} \tag{21}$$

$$\mu_t = E_t \Lambda_{t,t+1} \Omega_{t+1} \left[R_{kt+1} - R_{t+1}\right] \tag{22}$$

where the shadow value of net worth at $t + 1$ is

$$\Omega_{t+1} = (1 - \sigma) + \sigma(\nu_{t+1} + \phi_{t+1} \mu_{t+1})$$

and holds state by state. The gross rate of return on bank assets is given by

$$R_{kt+1} = \Psi_{t+1} \frac{Z_{t+1} + Q_{t+1}(1 - \delta)}{Q_t}.$$

Regarding the shadow value of net worth, the first term corresponds to the probability of exiting the banking business, while the second term represents the marginal value of an extra unit of net worth given that the banker survives. For a continuing banker, the marginal value of net worth corresponds to the sum of the benefit of an extra unit of deposits ν_{t+1} plus the payoff of holding assets, the leverage ratio times the excess value of loans, $\phi_{t+1}\mu_{t+1}$. Because the leverage ratio and the excess return vary counter cyclically, the shadow value of net worth too. In other words, because banks' incentive constraint is more binding during recessions, an extra unit of net worth is more valuable in bad times than in good times.

Then, from Equation (**??**), the marginal value of deposits is equal to the expected augmented stochastic discount factor (the household discount factor times the shadow value of net worth) times the risk free interest rate, R_{t+1}. According to Equation (**??**), the excess value of a unit of assets relative to deposits is the expected value of the product of the augment stochastic discount factor and the difference between the risky and the risk free rate of return, $R_{kt+1} - R_{t+1}$. This "finance premium" is also counter-cyclical. These effects impact on the leverage ratio of the bank, then, uncertainty tights bank's ability on obtaining funds.

From Equation (**??**),

$$\frac{\nu_{st}}{Q_t} = \frac{\nu_{bt}}{Q_{bt}},$$

which implies that the discounted rate of return on home assets has to be equal to the discounted rate of return on global loans

$$E_t\Lambda_{t,t+1}\Omega_{t+1}R_{kt+1} = E_t\Lambda_{t,t+1}\Omega_{t+1}R_{bt+1}, \tag{23}$$

where R_{bt} will be defined in the next section and it is related to the return on non-financial foreign firms. Banks are indifferent between providing funds to non-financial home firms and to foreign banks because the expected return on both assets is equalized. Next, I turn to the foreign banks problem.

2.4.2 Foreign Banks

Similar to home banks, an individual foreign bank's balance sheet states that the total value of funds, which includes deposits from households d_t^*, loans from home banks b_t^*, and retained net worth n_t^*, has to be equal to total loans in the following way

$$Q_t^* s_t^* = n_t^* + d_t^* + Q_{bt}^* b_t^*.$$

The net worth of the bank can also be thought in terms of payoffs; then, the total net worth is the payoff from assets funded at $t-1$, net of borrowing costs, which include the international loans,

$$n_t^* = [Z_t^* + (1-\delta)Q_t^*]s_{t-1}^*\Psi_t^* - R_t^* d_{t-1}^* - R_{bt}^* Q_{bt-1}^* b_{t-1}^*.$$

The problem of a foreign banks is equivalent to the problem of home banks, except for the fact that the interbank loans are a liability for these banks. At the end of period t, the bank maximizes the present value of the future dividends taking into the account the probability of continuing being a banker in the next periods; therefore, the value of the bank is defined by

$$V_t^* = E_t \sum_{i=1}^{\infty} (1-\sigma^*)\sigma^{*,i-1}\Lambda_{t,t+i}^* n_{t+i}^*,$$

where $\Lambda_{t,t+i}^*$ is the stochastic discount factor of the foreign households.

Foreign banks' liabilities consist on household deposits and international loans. Then, a foreign bank might transfer a fraction θ^* of divertable assets back to her own family. Divertable assets are composed of total gross assets net of the global borrowing. Again, if a bank diverts funds for its personal gain, she defaults and shuts down.

The case that I analyze here is equivalent to $\omega = 1$ in Gertler and Kiyotaki. Banks cannot divert funds financed by other banks. In particular, home banks can perfectly recover the interbank market loans. Foreign banks are only constrained on obtaining funds from foreign households, and not from home banks. In this case, the framework can be thought as a one with asset market integration. As I show below, the expected discounted rate of return on global interbank loans is equal to the expected discounted rate of return of loans to non-financial foreign firms and to non-financial home firms, see Equation (**??**). Then, home loan market and foreign loan market behave in a similar way.

Let $V_t^*(s_t^*, b_t^*, d_t^*)$ be the maximized value of V_t^*, given an asset and liability configuration at the end of period t. Therefore, the following incentive constraint must hold for each individual bank to ensure that a bank does not divert funds,

$$V_t^*(s_t^*, b_t^*, d_t^*) \geq \theta^*(Q_t^* s_t^* - Q_{bt}^* b_t^*), \tag{24}$$

where the R.H.S. shows the funds that a bank can run away with, which are total value of assets minus the borrowing from home banks.

At the end of period $t-1$, the value of the bank satisfies the following Bellman

equation

$$V_t^*(s_{t-1}^*, b_{t-1}^*, d_{t-1}^*) = E_{t-1}\Lambda_{t-1,t}\Big\{(1-\sigma^*)n_t^* + \sigma^*[\max_{s_t^*, b_t^*, d_t^*} V^*(s_t^*, b_t^*, d_t^*)]\Big\}. \tag{25}$$

Then, the problem of the bank is to maximize Equation (**??**) subject to the borrowing constraint, Equation (**??**).

I guess and verify that the form of the value function of the Bellman equation is linear in assets and liabilities,

$$V(s_t^*, b_t^*, d_t^*) = \nu_{st}^* s_t^* - \nu_{bt}^* b_t^* - \nu_t^* d_t^*, \tag{26}$$

where ν_{st}^* is the marginal value of assets at the end of period t, ν_{bt}^*, the marginal cost of holding global interbank loans, and ν_t^*, the marginal cost of deposits.

Maximizing the objective function (**??**) with respect to (**??**), with λ_t^* as the constraint multiplier, yields similar first-order conditions to the ones from home. Rearranging the FOCs of the maximization problem of the bank results in

$$(\nu_{bt}^* - \nu_t^*)(1+\lambda_t^*) = \lambda_t^* \theta^* Q_{bt}^* \tag{27}$$

$$\Big(\frac{\nu_{st}^*}{Q_t^*} - \frac{\nu_{bt}^*}{Q_{bt}^*}\Big)(1+\lambda_t^*) = 0 \tag{28}$$

$$\Big[\theta^* - \Big(\frac{\nu_{st}^*}{Q_t^*} - \nu_t^*\Big)\Big] Q_t^* s_t^* - \left[\theta^* - \left(\frac{\nu_{bt}^*}{Q_{bt}^*} - \nu_t^*\right)\right] Q_{bt}^* b_t^* = \nu_t^* n_t^*. \tag{29}$$

Equation (**??**) suggests that the shadow value of global borrowing and domestic assets are equalized,

$$\frac{\nu_{st}^*}{Q_t^*} = \frac{\nu_{bt}^*}{Q_{bt}^*}; \tag{30}$$

or if I write it in terms of returns:

$$E_t \Lambda_{t,t+1}^* \Omega_{t+1}^* R_{kt+1}^* \quad = \quad E_t \Lambda_{t,t+1}^* \Omega_{t+1}^* R_{bt+1}^*. \tag{31}$$

I refer to this case as asset market integration because of the equalization of returns between the global and the non-financial firms loans. Then, given a shock, the return on the global interbank asset is going to be as volatile as the return on domestic asset, emphasizing the transmission mechanism from one country to the other one.

Let μ_t^* be the excess value of a unit of assets (or international borrowing) relative to deposits,

$$\mu_t^* = \frac{\nu_{st}^*}{Q_t^*} - \nu_t^*. \tag{32}$$

The incentive constraint can be written as

$$\begin{aligned} Q_t^* s_t^* - Q_{bt}^* b_t^* &= \frac{\nu_t^*}{\theta^* - \mu_t^*} n_t^* \\ Q_t^* s_t^* - Q_{bt}^* b_t^* &= \phi_t^* n_t^*. \end{aligned} \tag{33}$$

Similar to home banks, how tightly the constraint is binding depends positively on the fraction of assets and negative on the excess value of bank asset. Equivalent to the home bank's problem, I call ϕ_t^* leverage.

With Ω_{t+1}^* as the shadow value of net worth at date $t+1$, and R_{kt+1}^* as the gross rate of return on bank assets, after verifying the conjecture of the value function it yields

$$\nu_t^* = E_t \Lambda_{t,t+1}^* \Omega_{t+1}^* R_{t+1}^* \tag{34}$$

$$\mu_t^* = E_t \Lambda_{t,t+1}^* \Omega_{t+1}^* \left[R_{kt+1}^* - R_{t+1}^* \right] \tag{35}$$

with

$$\begin{aligned} \Omega_{t+1}^* &= 1 - \sigma^* + \sigma^* \left(\nu_{t+1}^* + \phi_{t+1}^* \mu_{t+1}^* \right) \\ R_{kt+1}^* &= \Psi_{t+1}^* \frac{Z_{t+1}^* + Q_{t+1}^* (1-\delta)}{Q_t^*}. \end{aligned}$$

2.4.3 Aggregate Bank Net Worth

Finally, I can aggregate across home banks, from Equation (**??**):

$$Q_t S_t + Q_{bt} B_t = \phi_t N_t. \tag{36}$$

Furthermore,

$$N_t = (\sigma + \xi) \left\{ \left[Z_t + (1-\delta) Q_t \right] S_{t-1} \Psi_t + R_{b,t} Q_{b,t-1} B_{t-1} \right\} - \sigma R_t D_{t-1}.$$

The last equation specifies the net worth's law of motion of the home banking system. Capital letters indicate aggregate variables. The first term in the curly brackets represents the loans made last period. The second term in the curly brackets is the return on funds that the household invested on the foreign economy. Both loans are scaled by the old bankers (that survived from last period) plus the start-up fraction of loans that young bankers receive. The last term in the equation is total return on households deposits that banks need to pay back.

For foreign banks the aggregation yields

$$N_t^* = (\sigma^* + \xi^*) \left[Z_t^* + (1-\delta) Q_t^* \right] S_{t-1}^* \Psi_t^* - \sigma^* R_t^* D_{t-1}^* - \sigma^* R_{bt}^* Q_{bt-1}^* B_{t-1}^*,$$

where R^*_{bt} equals R^*_{kt}, from Equation (**??**). The balance sheet of the aggregate foreign banking system can be written as

$$Q^*_t S^*_t - Q^*_{bt} B^*_t = \phi^*_t N^*_t. \tag{37}$$

2.4.4 Global interbank market

Because the survival rate of home banks is higher than the survival rate of foreign banks, at the steady state, home banks invest in the foreign economy; therefore, they lend to foreign banks. It is in this sense that an international interbank market arises. Then, foreign banks have an incentive to borrow from home banks because the former are more constrained than the latter.

Other way of thinking about the global interbank market is by assuming that the deposits that foreign banks can get from foreign households are not enough to cover the capital that foreign firms demand. In other words, in the foreign country, capital is higher than national savings. And, because at home deposits are higher than investment, there is a gap for an international transaction.

Regarding the interest rate, the return on loans to foreign banks made by home banks is R_{bt}. This rate is equalized to the return on loans to home firms, R_{kt}, in expected terms. Then, they are indifferent between lending to home firms or to foreign banks, from Equation (**??**)

$$E_t \Lambda_{t,t+1} \Omega_{t+1} R_{kt+1} = E_t \Lambda_{t,t+1} \Omega_{t+1} R_{bt+1}.$$

For foreign banks, the rate of return that they pay on global loans is equal to Equation (**??**):

$$E_t \Lambda^*_{t,t+1} \Omega^*_{t+1} R^*_{kt+1} = E_t \Lambda^*_{t,t+1} \Omega^*_{t+1} R^*_{bt+1}.$$

In addition, I assume that the rate of return on the global asset market is related to the gross return on capital in the foreign country in the following way

$$R^*_{b,t+1} = \Psi^*_{t+1} \frac{Z^*_{t+1} + Q^*_{b,t+1}(1-\delta)}{Q^*_{bt}}. \tag{38}$$

Then, the quality of capital shock at foreign also enters on the rate of return of the global interbank asset.

2.5 Equilibrium

To close the model I need equilibrium in the different markets. The equilibrium in the final goods market for home and for foreign are

$$Y_t = C_t + I_t\Big[1 + f\Big(\frac{I_t}{I_{t-1}}\Big)\Big] + G_t \text{ and} \tag{39}$$

$$Y_t^* = C_t^* + I_t^*\Big[1 + f\Big(\frac{I_t^*}{I_{t-1}^*}\Big)\Big] + G_t^*. \tag{40}$$

Then for the intermediate-competitive goods market,

$$X_t^* = X_t^F\frac{m}{1-m} + X_t^{*F} \quad \text{and} \quad X_t = X_t^H + X_t^{*H}\frac{1-m}{m}. \tag{41}$$

The markets for securities are in equilibrium when

$$S_t = I_t + (1-\delta)K_t = \frac{K_{t+1}}{\Psi_{t+1}} \quad \text{and} \quad S_t^* = I_t^* + (1-\delta)K_t^* = \frac{K_{t+1}^*}{\Psi_{t+1}^*}.$$

The conditions for the labor market are

$$\chi L_t^{\gamma} = (1-\alpha)\frac{X_t}{L_t C_t} \quad \text{and} \quad \chi L_t^{*\gamma} = (1-\alpha)\frac{X_t^*}{L_t^* C_t^*}. \tag{42}$$

The global asset is in zero net supply, as a result

$$B_t = B_t^*\frac{1-m}{m}. \tag{43}$$

To close the model the last conditions correspond to the riskless debt. Total household savings equal total deposits plus government debt. Government debt is perfect substitute of deposits to banks,

$$D_t^h = D_t + D_{gt} \quad \text{and} \quad D_t^{h*} = D_t^* + D_{gt}^*. \tag{44}$$

I introduce government in the next section.

3 Unconventional Policy

Following Gertler and Kiyotaki, I introduce one possible intervention of a local central bank. I consider that a central bank can lend directly to local non-financial firms

in order to mitigate the effect of the crisis. I suppose that the policy is carried out only by the foreign policy maker because the foreign country is directly hit by the shock. Then, the central bank endogenously determinates the fraction of private credit. The level of intermediation follows the difference between the spread of the expected return on capital and the deposits rate, and their steady state level

$$\varphi_t^* = \nu_g^*[E_t(R_{k,t+1}^* - R_{t+1}^*) - (R_k^* - R^*)]. \tag{45}$$

Because the central bank is going to lend directly to non-financial firms, the total assets of a firm can be written as

$$Q_t^* S_t^* = Q_t^*(S_{pt}^* + S_{gt}^*)$$

where S_{pt}^* are the loans made by financial firms, and S_{gt}^* the ones made by the government. Assuming that S_{gt}^* is a fraction of the total credit, I can rewrite Equation (**??**),

$$\begin{aligned} Q_t^*(\underbrace{S_t^* - \varphi_t^* S_t^*}_{S_{pt}^*}) - Q_{bt}^* B_t^* &= \phi_t^* N_t^* \\ Q_t^* S_t^*(1 - \varphi_t^*) - Q_{bt}^* B_t^* &= \phi_t^* N_t^*. \end{aligned} \tag{46}$$

Furthermore, the equations of the foreign banking system become

$$\begin{aligned} Q_t^* S_t^*(1 - \varphi_t^*) &= N_t^* + D_t^* + Q_{bt}^* B_t^* \\ N_t^* &= (\sigma^* + \xi^*)[Z_t^* + (1-\delta)Q_t^*]S_{t-1}^* \Psi_t^*(1 - \varphi_{t-1}^*) - \sigma^* R_t^* D_{t-1}^* - \sigma^* R_{bt}^* Q_{b,t-1}^* B_{t-1}^*. \end{aligned}$$

3.1 Government

Consolidating monetary and fiscal policy, the government budget constraint is going to be such that the total expenditure on goods, G_t^*, total loans to firms, S_{gt}^*, and debt issued last period, $R_t^* D_{gt-1}^*$, have to equal the resources for that period; resources are mainly taxes/subsidies, T_t^*, new debt issued this period, D_{gt}^*, and the return on loans to firms made last period. Then,

$$G_t^* + Q_t^* S_{gt}^* + R_t^* D_{gt-1}^* = T_t^* + D_{gt}^* + [Z_t^* + (1-\delta)Q_t^*]\,\Psi_t^* S_{gt-1}^*.$$

The debt that government issues is a perfect substitute of the deposits to banks, therefore, the rate that they pay is the same and households are indifferent between lending to banks and to the government. Government expenditure is a constant fraction of total output. Taxes arise outside the steady state as next condition shows

$$T_t^* = \nu_\tau^*(R_t^* D_{gt-1}^* - R^* D_g^*).$$

4 Crisis experiment

In this section, I present numerical experiments to show how the model captures key aspects of the international transmission of a financial crisis through the asset market and how credit market intervention can help to mitigate the effects of the crisis. One aspect that I highlight is how the global asset market works as insurance for the economy that is hit by a shock.

First, I present the calibration. Then, I analyze a crisis experiment without response of the government, making a remark in the properties and the international transmission mechanism of the model. Finally, I show a possible response of the central bank given that the crisis hits the economies.

4.1 Calibration

The calibration is specified in Table **??**. The parameters that correspond to the non-financial part of the model, i.e. households and non-financial firms, follow the literature. The discount factor, β is set to 0.99, resulting in a risk free interest rate of 1.01% at the steady state. The inverse of the Frisch elasticity of labor supply, γ, and the relative weight of labor in the utility faction, χ, are equal to 0.1 and 5.584, respectively. The capital share in the production of the intermediate good, α, is 0.33 and the parameter in the adjustment cost in investment, κ, equals 3. The depreciation rate of capital is 2.5% quarterly.

The elasticity of substitution between home and foreign goods in the production of the final good, η, is set to be less than one, as the estimates from **?**, **?**, and **?**. This implies a complementarity between domestic and foreign goods. Regarding the home bias, ν, it is defined by the size of the home economy and the degree of openness. Both parameters are determined by the ratio of real imports to real final domestic demand for Switzerland, using SECO data from 2000Q1 until 2007Q2. Then, the implied size of Switzerland is set to 0.49, while the degree of openness is 0.86. This yields a home bias for home -$1-(1-\lambda)m$- of 0.5614, while the home bias for foreign -$(1-m)(1-\lambda)$- is 0.5786.

The parameters of the financial sector are such that the average credit spread is 110 basis points per year; the credit spreads are equal for both economies. This is a rough approximation of the different spreads for the pre-2007 period. In particular, how tightly the constraint is binding, θ, matches that target. The start-up fraction that the new banks receive, ξ, corresponds to a 0.18% of the assets that they have from last period, which corresponds to the value used by **?**. The survival rate is

		Home	Foreign
β	discount factor	0.9900	0.9900
γ	inverse elasticity of labor supply	0.1000	0.1000
χ	relative utility weight of labor	5.5840	5.5840
α	effective capital share	0.3330	0.3330
κ	adj cost parameter	3.0000	3.0000
δ	depreciation	0.0250	0.0250
ν	home bias	0.5614	0.5786
η	elasticity of substitution	0.7000	0.7000
m	islands	0.4900	0.5100
ξ	start-up	0.0018	0.0018
θ	fraction of div assets	0.4067	0.4074
σ	survival rate	0.9720	0.9700
ρ^*_ψ			0.0000
σ^*_ψ			0.0500

Table 1: Calibration

different across countries, as a result a global interbank market exists at the steady state, being 0.972 and 0.97 for home and foreign banks, respectively. On average, home banks survive 9 years, while foreign banks around 8 years. At the steady state, the holding of global asset represents 31% of the total assets of the home banks, which matches the data for total lending of Swiss banks from 2000Q1 until 2007Q2 (see Appendix for more details regarding the data and its sources).

I assume an i.i.d. negative quality of capital shock of 5% that hits the foreign economy and is transmitted to home.

4.2 No policy response

Figures **??** and **??** show the impulse responses to a decline in the foreign quality of capital of 5% in period t comparing three models. The first model is one without financial frictions and in financial autarky and is the green thick dashed line. The second model has financial frictions but not trade in assets, and is the blue full line. The financial frictions are à la Gertler and Kiyotaki. The third model is with financial frictions and a global interbank market (financial openness); it is the red thin dashed line. Comparing these models shows how the transmission mechanism across

countries changes given that in the first two there is only international spillover due to the trade in intermediate goods, while in the third one, I add the international financial mechanism. Moreover, it will help on understanding the insurance role of the interbank market. Figure **??** shows the foreign economy variables, while Figure **??** shows the home variables.

Given a decrease in Ψ^*, foreign quality of capital shock, the foreign capital

Results_130404_6.pdf

Figure 3: IRF, model comparison without policy response - Foreign variables

decreases because of the direct impact, as we learn from Equation (**??**). If there are no banks in the economy, no financial frictions, and the countries are in financial autarky, foreign economy starts to work on the recovery of their level of capital; the economy channels resources to increase investment, and so does the price of the capital, Q_t^*. Production, X_t^*, goes down because of the impact of the shock and the decrease in capital. On impact, consumption, C_t^*, drops due to the reduction in the labor income (wages are falling). Total demand in F, Y_t^*, also falls because the decrease in consumption is higher than the recovery of investment. The country decreases not only its demand of local goods, X_t^{*F}, but also its imports, X_t^{*H}. However, the fall in home goods is less than the fall in foreign goods; therefore, the terms of trade slightly improve for home. Foreign goods are relatively cheaper than home

Results_130404_5.pdf

Figure 4: IRF, model comparison without policy response - Home variables

goods. For this model, the trade balance is defined by Equation (**??**) and equals zero every period because there is no international borrowing/lending.

The foreign demand of home goods decreases; then, home cuts down in production, X_t. This is the case because home is affected by the appreciation of its real exchange rate. Although the slight decrease in production, there is an increase in consumption and investment. Home economy gets a bust only in demand because foreign goods are cheaper. In this model without financial frictions and in financial autarky, there is neither international co-movement in consumption nor in total demand. Nevertheless, there is co-movement in production and asset prices, while the terms of trade improve for the home economy.

Regarding the model with financial frictions but without global interbank market, the foreign economy reacts to the shock as in Gertler and Kiyotaki. Given that in this model there are banks and they are financially constrained, when their asset (capital) goes down, they face a decrease in their net worth. Due to the fact that banks are also more constrained on how much they can borrow, and that firms reduce the demand for loans, there is a firesale of asset that prompts a bust in the price, Q_t^*.

The spread between the foreign rate of return on capital and the risk free rate, $E(R_k^*) - R^*$, jumps up. The behavior of the spread is a characteristic of the crisis period. In particular, the expected rate of return on capital increases because of the reduction in the quality of the capital.

Foreign production and consumption go down. Similar to the no financial frictions and financial autarky model, the terms of trade go slightly down, with an appreciation for the home economy. This is the case because the foreign economy experiences a deeper recession in demand than in production, with investment falling. Foreign behaves as in the previous model, decreasing its imports, while increasing its exports, X_t^F. The increase in foreign exports prompts a boom in demand at home.

When the demand of home goods from foreign decreases, production at home goes down. However, investment increases, the rise in the demand of capital comes with an expansion in the net worth of banks that follows an improvement in the asset price, the financial friction is less binding. Consumption and total demand go up because the home economy can increase the imports of foreign goods. The international transmission of the shock is similar to the previous model. The asset prices do not co-move in neither of the two models. Although there is a larger spillover to the home economy with financial frictions that without them, banks get a boom on their net worth after a negative quality of shock in foreign.

In the model with global interbank market, as in the model with financial frictions and in financial autarky, home banks have a higher survival rate than foreign banks; then, the former can accumulate more net worth than the latter. With financial openness, home banks can lend to foreign banks. Hence, the introduction of an international asset allows the foreign economy to borrow internationally by diversifying the liabilities of the banks, and to pool a country specific shock. These asset markets characteristics have been first discussed by **?**.

When the shock hits the foreign economy, local capital, production, asset price, and net worth fall. On impact, the reaction is similar for the two models with financial frictions, as Figure **??** suggests (look at the full-blue and the dashed-red line). The mechanism that takes place for these variables is the same as explained for the case with financial frictions and financial autarky.

Total foreign demand drops less in this model because consumption and investment fall less. The decrease on the interest rate that foreign banks pay on deposits prompts the smoother reduction of consumption and investment. Moreover, the net worth of foreign banks shrinks less because they can diversify the impact of the crisis between the reduction of deposits and the interbank market borrowing. It is in this sense that the international interbank market works as an insurance.

Given the shock, and the structure of the interest rate on the global interbank

market, Equation (??), the return that foreign banks have to pay to home banks goes up. Therefore, they reduce how much they borrow from them. Not only the quantities of the international loans are going to decrease, but also the price of these loans. Then, the recession is transmitted to the home economy. Home banks experience a decrease in their net worth because their asset side is shrinking, Figure ??. This is partly reflected in the current account equation. In this framework there is some level of financial openness; henceforth, the current account is defined by

$$CA_t = Q_{b,t}B_t - R_{bt}Q_{b,t-1}B_{t-1} - \left(X_t^{*H} \frac{1-m}{m} \frac{P_t^H}{P_t} - X_t^F \tau_t \frac{P_t^H}{P_t} \right).$$

Given that the net financial income of the home economy is falling by 40% points, the trade balance (exports minus imports) has to shrink too. In this sense, the imports are decreasing, while exports and the terms of trade are increasing.

Home economy experience two types of spillovers: the demand and the global asset effects. The demand effect prompts an increase in production because the home economy experiences a depreciation of the exchange rate. The global asset effect generates a tightening of the home borrowing constraint because there is a decrease in the volume of international borrowing.

Considering that the price and the quantities of the international asset market are going down, home banks have to reduce how much they can lend to local firms; hence, the price of capital goes down. This takes investment down.

Therefore, home and foreign consumption, asset price, and total demand co-move, while production does not.[3] Moreover, the asset market across countries is integrated because of the equalization of returns of the asset market at home and abroad.

The qualitative behavior of the model matches the VAR evidence shown in Figure ??. In the data, a decrease in the American loans prompts a decrease in the domestic asset price that then is transmitted to the other economy. A depression of the total final demand follows, with a decrease in total foreign loans, a reduction in the net interest payment and a collapse of the asset price.

Home economy gets a larger co-movement with the foreign economy in a framework with financial openness than without it. Home economy experiences a depression because of the quality of capital shock abroad, as shown by the VAR evidence and the model. Moreover, through the global interbank market, foreign economy manages to partially insurance itself against the shock.

[3]Production showing negative international co-movement could be explained by the fact that the model is real and it abstracts from many rigidities that the usual DSGE models have.

4.3 Policy response

In this section, I analyze a possible credit market intervention by the foreign central bank that tries to mitigate the effects of the crisis. In particular, I look at direct lending to non-financial firms. What motivated the Federal Reserve to intervene in the credit market was the abnormal credit spread in several markets. It is in this sense, that Gertler and Kiyotaki model the credit policy. The central bank can choose the fraction of private credit to intermediate by following the difference between the spread and its steady state value, as in Equation (**??**). I assume that the policy is only used in the country hit by the shock. Figures **??** and **??** show the results. The full black line is the model with policy, while the red dashed line is the model without policy, in both cases with global banks.

The policy parameter ν_g is set to be 100. Then, the central bank starts sell-

Results_130325_8.pdf

Figure 5: IRF, Unconventional monetary policy - Foreign variables

ing assets in the capital market if the spread between the risky and the risk free interest rate is higher than the steady state value. Because the shock prompts this circumstance, the central bank intervenes in the market by selling assets; the initial intervention is less than 7.5% of total foreign assets. By increasing the amount of

Results_130325_7.pdf

Figure 6: IRF, Unconventional monetary policy - Home variables

loans there is a reduction on the price of them. In this sense, the risky interest rate is damped, as I show in Figure **??**. In consequence, the net worth of the foreign banks is reduced by at least 10% less than without the policy. Moreover, the price of the capital remains almost constant. Then, investment does not fall. Because the price and the interest rate of the global loans adjust, foreign banks do not change their behavior in terms of international interbank quantities.

This specific policy shuts down the increase of the expected rate of return on foreign capital. Because of this, the rate of return on global interbank assets that foreign banks need to pay to home banks does not raise as much as in the model without policy. Then, the price of the asset does not move and that is why only the quantities adjust. Home banks cannot access directly to the monetary policy but they get benefits from it by this mechanism.

The global lending of home banks is reduced by less with the credit policy than without it. The net worth of home banks drops less, as we learn from Figure **??**. Moreover, the asset price increases with the foreign policy, this is the case because the net worth is reduced by 2% on impact and, as we know from the previous analysis, home economy experiences a boom in terms of production because of the deprecia-

tion of the terms of trade.

In conclusion, with this credit policy, not only the foreign economy gets a smoother impact of the crisis, but also the home economy benefits from it. Although home banks cannot access directly to the credit given by the foreign central bank, it benefits from the impact of this policy on the global interbank market. In particular, the net worth of the home banks and the interbank market price move slightly. In addition, home consumption drops by almost 50% less, and total demand falls by a third less than without the policy.

5 Conclusions

I have presented a two-country DSGE model with financial intermediaries that helps on explaining part of the international transmission mechanism of the last financial crisis. In particular, banks in both countries are borrowing constrained. However, home economy can invest in the foreign economy through banks. Therefore, home banks lend to foreign banks using a global asset that has its return related to the return on capital of the foreign economy.

After comparing a model with financial frictions but in financial autarky with one with a global interbank market, I conclude that the latter one develops a higher co-movement of the crisis that matches qualitatively the behavior of the data, as shown in the VAR analysis. When a quality of capital shock hits the foreign economy, not only the domestic economy presents a depression in real and financial variables, but also the economy from abroad. The global interbank market prompts this international transmission. Because the price of the asset is going down, home banks want to reduce how much they invest in the foreign economy. As a result, the net worth of home banks drops. Then, the quantity of the global transaction shrinks. Home banks face a reduction in their balance sheet; in addition, they are more constrained to lend in the domestic market. The price of the home domestic assets drops prompting a fall in investment, consumption, and total demand. The key aspect of the transmission mechanism is the equalization of returns across countries; this implies co-movement in asset prices and spreads between the risky and the risk free interest rate.

Then, I study the introduction of unconventional monetary policy, in particular, direct lending of the foreign central bank to non-financial firms. This policy is effective on mitigating the effects of the crisis not only in the domestic country, but also abroad. Because of the equalization of returns across countries, when the central bank intervenes to reduce the abnormal excess return, the expected return on assets in foreign falls. This causes the price of the global interbank loan to decrease by

much less, prompting a lower decrease of home banks net worth.

In the model, home can only invest in foreign through the banks. I just look at the net foreign asset position. In reality, the FX swaps and the interbank market, among other derivatives, make the relation across banking systems much more complicated. I believe that this simple relation between global banks helps on understanding part of the international transmission of the crisis.

A Data and Sources

lhplo_us Real U.S. loans. Loans and leases in bank credit, all commercial banks (in billions of dollars, seasonally adjusted), divided by consumer price index. Source: Federal Reserve Bank of St. Louis (FRED).

lhpsp500 Real S&P 500. S&P 500 Stock Price Index (not seasonally adjusted). Source: FRED.

lhpfdd Real Swiss domestic demand. Domestic demand (in millions of Swiss Francs, at prices of preceding year, chained values, reference year 2005, seasonally adjusted). Source: State Secretariat for Economic Affairs (SECO).

lhplo_usd Real Swiss loans denominated in U.S. dollars. Domestic and foreign assets, claims against banks plus claims against customers denominated in U.S. dollars for all banks (in millions of Swiss Francs), divided by consumer price index. Source: Monthly Balance Sheets, Monthly Bulletin of Banking Statistics, Swiss National Bank (SNB) and SECO.

hpnip Real Swiss net interest payments. Net labor and investment income (in billions of Swiss Francs), divided by consumer price index. Source: Swiss Balance of Payments, SNB and SECO.

lhpsmi Real SMI. Swiss market index (not seasonally adjusted). Source: Monthly Statistical Bulletin, SNB.