

# 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 constraint on how much they can borrow. The main goal is to have a framework that not only captures some aspect of the international transmission of a financial crisis, but can also help on 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 on mitigating the effects of this simulated crisis.

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# 1 Introduction

Half of the Swiss banks assets are denominated in foreign currency; and half of them are in U.S. dollars. Starting in 2002, Swiss banks increased their net foreign asset position (assets minus liabilities) in U.S. dollars. Because they were holding more assets than liabilities, they needed to finance this gap with other derivatives. As McGuire and von Peter (2009) sustain, this gap was closed by the use of the foreign exchange (FX) swaps between Swiss and American institutions. In particular, Swiss banks used the FX swaps to convert the domestic currency liabilities into foreign currency, and then to buy foreign assets. In this sense, Swiss banks borrowed short term U.S. dollars from U.S. agents to finance their long-term U.S. dollar denominated assets. Figure 1 shows the net foreign asset position in U.S. dollars for the Swiss banking sector. The data provides a measure on the Swiss banks risk exposures to the inability to roll over the FX U.S. dollar denominated swaps (OECD, 2009).

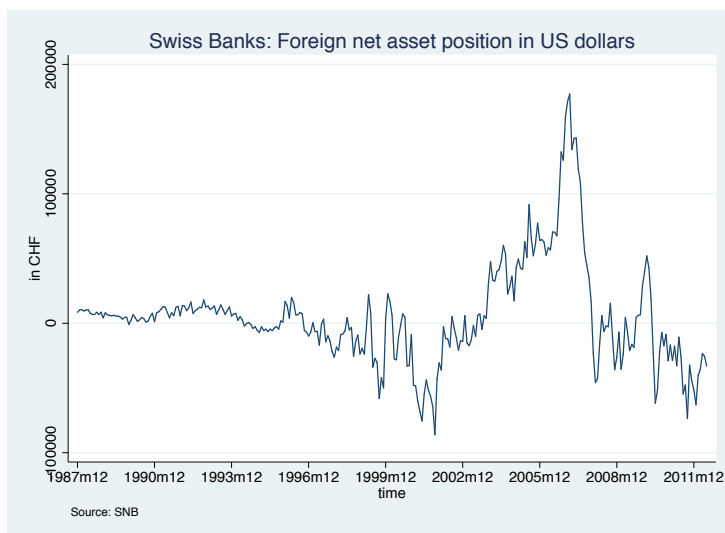


Figure 1: Swiss Banks: Foreign net asset position in U.S. dollars

When the U.S. dollar supply started to scarce, coming from the problems in the housing sector, Swiss banks found it more costly to roll-over their FX dollar denominated swaps. This, in addition to the failure of Lehman Brothers in September 2008, triggered a severe liquidity crisis in the provision of U.S. dollars. Therefore, banks could not roll over their debt. To pay back their liabilities, Swiss banks started a firesale of U.S. dollar denominated assets. This situation is reflected in Figure 1,

where there is a reduction on the net asset position in U.S. dollars at the end of the year 2007. The increase in the supply of U.S. dollar denominated assets went along with a bust in the price of these assets. This prompted a reduction in the net worth of Swiss banks. Because of the large size of the Swiss banks relative to the size of the economy, the crisis spread to the local economy.

As a result of the liquidity crisis in the provision of U.S. dollars, 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 and an international asset, I am interested in the transmission mechanism from one country to the other one. I also focus on the role of insurance of the international asset market. Furthermore, I look at how unilateral unconventional monetary policy might mitigate the effects of the crisis. To answer to these questions, I develop a two-country dynamic stochastic general equilibrium model (henceforth, DSGE) that builds on Gertler and Kiyotaki (2010) and Gertler and Karadi (2011).

In the model, banks finance can their activity through two different sources. Banks have access to a retailer 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. Foreign banks do not have a constraint on borrowing from home banks. I assume a central bank per country. Furthermore, I abstract from any other frictions, including the one of banks lending to non-financial firms.

First, I use the model to study how a country-specific quality of capital shock, that simulates part of the financial crisis, spills over the other country. The shock occurs at foreign. I study the transmission mechanism in the context of imperfect substitutable intermediate goods. In particular, I compare a model without financial frictions, that I call international real business cycle model, with a model with financial frictions but without global banks, à la Gertler and Kiyotaki. These models consist of economies in financial autarky. Then, I allow for an international asset. I study the case in which foreign banks are not constraint on how much they can borrow from home banks. When foreign banks are allow to borrow from home banks, the international asset works as an insurance for the foreign economy. Moreover, this economy works as one with integration of the asset market.

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 on mitigating the effects

of the crisis domestically and abroad. Specifically, I study if the unilateral monetary policy helps to have a faster recovery from a crisis and if the spillover in the home economy is smaller under the policy framework.

What is new in this framework is the analysis of the transmission mechanism of a financial crisis across countries. In particular, the transmission through the international asset 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 will show, the introduction of the international asset prompts high level of co-movement between the foreign and the home economy.

As in the previous literature, I simulate the model given a quality of capital shock. The purpose of this type of shock is to have a deterioration on the value of intermediate portfolios. The shock is country specific and I assume that it occurs in foreign. When the shock hits the economy the 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 for financial intermediaries on obtaining funds from depositors, it takes longer to the economy to recover. Therefore, firms demand less loans from the banks because they are reducing how much they borrow; in addition, the supply of loans busts because banks are more financially constraint. 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 constraint on how much they can borrow. In addition, because of the shock, the return on the foreign and the international asset go up. The latter reduces how much foreign banks borrow from home banks. Less demand prompts lower price. Then, the asset side of the net worth of home banks goes down because of prices and quantities. This tightens home borrowing constraint and depreciates the price of investment at home. Therefore, the price of the assets at home and in foreign fall prompting a decrease in investment in both countries.

My analysis is related to two different economic literatures. The first class of papers is the international real business cycle one; the second group is financial intermediaries in open economies. Regarding the international business cycle synchronization, Backus, Kehoe, and Kydland (1992) built a standard international real business cycle (IRBC) model. They found 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 tried to improve the results by including frictions in the financial markets to the IRBC model, like Faia (2007) who introduces the Bernanke, Gertler, and Gilchrist (1999) 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. Mendoza and Quadrini (2010) study financial globalization in a two-country model with banks and a bank country-specific capital shock. However, they do not study the business cycle because production is constant. On the other hand, Ueda (2012) analyzes the international business cycle in a two-country DSGE model with banks. Although he presents a very complete model, the financial frictions arises 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 Kollmann, Enders, and Müller (2011). 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.

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 Gertler and Kiyotaki (2010). My focus, however, is on the international transmission of a simulated financial crisis. In particular, I introduce a global asset, which contributes to the international spillover of the crisis.

I try to keep the framework as simple as possible to analyze clearly the effects of 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 produce  $X_t$  in the following way,

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

where  $A_t$  is the 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

$$S_t = I_t + (1 - \delta)K_t \quad (2)$$

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,  $\Psi_{t+1}$ ,

$$K_{t+1} = S_t \Psi_{t+1}. \quad (3)$$

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  $\Psi_t$  and  $\Psi_t^*$  are mutually independent and i.i.d. The shock serves as a trigger for the financial crisis.

As in Heathcote and Perri (2002), I assume that there are local perfectly competitive distributors firms that combine local and imported goods to produce final goods. These are used for consumption and investment using a constant elasticity of substitution technology

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

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

Non-financial firms acquire new capital from capital good producers who operate at a national level. I assume convex adjustment costs in the gross rate of investment

for capital goods producers, as in Christiano, Eichenbaum, and Evans (2005). Then, the final domestic output is divided into domestic households' consumption,  $C_t$ , domestic investment,  $I_t$ , and government consumption,  $G_t$ ,

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

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

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

with  $\tau_t$  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

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

where  $E_t$  is the expectation operator condition on information on date  $t$  and  $\gamma$ , the inverse of Frisch elasticity. I do abstract from many frictions 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 of 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 ( $I_{t-1}, S_{t-1}, A_t, \Psi_t, I_{t-1}^*, S_{t-1}^*, A_t^*, \Psi_t^*$ ) 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 two 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 through 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 by 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 households 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.

Household chooses consumption, deposits, and labor ( $C_t$ ,  $D_t$ , and  $L_t$ , respectively) to maximize expected discounted utility, Equation (6), subject to the flow of funds constraint,

$$C_t + D_{t+1} = W_t L_t + R_t D_t + \Pi_t, \quad (7)$$

where  $W_t$  is the wage rate and  $\Pi_t$  are the profits from ownership of banks and non financial firms. Then, the first order conditions for the problem of the households are given by

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

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

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

Due to the fact that banks might be financially constrained, a bank retains earnings to accumulate assets. 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. 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  $\sigma$  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 its household, and becomes a worker. As I explain later, to motivate the 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 to operate needs positive funds, therefore, every young banker receives a start-up constant fraction  $\xi$  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 producers 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 (1). Labor is mobile inside the same country and the wage is defined by

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

The gross profits per unit of capital  $Z_t$  are

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

To simplify, I assume that non-financial firms do not face any financial frictions in 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 (4). Then, the demand that the intermediate competitive goods producers face is given by

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

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

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

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 take final output,  $Y_t$ , and 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

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

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 retain earnings from previous periods. As noted earlier, the survival rate of home banks  $\sigma$  is higher than the one of foreign banks  $\sigma^*$ . 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 asset market. Therefore, home banks fund their activity through a retail market (deposits from households) and foreign banks fund their lending through a retail market 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 funds they can borrow. It is in this sense that 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  $t + 1$ .

Next, I describe separately the particularities 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  $d_t$ ,

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

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:

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

where  $Z_t$  is the dividend payment at  $t$  on loans funded the previous period, and it is defined by Equation (11).

Because the bank is financially constrained, it is optimal to accumulate retained earning 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 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 households, Equation (9).

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 obtained funds, the bank may transfer a fraction of assets back to her own household. Because the households know this, they limit the funds lent to banks.

Moreover, the funds that the bank might divert is a fraction  $\theta$  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 constrain must hold for each individual bank to ensure that the bank does not divert funds:

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

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

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

Then, the problem of the bank is to maximize Equation (14) subject to the borrowing constraint, Equation (13).

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

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

where  $\nu_{st}$  is the marginal value of assets at the end of period  $t$ ,  $\nu_{bt}$ , the marginal value of global lending, and  $\nu_t$ , the marginal cost of deposits.

Maximizing the objective function (14) with respect to (13), with  $\lambda_t$  as the constrained 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:

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

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

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

From Equation (17), I can verify that the marginal cost of borrowing in the international asset market is equal to the marginal value of assets in terms of home final good. Let  $\mu_t$  be the excess value of a unit of assets relative to deposits, Equations (16) and (17) yield:

$$\mu_t = \frac{\nu_{st}}{Q_t} - \nu_t. \quad (19)$$

Rewriting the incentive constraint (18), 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

$$Q_t s_t + Q_{bt} b_t = \phi_t n_t. \quad (20)$$

The last equation establishes how tightly the constraint is binding, depending positively on the fraction that banks can divert and negatively on the excess value of bank assets.

I verify the conjecture regarding the form of the value function using the Bellman equation (14) and the guess (15). For the conjecture to be correct the cost of deposit and the excess value of bank assets have to satisfy:

$$\nu_t = E_t \Lambda_{t,t+1} \Omega_{t+1} R_{t+1} \quad (21)$$

$$\mu_t = E_t \Lambda_{t,t+1} \Omega_{t+1} [R_{kt+1} - R_{t+1}] \quad (22)$$

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 bank, the marginal value of net worth corresponds to the sum of the benefit of an extra unit of deposits  $\nu_{t+1}$  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 (21), 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,  $R_t$ . According to Equation (22), the excess value of asset per unit 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 (16),

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

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

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

where  $R_{bt}$  will be defined in the next section and it depends on the return on non-financial foreign firms. Because the return on both assets that home banks hold is equalized, they are indifferent between providing funds to non-financial home firms and to foreign banks. Next, I turn to the foreign banks problem.

### 2.4.2 Foreign Banks

Similar to home banks, an individual foreign bank's balance of flow constraint sets that the total value of funds, which includes deposits from households  $d_t^*$ , loans from home banks  $b_t^*$ , and retained net worth  $n_t^*$ , have to equalize 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 be also thought in term 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 foreign banks is equivalent to the problem of home banks, except for the borrowing constraint. 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  $\theta^*$  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 assets financed by the loans they made. 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 loans is equal to the expected discounted rate of return of loans to non-financial foreign firms. Then, they behave in a similar way, integrating the asset side of the home and foreign banks.

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 constrain must hold for each individual bank to ensure that a the bank does not divert funds,

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

where the R.H.S. is 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

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

Then, the problem of the bank is to maximize Equation (25) subject to the borrowing constraint, Equation (24).

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

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

where  $\nu_{st}^*$  is the marginal value of assets at the end of period  $t$ ,  $\nu_{bt}^*$ , the marginal cost of holding global loans, and  $\nu_t^*$ , the marginal cost of deposits.

Maximizing the objective function (25) with respect to (24), with  $\lambda_t^*$  as the constrained multiplier, yields similar first-order conditions to the ones from home. Rearranging the FOCs of the maximization problem of the bank results in

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

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

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

Equation (28) suggests that the shadow value of global borrowing and domestic assets are equalized,

$$\frac{\nu_{st}^*}{Q_t^*} = \frac{\nu_{bt}^*}{Q_{bt}^*}, \quad (30)$$

or if I write it in terms of returns:

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

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

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

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

The incentive constraint can be written as

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

Similar to home banks, how tightly the constraint is binding depends positive on the fraction of assets and negative on the excess value of bank asset. Equivalent, I call  $\phi_t^*$  leverage.

With  $\Omega_{t+1}^*$  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

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

$$\mu_t^* = E_t \Lambda_{t,t+1}^* \Omega_{t+1}^* [R_{kt+1}^* - R_{t+1}^*] \quad (35)$$

with

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

### 2.4.3 Aggregate Bank Net Worth

Finally, I can aggregate across home banks, from Equation (20):

$$Q_t S_t + Q_{bt} B_t = \phi_t N_t. \quad (36)$$

Furthermore,

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

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

For foreign banks the generic aggregation yields

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

where  $R_{bt}^*$  equals  $R_{kt}^*$ . The balance sheet of the aggregate foreign banking system can be written as

$$Q_t^* S_t^* - Q_{bt}^* B_t^* = \phi_t^* N_t^*. \quad (37)$$

### 2.4.4 Global asset 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 market arises. Then,

because foreign banks are more constrained than home banks, they have an incentive to borrow from the latter.

Other way of thinking about the global asset 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,

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

For foreign banks, the rate of return that they pay on global loans is

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

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

$$R_{b,t+1}^* = \Psi_{t+1}^* \frac{Z_{t+1}^* + Q_{b,t+1}^*(1 - \delta)}{Q_{bt}^*}. \quad (38)$$

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

## 2.5 Equilibrium

To close the model I need equilibrium in the different markets. Equilibrium in the final goods market at home and in foreign is

$$Y_t = C_t + I_t \left[ 1 + f\left(\frac{I_t}{I_{t-1}}\right) \right] + G_t \quad (39)$$

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

Then for the intermediate-competitive goods market,

$$X_t^* = X_t^F \frac{m}{1 - m} + X_t^{*F} \quad (41)$$

$$X_t = X_t^H + X_t^{*H} \frac{1 - m}{m}. \quad (42)$$

The market for securities is in equilibrium when

$$\begin{aligned} S_t &= I_t + (1 - \delta)K_t = \frac{K_{t+1}}{\Psi_{t+1}} \\ S_t^* &= I_t^* + (1 - \delta)K_t^* = \frac{K_{t+1}^*}{\Psi_{t+1}^*}. \end{aligned}$$

The conditions for the labor market are

$$\chi L_t^\gamma = (1 - \alpha) \frac{X_t}{L_t C_t} \quad (43)$$

$$\chi L_t^{*\gamma} = (1 - \alpha) \frac{X_t^*}{L_t^* C_t^*}. \quad (44)$$

The last condition is the one for the global asset, which is in zero net supply

$$B_t = B_t^* \frac{1 - m}{m}. \quad (45)$$

### 3 Unconventional Monetary 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 non-financial firms in order to mitigate the effect of the crisis. 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

$$\varphi_t = \nu_g [E_t(R_{k,t+1} - R_{t+1}) - (R_k - R)]. \quad (46)$$

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 just a fraction of the total credit, we can rewrite Equation (36),

$$\begin{aligned} Q_t \underbrace{(S_t - \varphi_t S_t)}_{S_{pt}} + Q_{bt} B_t &= \phi_t N_t \\ Q_t S_t (1 - \varphi_t) + Q_{bt} B_t &= \phi_t N_t. \end{aligned} \quad (47)$$

Furthermore, the equations of the home banking system will be

$$Q_t S_t (1 - \varphi_t) + Q_{bt} B_t = N_t + D_t$$

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

Equivalent for the foreign banks,

$$Q_t^* S_t^* (1 - \varphi_t^*) = N_t^* + D_t^* + Q_{bt}^* B_t^*$$

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

## 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 on mitigating 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 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 1. 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,  $\beta$  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,  $\gamma$ , and the relative weight of labor in the utility function,  $\chi$ , are equal to 0.1 and 5.584, respectively. The capital share in the production of the intermediate good,  $\alpha$ , is 0.33 and the parameter in the adjustment cost in investment,  $\kappa$ , 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,  $\eta$ , is set to be less than one, as the estimates from Heathcote and Perri (2002), Stockman and Tesar (1995), and Whalley (1985). This implies a complementarity between domestic and foreign goods. Regarding the home bias,

	Home	Foreign
$\beta$ discount factor	0.9900	0.9900
$\gamma$ inverse elasticity of labor supply	0.1000	0.1000
$\chi$ relative utility weight of labor	5.5840	5.5840
$\alpha$ effective capital share	0.3330	0.3330
$\kappa$ adj cost parameter	3.0000	3.0000
$\delta$ depreciation	0.0250	0.0250
$\nu$ home bias	0.5255	0.8245
$\eta$ elasticity of substitution	0.6000	0.6000
$m$ islands	0.2700	0.7300
$\xi$ start-up	0.0018	0.0018
$\theta$ fraction of div assets	0.4067	0.4074
$\sigma$ survival rate	0.9720	0.9700
$\rho_\psi^*$		0.0000
$\sigma_\psi^*$		0.0500

Table 1: Calibration

$\nu$ , 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 and United States, using quarterly data from 1993 to 2011. Then, the implied size of Switzerland is set to 0.27, while the degree of openness is 0.67. This yields a home bias for home  $-1 - (1 - \lambda)m$ - of 0.5255, while the home bias for foreign  $-(1 - m)(1 - \lambda)$ - is 0.8245.

The parameters of the financial sector are such that the average credit spread is 110 basis points per year, and is 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,  $\theta$  matches that target. The start-up fraction that the new banks receive,  $\xi$ , corresponds to a 0.18% of the assets that they have from last period, which corresponds to the value used by Gertler and Kiyotaki (2010). Thus, the survival rate is different across countries to get at the steady state level a global asset market, being 0.972 and 0.97 for home and foreign banks, respectively. Home banks survival on average 9 years, while foreign banks around 8 years.

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

## 4.2 No policy response

Figures 2 and 3 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, which I call IRBC, and it is the green thick dashed line. The second model has financial frictions, and it is the blue full line. The financial frictions are à la Gertler and Kiyotaki. Both models have economies in financial autarky. The third model is with financial frictions and with a global asset market, hereafter GAM; it is the red thin dashed line. The idea of comparing these models is to show how the transmission mechanism across countries changes given that in the first two models there is only international spill-overs due to the trade in intermediate goods, while in the third model I add the financial mechanism. Figure 2 shows the foreign economy variables, while Figure 3 shows the home variables.

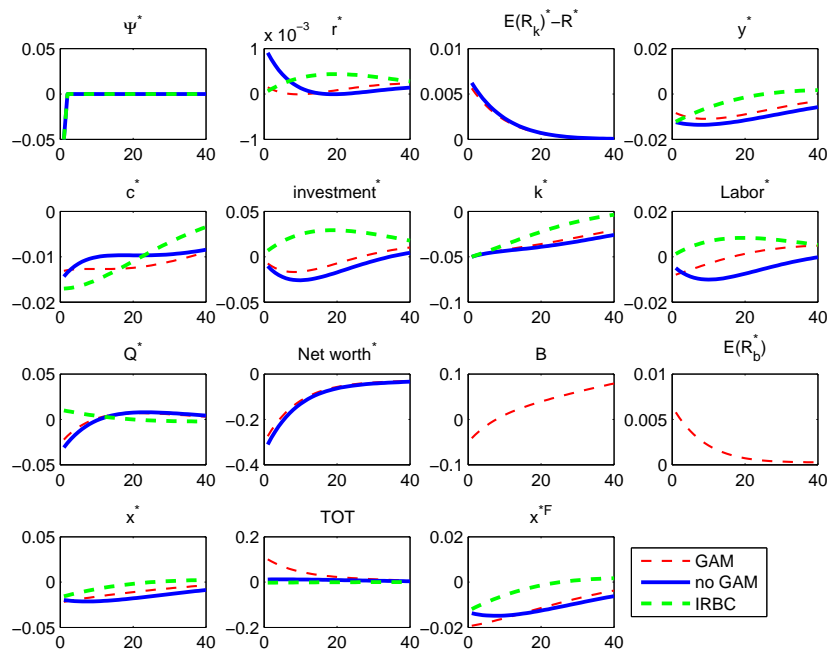


Figure 2: IRF, model comparison without policy response - Foreign variables

Given a decrease in  $\Psi^*$ , quality of foreign capital shock, the foreign capital decreases because of the direct impact, as we learn from Equation (3). If there are no banks in the economy, IRBC case, there are no frictions, and the foreign economy starts to work on the recovery; the price of the capital,  $Q_t^*$ , increases and so does

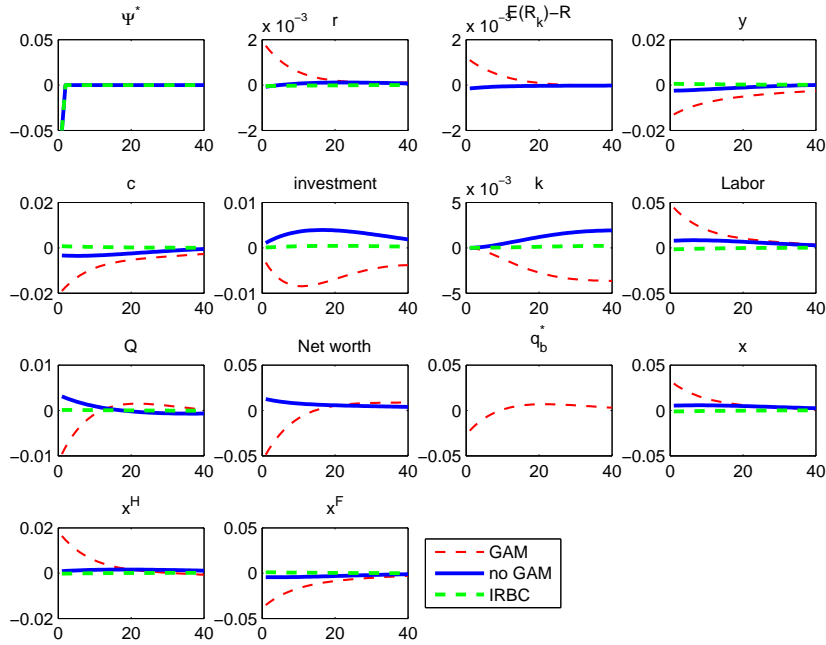


Figure 3: IRF, model comparison without policy response - Home variables

investment. Production,  $X_t^*$ , and consumption,  $C_t^*$ , go down because of the impact of the shock and the decrease in capital. Total demand abroad,  $Y_t^*$ , also falls because the decrease in consumption is higher than the recover of investment. The country decreases not only its demand of local goods,  $X_t^{*H}$ , but also its imports,  $X_t^{*F}$ . 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 goods. For this model, the trade balance is defined by Equation (5) and it equals zero every period.

The foreign demand of home goods is decreasing then, home decreases production,  $X_t$ . This is the case because home is affected by the improvement on its terms of trade. Although the slight decrease in production, there is an increase in consumption and investment. Home economy gets a bust only in production. In this model without financial frictions, there is neither co-movement in consumption or asset price. Nevertheless, there is co-movement in production, with the terms of trade improving for the home economy. However, the spill over home is very small.

Regarding the model with financial frictions but without asset market (no GAM), the foreign economy reacts to the shock as in Gertler and Kiyotaki. As in the previous model, when the economy is hit by the shock, the foreign capital goes down.

Given that in this model there are banks and they are financially constraint, when their asset (capital) goes down, they face a decrease in their net-worth. Due to the fact that banks are also more constraint 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 of the asset,  $Q_t^*$ .

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

Foreign production and consumption go down. Contrary to the IRBC model, the terms of trade go up, with a depreciation for the home economy. This is the case because the foreign economy experiences a deeper recession than in the IRBC model, with production and investment falling. Then, because of the scarcity of foreign goods, the terms of trade go up. Due to this shift in the relative prices, foreign increases its imports, while decreases its exports,  $X_t^F$ . The increase in foreign imports prompts an increase in production at home.

Because of the financial friction, when the demand of home goods from foreign increases, not only the production is going to increase, but also there is going to be a boom in terms of investment at home. Given that the production increases, the raise in the demand of capital comes with an expansion in the net worth of banks that follows an improvement in the asset price. However, consumption and total demand go down because deposits are going up (to cover for the higher net worth) and the labor income is going down. Different to the IRBC model, there is no co-moment in production and the terms of trade worsen for home. The asset price does not co-move, in neither of the models. Consumption and total demand co-moves. Although the transmission to the home economy is more important than in the IRBC model, is still very small.

In the GAM model, home banks have a higher survival rate than foreign banks; then, the former can accumulate more net worth than the latter. Because the home economy is smaller than the foreign in terms of total production, home banks can lend to foreign banks. Hence, the introduction of an international asset allows the foreign economy not only to borrow internationally by diversifying the liabilities of the banks, but also to pool a country specific shock. These asset markets characteristics have been first discussed by Cole (1993).

When the shock hits the foreign economy, capital, production, asset price, and net-worth fall. On impact, the reaction is similar for the two models with financial frictions, as Figure 2 suggests (look at the blue and the dashed-red line). The mechanism that works for these variables is the same as explained above.



Total foreign demand, on the other hand, drops less in the GAM model because consumption falls less. This is prompted by a smaller increase in the interest rate that foreign banks pay on deposits. Banks have to increase less the interest rate that they pay on domestic deposits because they also need to pay for the global loans, which are related with the state contingent interest rate. It is in this sense that the international asset market works as an insurance.

Given the shock, and the structure of the interest rate on the global asset market, Equation (38), the return that foreign banks have to pay to home banks goes up. Therefore, they need to 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 spills over the home economy. Home banks experience a decrease in their net-worth because their asset side is shrinking, Figure 3. 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

$$CA_t = 0 = Q_{b,t}B_t - R_{bt}Q_{b,t-1}B_{t-1} - \left(X_t^{*H} \frac{1-m}{m} \frac{P_t^H}{P_t} - X_t^F \tau_t \frac{P_t^H}{P_t}\right).$$

Given that the net financial income of the home economy is falling by 40% points, the trade balance result (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 spill-overs. On the one hand, the demand effect: it prompts an increase in production because the terms of trade get worsen for the home economy. On the other hand, the decrease in the volume of international borrowing transactions: this is motivated by the tightening of the foreign borrowing constraint.

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, and then, the price of capital goes down. This takes investment down. Then, consumption, asset price, and total demand co-moves, while production does not<sup>1</sup>. Because assets at home behave in a similar way to asset abroad, and they experience an equalization of their returns due to the global asset, the asset market seems to be integrated.

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. Moreover, through the global

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<sup>1</sup>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.

asset market, foreign economy manages to insurance itself against the shock.

### 4.3 Policy response

In this section, I analyze a possible credit market intervention by the foreign central bank that has as an objective mitigating the effects of the crisis. In particular, I look at direct lending to 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 (2010) 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 (46). I assume that the policy is only used in the country hit by the shock. Figures 4 and 5 show the results. The full black line is the model with policy, while the red dashed line is the model without policy.

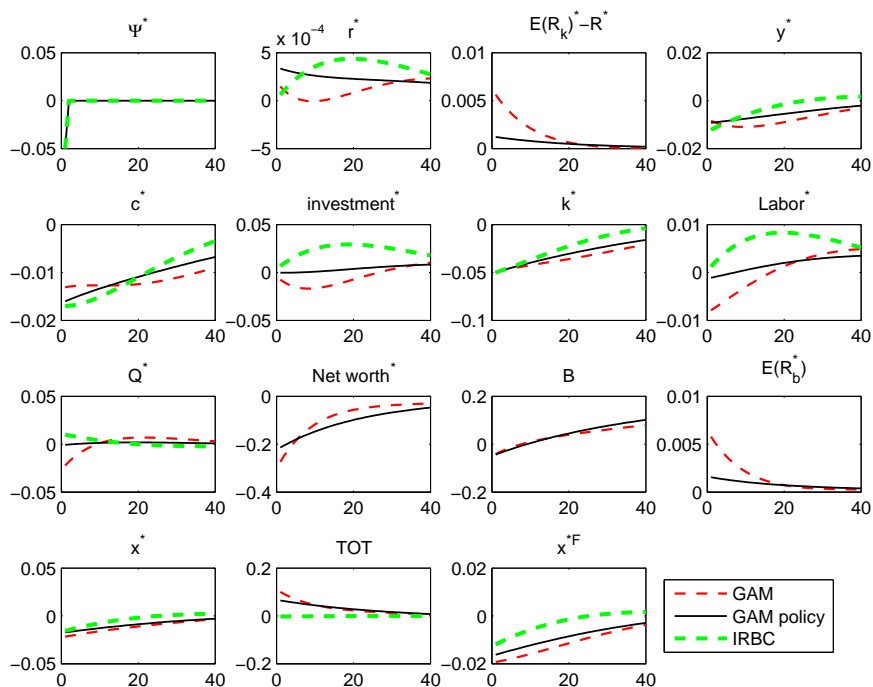


Figure 4: IRF, Unconventional monetary policy - Foreign variables

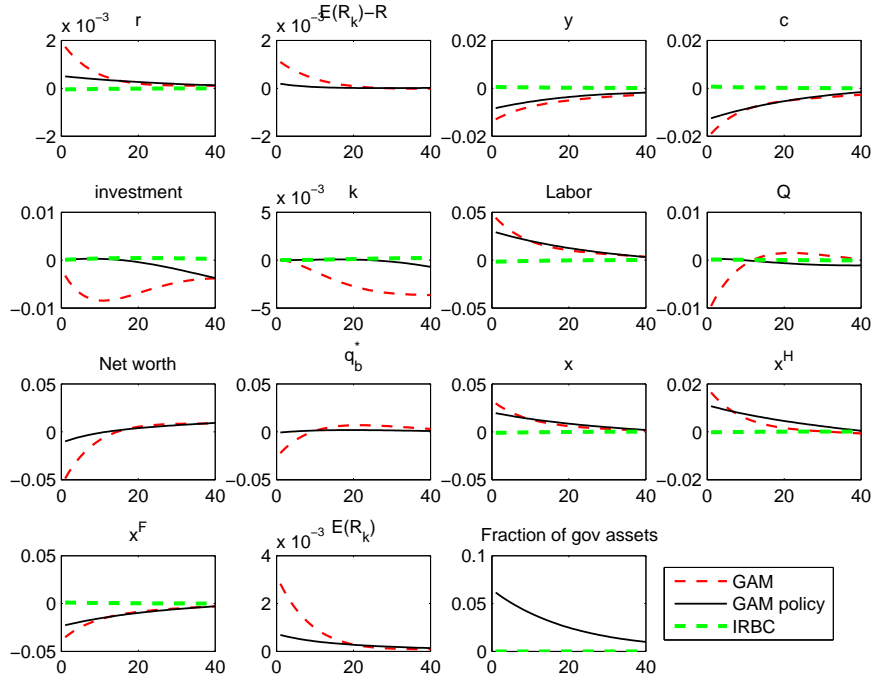


Figure 5: IRF, Unconventional monetary policy - Home variables

The policy parameter  $\nu_g$  is set to be 100. Then, the central bank starts selling 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; and therefore, reducing the price of them. In this sense, the risky interest rate is damped, as I show in Figure 4. 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 asset quantities.

This specific policy shuts down the increase in the expected rate of return on foreign capital. Because of this, the rate of return on global assets that foreign banks need to pay to home banks does not raise 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 are benefited 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 5. 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 depreciation of the terms of trade. The foreign central bank ends up intermediating less than 7.5% of the total foreign assets.

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, the impact of this policy on the global asset market influences them. In particular, the net worth of the home banks almost does not move and the asset price of the asset is even going up. 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 constraint. 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 an international financial asset, I arrive to the conclusion that the latter one develops a higher co-movement of the crisis. 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 asset prompts the transmission. Because the return of the international asset jumps, the foreign banks want to cut the financing from home banks. This prompts a depression of the price of the asset that is reinforced by the drop in the net worth of the home banks. Then, the quantity of the global transaction shrinks. Home banks face a reduction in their balance sheet; moreover, they are more constraint to lend in the domestic market. The price of the home domestic assets drops, falling investment, consumption, and total demand. The equalization of returns across countries is the key mechanism of the transmission.

Then, I study the introduction of an 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 banks intervenes to reduce the abnormal excess return, the expected return on assets in foreign falls. This causes the return on the global asset to increase 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 the understanding part of the international transmission of the crisis.

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