Financial Intermediation in a Global Environment

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Abstract

I develop a two-country DSGE model with global banks (financial intermediaries in one country lend to banks in the other country). Banks are financially constrained on how much they can borrow from households. The main goal is to obtain a framework that captures the international transmission of a financial crisis through the balance sheet of the global banks as well as to explain the insurance mechanism of the international asset market. A negative shock to the value of the capital in one country generates a global financial crisis through the international interbank market. Unconventional credit policies help to mitigate the effects of a financial disruption. The policies are carried out by the policy maker of the country directly hit by the shock. Consumers of that country are better off with policy than without it, while consumers from the other country are worse off.

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1 Introduction

Global banks propagated the financial crisis of 2007-2009 internationally. The crisis originated in the U.S. housing sector and spread to a number of economies that had investments in the United States. As a result of the loss of the value of U.S. assets and the large asset position of Swiss banks with U.S. counterparties, the banks in Switzerland were forced to write down several hundred billions U.S. dollars on bad loans. UBS, the largest Swiss bank and one of the largest global banks in the world, wrote off more than $50 billion U.S. dollars related to bad investments. In this paper, I build a two-country model to study the role of global financial intermediaries (banks that interact with other banks across international borders) in explaining the international transmission of the recent financial crisis.

The United States is a relatively big economy with a small banking sector. In 2008, the assets of U.S. commercial banks were only 77% of the U.S. GDP. However, the United States borrowed a similar amount from abroad. The size of the assets of banks outside the United States with U.S. counterparties were 65% of the total of U.S. commercial banks assets (and 50% of U.S. GDP).[1] These loans came mainly from Switzerland. Figure 1 documents this evidence. The left axis shows the cumulative of the BIS reporting countries, while the right axis documents the ratio of Swiss claims with respect to total foreign claims.

Switzerland is a relatively small open economy with a big banking sector. In 2008, the assets of Swiss banks were 542% of the Swiss GDP. The Swiss banks' assets with U.S. counterparties were 16% of the Swiss banks' total assets.[2] Total assets of UBS, $1.2879 trillion U.S. dollars, alone represented 246% of Swiss GDP and 8.7% of U.S. GDP. As early as 2007, UBS was considered one of the big firms in the U.S. mortgage market. (Morgenson, 2007)

Moreover, Swiss banks in general and UBS in particular are net lenders to the United States. To invest in the United States, UBS borrowed U.S. dollars. During normal times, UBS could roll over their debts. In 2007, the problems in the U.S. housing sector hit financial institutions and many banks found themselves in distress. This, in addition to the failure of Lehman Brothers in September 2008, triggered a severe liquidity crisis in the interbank market. The spread between the interest rates on interbank loans and the U.S. T-bills increased 350bps. Assets in the United States started to lose value. Not only the assets of U.S. commercial banks lost

[1] The data corresponds to BIS reporting countries.

[2] Swiss banks' assets denominated in U.S. dollars were 30% of total Swiss banks' assets. This implies that Swiss banks have U.S. dollar denominated loans in other countries than the United States.

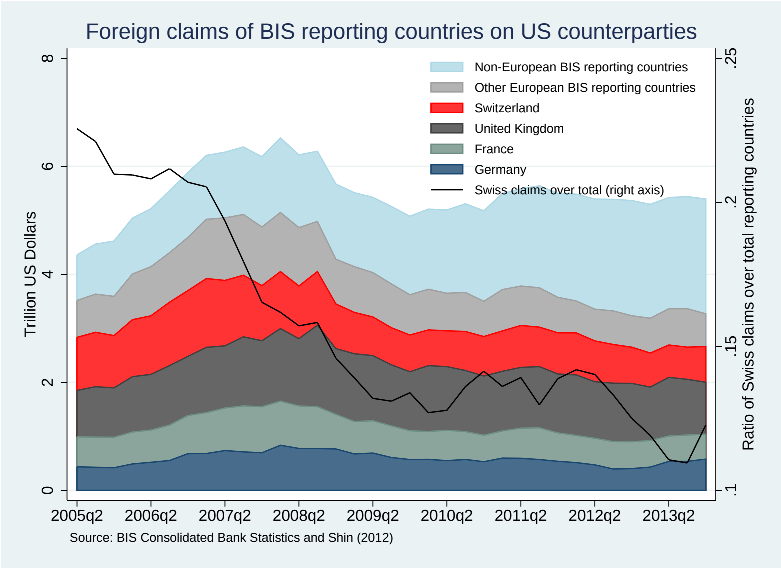

Figure 1. Foreign Claims of BIS Reporting Countries on U.S. Counterparties, 2005Q2-2013Q4

value but also assets in the United States held by global banks. To honor its debts and because assets were losing value, UBS started to sell its assets in the United States. From 2008 to 2009, UBS assets shrank by 28%; it reported losses for at least $ 50 billion U.S. dollars (Craig, Protess, and Saltmarsh, 2011). The decrease in the value of UBS' assets in the United States drove a reduction in the net worth of UBS and other Swiss banks. Because of the large position that UBS held in the United States, and because of the large size of the Swiss banking system, the crisis in the United States spread to the Swiss economy.

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

All the unconventional policies that the Fed carried out as lender of last resort totaled $29,616.4 billion U.S. dollars, almost twice the U.S. GDP in 2008. Excluding the liquidity swap agreements with other central banks, 83.9% ($16.41 trillion U.S. dollars) of all assistance was provided to only 14 institutions. Among them we find the 2 big Swiss banks: UBS and Credit Suisse receiving 2.2% and 4% of the assistance, respectively. (Felkerson, 2011)

To understand better the transmission of the financial crisis from the United States to Switzerland, I estimate a VAR. Figure 2 shows the orthogonalized impulse responses functions from a VAR with two lags with U.S. and Swiss data. The core VAR consists of six variables: real loans of U.S. banks, the S&P500 index, real Swiss domestic demand, real Swiss U.S. dollar denominated loans, real Swiss net interest payments, and the Swiss market index, SMI, from 1988Q2 to 2012Q2.[3] All data are in log (except 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.[4]

The VAR exposes the response to a one-standard deviation innovation (negative) to the loans and leases in bank credit for all U.S. commercial banks. The shock captures one of the initial characteristics of the financial crisis: the decrease in the value of the U.S. banks' loans. The shock suggests a decrease in the S&P 500 index. Then, the crisis is transmitted to Switzerland, where final domestic demand, the loans denominated in U.S. dollars that Swiss banks make, net interest payments, and the stock market index fall. Swiss domestic demand and net interest payments react on impact. The return that Swiss banks get from the loans in U.S. dollars shrinks and drives the initial reduction on the net interest payments. After four periods, there is less volume of loans denominated in U.S. dollars, and the total net interest payment bounces. The VAR highlights a significant and negative reaction of the Swiss (real and financial) economy to a decrease in the U.S. banks' loans and leases. Furthermore, the co-movement of the stock indexes suggests a strong cross-country relation of the asset prices. While U.S. loans go down because of the shock, the Swiss banks' loans denominated in U.S. dollar shrink, emphasizing the co-movement across countries. In this paper, I build a dynamic stochastic general equilibrium model (henceforth DSGE) that explains these interactions.

I propose a two-country (home and foreign) model with global banks and financial frictions to examine the international transmission of a financial crisis through

[3] See Appendix for the definition and the sources of the data. I use the Swiss banks' U.S. dollar denominated loans and not the Swiss banks' loans with U.S. counterparties because data on first are given quarterly and start in 1980, while data regarding the second are provided annually and start in 2002.

[4] The Akaike information criterion (AIC) suggests the use of two lags. Given the comments of Kilian (2011), 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 the Swiss real interest rate and the consumer price index does not alter the results either. A smaller specification of the VAR also suggests that thee lag order is equal to 2 and the general behavior is similar. I have estimated a VAR with the Wilshire 5000 index instead of the S&P500 index and the results do not change.

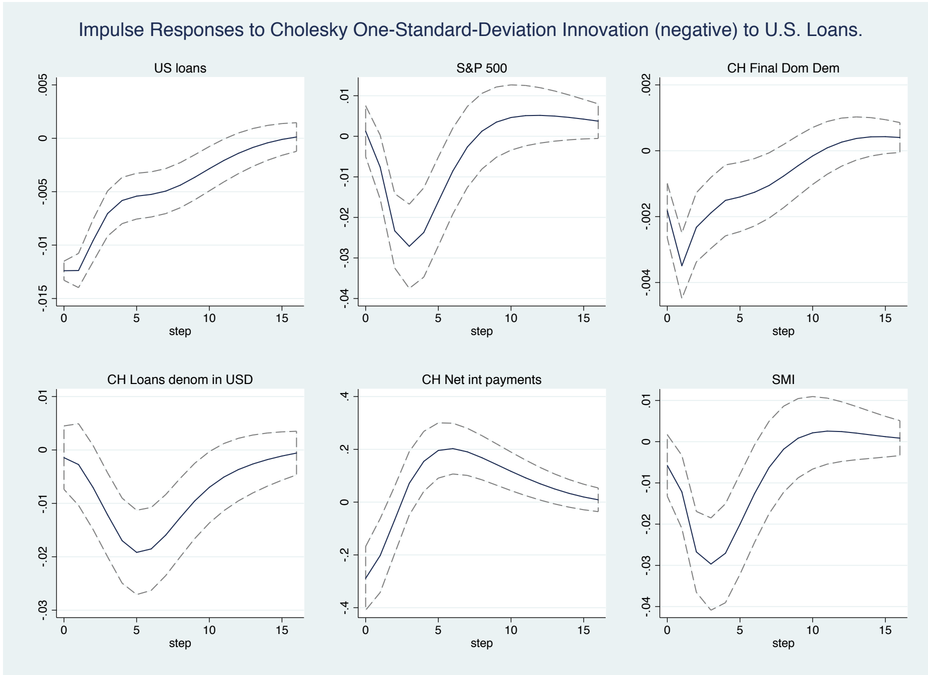

Figure 2. VAR Evidence

Note: VAR estimated for 1988Q2 to 2012Q2. The dashed lines indicate the 67% confident intervals. The Cholesky ordering is U.S. loans, S&P500, Swiss final domestic demand, Swiss loans denominated in U.S. dollars, Swiss net interest payments, and SMI. The vertical axis shows the percent deviation from the baseline.[a]

[a]VAR estimated with 2 standard deviations confident intervals are available by request. The results are robust to this specification.

the global interbank market. Home is a relatively small country with a big banking sector, such as Switzerland, while foreign is a big economy with a relatively small banking sector, such as the United States. The model builds on the closed economy models of Gertler and Kiyotaki (2010) and Gertler and Karadi (2011). There are home and foreign banks. They use their net worth and local deposits to finance domestic non-financial business. Banks can also lend to and borrow from each other through the global interbank market. Although banks can finance local businesses by buying their securities without friction, they face a financing constraint in raising deposit from local households because banks are subject to a moral hazard problem. Home banks (Swiss banks) have a longer average lifetime and a larger net worth (relative to the size of the economy) than foreign banks (U.S. banks); as a consequence, home banks lend to foreign banks in the interbank market and effectively participate in risky finance in the U.S. market.

As in the previous literature (Gertler and Kiyotaki (2010), Gertler and Karadi (2011), and Gertler, Kiyotaki, and Queralto (2012)), I simulate the model giving a negative shock to the value of capital, the so-called quality of capital shock. When there is a reduction in the value of capital and securities in the United States, both U.S. and Swiss banks lose some of their net worth. Because banks are constrained in raising deposits, they have to reduce financing businesses, which further depresses the value of securities and the banks' net worth. Swiss banks are affected because the asset price of their loans in the United States shrinks, and so does their net worth. Then, Swiss banks have to reduce providing loans to domestic firms because their asset side is shrinking and they are financially constrained. Therefore, the adverse shock in the larger economy leads to a decline in the asset price, investment, and domestic demand in both economies through the global interbank market.

First, I examine how a country-specific quality of capital shock is transmitted internationally. By looking at different models, I argue that the model with global banks is the only one that is able to replicate the facts shown in the VAR. I compare a model without financial frictions with a model with financial frictions but without global banks, à la Gertler and Kiyotaki (2010). Countries in these two models are in financial autarky. In these models there is very little transmission of the financial crisis which is due to the trade channel. Then, I allow for an international asset, that I will call international interbank market. When foreign banks are allowed to borrow from home banks, the interbank market insures the foreign economy against the shock. Given that there are no financial frictions on borrowing from home banks, there is integration of the domestic assets markets. In comparison to the financial autarky case, integration amplifies the transmission of the crisis and prompts a global financial crisis. To a quality of capital shock in foreign, the model shows similar characteristics to the VAR evidence: there is asset price co-movement across countries, home banks decrease how much they lend to foreign banks, and the home economy experiences a decrease in the final domestic demand.

Next, I turn to policy analysis during a crisis. I focus on three interventions: the government can lend directly to non-financial firms, provide credit in the interbank market, or provide direct financing to banks by buying part of their total net worth. All these policies prompt a higher price of the domestic asset relaxing the domestic banks' constraint. I assume that there is no information asymmetry between the government and the banks, as opposed to the households and the banks. Looking at the second order approximation of the model, the average capital stock in the country of the intervention shrinks but the price of this asset goes up in all of the intervention methods. When the policy is carried out only by the foreign central bank, a lower stock of foreign capital implies a lower level of borrowing from home banks and a higher demand in domestic deposits. Consumption increases and labor decreases; foreign households are better off. Because the income from the international asset decreases, home banks invest more at home and reduce domestic deposits because they have to finance fewer loans. Home households start to work more and consume less, their production is consumed by foreign households. Home consumers are worse off.

What is new in this framework is the study of the international transmission mechanism of a financial crisis through the global interbank market with constrained financial intermediares. The introduction of the global interbank market in the model prompts a high level of co-movement between the foreign and the home economy, with similarities to the VAR shown in Figure 2. There is international co-movement of asset prices, the banks' net worth, and total final demands.

1.1 Related Literature

Three strands of literature are related to my analysis. The first concerns international real business cycles; the second strand is related to the introduction of financial intermediaries in open economies; while the third group refers to the international transmission of financial shocks. Regarding international business cycle synchronization, Backus, Kehoe, and Kydland (1992) build a standard international real business cycle (IRBC) model. They find that the model predicts a negative international correlation for investment and output to a technology shock correlated across countries, which does not match the data. It is efficient to allocate the resources in the more productive country, while reducing them in the less productive one. After a country-specific quality of capital shock, my model is able to replicate international co-movement of investment and final domestic demands, as seen in the data. Several papers try to improve these results by including frictions in the financial markets to the IRBC model; Faia (2007) introduces the Bernanke, Gertler, and Gilchrist (1999) model in a two-country framework. The 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 country-specific capital shock. However, production is constant. Ueda (2012) analyzes the international business cycle in a two-country DSGE model with banks. Although he presents a comprehensive model, financial frictions arise because there is an asymmetric information problem between the firms and the financial intermediaries. There is no gap for an international interbank market: global banks have deposits from both countries and lend in either of them. Kollmann, Enders, and Müller (2011) also miss the cross-country intra-relation of banks. In their paper, they look at how far 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 of activity in both countries.

Krugman (2008) points out the relevance of the international transmission of financial shocks to understand how the latest crisis that originated in the U.S. housing sector was transmitted to different countries. Devereux and Yetman (2010) 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. Devereux and Sutherland (2011) 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, Dedola and Lombardo (2012) show how equalization of asset prices leads to a higher propagation of an asymmetric shock. In this literature, banks are not modeled explicitly and the authors solve the model using portfolio choice. In my model, I add banks and simplify the portfolio problem by pinning down from the data the fraction of interbank lending from home to foreign banks.

My paper is closely related to the work of Dedola, Karadi, and Lombardo (2013). They develop a two country model with banks à la Gertler and Karadi (2011). Households can lend to home and foreign banks; and banks can make loans to home and foreign firms, i.e. there is full integration. The initial net foreign asset position is zero and the economies are symmetric. As opposed to this, in my model there is international interbank lending rather than direct cross-country lending of households to banks and of banks to firms. Moreover, at the deterministic steady state, home banks lend to foreign banks, as seen in the data for Switzerland and the United States. To a country specific quality of capital shock, the different characteristics of the model allow the framework presented in this chapter to generate a larger propagation across countries of the financial crisis, while in Dedola, Karadi, and Lombardo there is no global transmission after this type of shock.

The rest of the paper is organized as follows. In the next section, I describe in detail the full model. In Section 3, I explain the unconventional credit policy. Section 4 studies the effects of the foreign quality of capital shock. I examine the model with and without policy response and I focus on the welfare comparison across the different unconventional policies. I conclude in Section 5.

2 The Model

The model builds on the 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 interbank market, which contributes to the international spillover of the crisis.

I keep the framework as simple as possible to analyze the effects of global financial intermediation. In line with the previous literature, I focus on a real economy, abstracting from nominal frictions. First, I present the physical setup, a two country real business cycle model with trade in goods. Second, I add financial frictions. I introduce banks that intermediate funds between households and non-financial firms. Financial frictions constrain the flow of funds from households to banks. A new feature of this model is that home banks can invest in the foreign economy by lending to foreign banks. Moreover, I assume that foreign banks are not constrained on how much they can borrow from home banks. Households and non-financial firms are standard and described briefly, while I explain in more detail the financial firms. In what follows, I describe the home economy; otherwise specified, foreign is symmetric. Foreign variables are expressed with an *.

2.1 Physical Setup

There are two countries in the world: home and foreign. Each country has a continuum of infinitely lived households. In the global economy, there is also a continuum of firms of mass unity. A fraction m corresponds to home, while a fraction $1 - m$ to foreign. Using an identical Cobb-Douglas production function, each of the firms produces output with domestic capital and labor. Aggregate home capital, K_t, and aggregate home labor hours, L_t, are combined to produce an intermediate good 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 the productivity shock.

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 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. The shock affects asset price dynamics, because the latter is endogenous. The disruption refers to economic obsolesce, in contrast with physical depreciation. The shocks Ψ_t and Ψ_t^* are mutually independent and i.i.d. The foreign quality of capital shock serves as a trigger for the financial crisis.

As in Heathcote and Perri (2002), 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: $\nu = 1-(1-m)\lambda$ (Sutherland, 2005).

Non-financial firms acquire new capital from capital good producers, who operate at a national level. As in Christiano, Eichenbaum, and Evans (2005), there are convex adjustment costs in the gross rate of investment for capital goods producers. Then, the final domestic output equals domestic households' consumption, C_t, domestic investment, I_t, and government consumption, G_t,

$$Y_t = C_t + I_t\Big[1 + f\Big(\frac{I_t}{I_{t-1}}\Big)\Big] + G_t. \tag{5}$$

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

In Appendix B, I define the competitive equilibrium of the frictionless economy which is the benchmark when comparing the different models with financial frictions. It is a standard international real business cycle model in financial autarky with trade in goods. Next, I add financial frictions.

2.2 Households

There is a representative household for each country. 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 wages to the 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; I assume that they cannot hold capital directly. Deposits are riskless one period securities, and they pay R_t return, determined in period $t-1$.

Households choose consumption, deposits, and labor (C_t, D_t^h, and L_t, respectively) by maximizing expected discounted utility, Equation (6), 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. The first order conditions for the problem of the households are

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

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

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

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). Wage is defined by

$$W_t = (1-\alpha) P_t^H K_t^{\alpha} L_t^{-\alpha} \quad \text{with } P_t^H = \nu^{\frac{1}{\eta}} Y_t^{-1} \left(X_t^H\right)^{\frac{-1}{\eta}}. \tag{10}$$

The price of the final home good is equalized to 1. The gross profits per unit of capital Z_t are

$$Z_t = \alpha P_t^H L_t^{1-\alpha} K_t^{\alpha-1}. \tag{11}$$

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 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. 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,

$$X_t = X_t^H + \frac{1-m}{m} X_t^{H*} \tag{12}$$

to produce the final good Y_t following the CES technology shown in Equation (4). Then, the demands faced by the intermediate competitive goods producers are

$$X_t^H = \nu \left[\frac{P_t^H}{P_t} \right]^{-\eta} Y_t \tag{13}$$

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, P_t^H the price of home goods at home, and P_t^{H*} the price of the home good abroad. By the law of one price, $P_t^{H*} NER_t = P_t^H$ with NER_t as the nominal exchange rate. Rewriting the price of the final good yields

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

where τ_t is the terms of trade, the price of imports, relative to exports. Because of home bias in the final good production, $P_t \neq P_t^* NER_t$; the real exchange rate is defined by $\varepsilon_t = \frac{P_t^* NER_t}{P_t}$.

2.3.2 Capital producers

Capital 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 goods, which equals the marginal cost of investment

$$Q_t = 1 + f\left(\frac{I_t}{I_{t-1}}\right) + \frac{I_t}{I_{t-1}} f'\left(\frac{I_t}{I_{t-1}}\right) - E_t \Lambda_{t,t+1} \left[\frac{I_{t+1}}{I_t}\right]^2 f'\left(\frac{I_{t+1}}{I_t}\right). \tag{14}$$

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

2.4 Banks

To finance their lending, banks get funds from national households and use retained earnings from previous periods. Banks are constrained on how much they can borrow from households. In order to limit the banker's ability to save to overcome being financially constrained, inside the household I allow for turnovers between bankers and workers. I assume that with i.i.d. probability σ a banker continues being a banker next period, while with probability $1 - \sigma$ it exits the banking business. If it exits, it transfers retained earnings back to its household, and becomes a worker. 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 new banker receives a start-up constant fraction ξ of total assets of the bank.

To motivate the global interbank market, I assume that the survival rate of home banks σ is higher that of foreign banks σ^*. Remember that the home economy is the relatively small open economy with a big financial sector. Then, home banks can accumulate more net worth to operate. In equilibrium, home banks lend to foreign banks. This interaction between home and foreign banks is what I call global interbank market. 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, deposits d_t, and retained earnings which I call net worth n_t; it decides how much to lend to non-financial firms s_t. Home banks also choose how much to lend to foreign banks b_t.

Banks are constrained on how much they can borrow from households. In this sense, financial frictions affect the real economy. By assumption, there is no friction when transferring resources to non-financial firms. 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, Q_t 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 equal the sum of bank's net worth n_t and home deposits d_t,

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

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 in the previous period, and is defined in Equation (11).

At the end of period t, the bank maximizes the present value of future dividends taking into account the probability of continuing being a banker in the next periods; the value of the bank is defined by

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

Following the previous literature, I introduce a simple agency problem to motivate the ability of the bank to obtain funds. After the bank obtains funds, it may transfer a fraction θ of assets back to its own household. Households limit the funds lent to banks.

If a bank diverts assets, it defaults on its debt and shuts down. Its creditors can re-claim the remained $1-\theta$ fraction of assets. 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. The following incentive constraint must hold for each individual bank to ensure that the bank does not divert funds:

$$V_t(s_t, b_t, d_t) \geq \theta(Q_t s_t + Q_{bt} b_t). \tag{15}$$

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

$$V(s_{t-1}, b_{t-1}, d_{t-1}) = E_{t-1}\Lambda_{t-1,t}\left\{(1-\sigma)n_t + \sigma\left[\max_{s_t,b_t,d_t} V(s_t, b_t, d_t)\right]\right\}. \tag{16}$$

The problem of the bank is to maximize Equation (16) subject to the borrowing constraint, Equation (15).

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

$$V(s_t, b_t, d_t) = \nu_{st}s_t + \nu_{bt}b_t - \nu_t d_t, \tag{17}$$

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 (16) subject to (15), 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 terms yields:

$$(\nu_{bt} - \nu_t)(1+\lambda_t) = \lambda_t\theta Q_{bt} \tag{18}$$

$$\left(\frac{\nu_{st}}{Q_t} - \frac{\nu_{bt}}{Q_{bt}}\right)(1+\lambda_t) = 0 \tag{19}$$

$$\left[\theta - \left(\frac{\nu_{st}}{Q_t} - \nu_t\right)\right]Q_t s_t + \left[\theta - \left(\frac{\nu_{bt}}{Q_{bt}} - \nu_t\right)\right]Q_{bt}b_t = \nu_t n_t. \tag{20}$$

From Equation (19), I 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 (18) and (19) yield:

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

Rewriting the incentive constraint (20), I define the leverage ratio net of international borrowing as

$$\phi_t = \frac{\nu_t}{\theta - \mu_t}. \tag{21}$$

Therefore, the balance sheet of the individual bank is written as

$$Q_t s_t + Q_{bt} b_t = \phi_t n_t. \tag{22}$$

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

I verify the conjecture regarding the form of the value function using the Bellman equation (16) and the guess (17). For the conjecture to be correct, the cost of deposits and the excess value of bank assets have to satisfy:

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

$$\mu_t = E_t \Lambda_{t,t+1} \Omega_{t+1} \left[R_{kt+1} - R_{t+1} \right] \tag{24}$$

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

$$\Omega_{t+1} = (1-\sigma) + \sigma(\nu_{t+1} + \phi_{t+1}\mu_{t+1}) \tag{25}$$

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

$$R_{kt+1} = \Psi_{t+1} \frac{Z_{t+1} + Q_{t+1}(1-\delta)}{Q_t}. \tag{26}$$

Regarding the shadow value of net worth, the first term corresponds to the probability of exiting the banking business; the second term represents the marginal value of an extra unit of net worth given the probability of survival. 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 varies counter-cyclically, the shadow value of net worth varies counter-cyclically, too. In other words, because the 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 (23), 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 (24), the excess value of a unit of assets relative to deposits is the expected value of the product of the augmented stochastic discount factor and the difference between the risky and the risk free rate of return, $R_{kt+1} - R_{t+1}$. The spread is also counter-cyclical.

From Equation (18)

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

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

$$E_t \Lambda_{t,t+1} \Omega_{t+1} R_{kt+1} \quad = \quad E_t \Lambda_{t,t+1} \Omega_{t+1} R_{bt+1}, \tag{27}$$

where R_{bt} will be defined in the next section and is related to the return on non-financial foreign firms expressed in home final goods. 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

The problem of the foreign banks is similar to the one from home banks, except that now the interbank market asset, b_t^*, are loans from home banks and they are on the liability side

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

The net worth of the bank can also be thought of 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,

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

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, but not from home banks. In this case, the framework can be thought off as one with asset market integration.

From the optimization problem of the foreign banks, the shadow value of global borrowing and domestic assets are equalized,

$$\frac{\nu_{st}^*}{Q_t^*} = \frac{\nu_{bt}^*}{Q_{bt}^*}; \tag{28}$$

or in terms of returns:

$$E_t \Lambda_{t,t+1}^* \Omega_{t+1}^* R_{kt+1}^* \quad = \quad E_t \Lambda_{t,t+1}^* \Omega_{t+1}^* R_{bt+1}^*. \tag{29}$$

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. Given a shock, the return on the global interbank asset is as volatile as the return on the domestic asset, emphasizing the transmission mechanism from one country to the other. Furthermore, the expected discounted rate of return on the global asset equalizes to the one on loans to non-financial home firms, see Equation (27). Then, the home loan market and the foreign loan market behave in a similar way. This is the integration of the asset markets.

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:

$$\nu^*_t = E_t \Lambda^*_{t,t+1} \Omega^*_{t+1} R^*_{t+1}$$
$$\mu^*_t = E_t \Lambda^*_{t,t+1} \Omega^*_{t+1} \left[R^*_{kt+1} - R^*_{t+1} \right]$$

with

$$\begin{aligned} \Omega^*_{t+1} &= 1 - \sigma^* + \sigma^* \left(\nu^*_{t+1} + \phi^*_{t+1} \mu^*_{t+1} \right) \\ R^*_{kt+1} &= \Psi^*_{t+1} \frac{Z^*_{t+1} + Q^*_{t+1}(1-\delta)}{Q^*_t}. \end{aligned} \quad (30)$$

2.4.3 Aggregate Bank Net Worth

Finally, aggregating across home banks, from Equation (22):

$$Q_t S_t + Q_{bt} B_t = \phi_t N_t. \quad (31)$$

Capital letters indicate aggregate variables. From the previous equation, I define the households deposits

$$D_t = N_t(1 - \phi_t). \quad (32)$$

Furthermore,

$$N_t = (\sigma + \xi) \left\{ R_{k,t} Q_{t-1} S_{t-1} + R_{b,t} Q_{b,t-1} B_{t-1} \right\} - \sigma R_t D_{t-1}. \quad (33)$$

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

For foreign banks, the aggregation yields

$$N^*_t = (\sigma^* + \xi^*) R^*_{k,t} Q^*_{t-1} S^*_{t-1} - \sigma^* R^*_t D^*_{t-1} - \sigma^* R^*_{bt} Q^*_{bt-1} B^*_{t-1}, \quad (34)$$

where R^*_{bt} equals R^*_{kt}, from Equation (29). The balance sheet of the aggregate foreign banking system can be written as

$$Q^*_t S^*_t - Q^*_{bt} B^*_t = \phi^*_t N^*_t. \quad (35)$$

2.4.4 Global interbank market

At the steady state, home banks invest in the foreign economy because the survival rate of home banks is higher than the survival rate of foreign banks; therefore, home banks lend to foreign banks. An international interbank market arises. Foreign banks have an incentive to borrow from home banks because foreign banks are more constrained than home banks. Another way of thinking about the global interbank market is to assume that the deposits foreign banks get from foreign households are not enough to cover the capital that foreign firms demand. In the foreign country (the bigger economy), capital is higher than national savings. And, because at home, deposits are higher than capital, there is a gap for an international transaction.

Regarding the interest rate, the return on loans to foreign banks made by home banks is $E_t(R_{bt+1}) = E_t(R^*_{bt+1}\frac{\varepsilon_{t+1}}{\varepsilon_t})$. The rate on global loans is equalized to the return on loans to home firms, R_{kt}, in expected terms in Equation (27); home banks are indifferent between lending to home firms or to foreign banks. For foreign banks, Equation (29) equalizes the rate of return on global loans to the rate of return on foreign loans. The double equalization drives the asset market integration. In addition, 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:

$$R^*_{b,t+1} = \Psi^*_{t+1}\frac{Z^*_{t+1} + Q^*_{b,t+1}(1-\delta)}{Q^*_{bt}}. \tag{36}$$

2.5 Equilibrium

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

$$Y_t = C_t + I_t\Big[1 + f\Big(\frac{I_t}{I_{t-1}}\Big)\Big] + G_t \text{ and} \tag{37}$$

$$Y^*_t = C^*_t + I^*_t\Big[1 + f\Big(\frac{I^*_t}{I^*_{t-1}}\Big)\Big] + G^*_t. \tag{38}$$

Then for the intermediate-competitive goods market,

$$X_t = X^H_t + X^{*H}_t\frac{1-m}{m} \quad \text{and} \quad X^*_t = X^F_t\frac{m}{1-m} + X^{*F}_t. \tag{39}$$

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

$$\chi L_t^{\gamma} = (1-\alpha)\frac{X_t}{L_t C_t} \quad \text{and} \quad \chi L_t^{*\gamma} = (1-\alpha)\frac{X_t^*}{L_t^* C_t^*}. \tag{40}$$

If the economies are in financial autarky, the net exports for home are zero in every period; the current account results in

$$CA_t = 0 = \frac{1-m}{m} X_t^{H*} - \tau_t X_t^F, \tag{41}$$

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

On the other hand, if there are global banks in the economy, the current account is

$$CA_t = Q_{b,t}B_t - R_{bt}Q_{b,t-1}B_{t-1} = X_t^{*H}\frac{1-m}{m}\frac{P_t^H}{P_t} - X_t^F \tau_t \frac{P_t^H}{P_t}. \tag{42}$$

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,

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

I formally define the equilibrium of the banking model in Appendix B.

3 Unconventional Policy

In 2008, the Fed started to intervene in different markets as lender of last resort to increase credit flows in the economy. The measures were taken under an extraordinary setting, namely, the financial crisis. From among the policies that the Fed carried out, I focus on two types: direct lending in credit markets and equity injections in the banking system. For the former, the Fed extended credit to partnerships and corporations in particular. The Commercial Paper Funding Facility (CPFF), Asset-Backed Commercial Paper Money Market Mutual Fund Liquidity Facility (AMLF), Money Market Investor Funding Facility (MMIFF), and the Term

Asset-Backed Securities Loan Facility (TALF) are programs that have these characteristics. Regarding equity injections, the Treasury provided capital facilities to Bear Stearns, JPMorgan Chase, Maiden Lane LLC, American International Group (AIG), Bank of America, and Citigroup. The facilities were under the Troubled Assets Relief Program (TARP) and started after the collapse of Lehman Brothers in September 2008.

UBS and Credit Suisse were exposed to illiquid securitized loans in the United States. They received assistance from the Fed by the Term Securities Lending Facility (TSLF), CPFF, Mortgage Backed Securities (MBS), and the term repurchase transactions (ST OMO), and from the Swiss National Bank (SNB).

In this section, I introduce three interventions carried out by the foreign central bank. The first two policies, direct intervention in the loan market and direct intervention in the interbank market are inspired by the policies that the Fed carried out to extend credit in specific markets. The third policy provides capital directly to banks and corresponds to equity injections; this policy can be related to the TARP program that the Treasury put in action. I build the modeling of these policies on Gertler and Karadi (2011), Gertler and Kiyotaki (2010), Gertler, Kiyotaki, and Queralto (2012), and Dedola, Karadi, and Lombardo (2013).

The extend to which the central bank intervenes is determined endogenously. The level of intervention follows the difference between the spread of the expected return on capital and the deposit rate, and their stochastic steady state level under no-policy:

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

where ν_g^* is a policy instrument; τ_{gt}^* follows an AR(1) process when there is a quality of capital shock in foreign; otherwise, it equals zero. This specification contrasts with the policy proposed in the previous literature in two dimensions. First, I target the stochastic steady state premium instead of the deterministic one. The spread is where banks accumulate earnings; by targeting the deterministic steady state, the net worth takes longer to return to its steady state value. In this sense, Kiyotaki (2013) suggests targeting the mean of the ergodic distribution of the variables taking into account the distribution of the shocks. Second, the policy is only active when there is a quality of capital shock in foreign, while in the other papers the policy is active when the premium is different from its deterministic steady state, even if it is coming from a productivity shock. I assume that $\tau_{gt}^* = \rho_{\tau_g^*} \tau_{gt-1}^* + \varepsilon_{\Psi^*,t}$, where $\varepsilon_{\Psi^*,t}$ is the same exogenous variable that drives the foreign quality of capital shock.

The policies are carried out only by the policy maker of the country directly hit by the shock. Next, I describe the three policies separately.

3.1 Loan Market Intervention

The central bank can lend directly to local non-financial firms in order to mitigate the effects of the crisis. The policy maker endogenously determines the fraction of private credit. The level of intermediation follows Equation (45). The total assets of a firm are

$$Q_t^* S_t^* = Q_t^* (S_{pt}^* + \mathcal{S}_{gt}^*),$$

where S_{pt}^* are the loans made by financial intermediaries, and $\mathcal{S}_{gt}^*$ the ones made by the government. Assuming that $\mathcal{S}_{gt}^*$ is a fraction of total credit, I can rewrite Equation (35),

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

Furthermore, the equations of the foreign banking system become

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

3.2 Interbank Market Intervention

The second policy is the provision of funds to banks through the interbank market. To what extent the policy maker intervenes is determined endogenously by Equation (45). By providing funds in the interbank market, the government increases the total quantity available in the market as such. There are public and private funds in the interbank market,

$$B_t^* = \mathcal{B}_{gt}^* + \tfrac{m}{1-m} B_t \tag{47}$$

with $\mathcal{B}_{gt}^* = \varphi_t^* Q_t^* S_t^*$. Foreign banks receive higher funding under policy than under no-policy. The net worth of foreign banks does not change in structure; the only difference is that B_t^* follows Equation (47). The interest rate that the banks pay on government loans is the same as the one paid to home banks.

3.3 Equity Injection

The third policy is equity injections. Under this policy, the central bank gives funds to home banks and the banks then decide how to allocate these extra resources optimally. Again, the quantity of funds that the government provides is a fraction of the total assets of the foreign banks, $\mathcal{N}^*_{gt} = \varphi^*_t Q^*_t S^*_t$. The net worth of the foreign banking system is set to be

$$N^*_t = (\sigma^* + \xi^*)\left[Z^*_t + (1-\delta)Q^*_t\right] K^*_t - \sigma^* R^*_t D^*_{t-1} - \sigma^* R^*_{bt} Q^*_{bt-1} B^*_{t-1} - \sigma^* R^*_{gt} \mathcal{N}^*_{g,t-1}.$$

Redefining Equation (35) yields

$$Q^*_t S^*_t = \phi^*_t N^*_t + \mathcal{N}^*_{gt} + Q^*_{bt} B^*_t. \tag{48}$$

The interest rate paid to the government is equal to the interest rate on capital.

3.4 Government

Consolidating monetary and fiscal policy, total government expenditure is the sum of consumption, G^*_t, loans to firms, $\mathcal{S}^*_{gt}$ (or total intervention), and debt issued last period, $R^*_t \mathcal{D}^*_{gt-1}$. Government resources are lump sum taxes, T^*_t, new debt issued, $\mathcal{D}^*_{gt}$, and the return on the intervention that the government made last period. The budget constraint of the consolidated government is

$$G^*_t + Q^*_t \mathcal{S}^*_{gt} + R^*_t \mathcal{D}^*_{gt-1} = T^*_t + \mathcal{D}^*_{gt} + \left[Z^*_t + (1-\delta)Q^*_t\right] \Psi^*_t \mathcal{S}^*_{gt-1},$$

where I present the equation with total loans to firms, but it should be defined according to the policy.

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 includes a constant fraction of total output and a cost for each unit of intervention issued,

$$G^*_t = \tau^*_{1S} Q^*_t S^*_{gt} + \tau^*_{2S} \left(Q^*_t S^*_{gt}\right)^2 + \bar{g}^* Y^*.$$

The efficiency cost are quadratic on the intervention of the central bank, as in Gertler, Kiyotaki, and Queralto (2012).

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. First, I present the calibration; next, I analyze a crisis experiment without response from the government and I highlight the role of the global asset market in the transmission of the crisis and how it works as insurance for the economy that is hit by a shock. Next, I study how credit market intervention by the foreign central bank can mitigate the effects of the crisis. I evaluate the welfare of the consumers under the different policies.

		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	1.0000	1.0000
δ	depreciation	0.0250	0.0250
ν	home bias	0.8500	0.9625
η	elasticity of substitution	1.1111	1.1111
m	size of the countries	0.0400	0.9600
ξ	start-up	0.0018	0.0018
θ	fraction of div assets	0.4067	0.4074
σ	survival rate	0.9740	0.9720
$\bar{g}$	steady state gov expenditure	0.1240	0.2000
τ^*_{1S}	cost of issuing loans		0.00125
τ^*_{2S}	cost of issuing loans		0.0120

Table 1. Calibration

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, 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 parameters that enter into the CES aggregator, η and ν, follow the calibrated values for Switzerland in Cuche-Curti, Dellas, and Natal (2009). The elasticity of substitution between home and foreign goods in the production of the final good, η, is set to be greater than one. This implies substitutability between domestic and foreign goods. The home bias, ν, is defined by the size of the home economy and the degree of openness. I calibrate the size of the countries to match the ratio between Swiss and U.S. GDP as an average between 2002 and 2008.

The parameters of the banking 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, explained by the parameter θ, matches that target. The start-up fraction that the new banks receive, ξ, is 0.18% of the last period's assets, which corresponds to the value used by Gertler and Kiyotaki (2010). The global interbank market exists because the survival rate is different across countries, 0.974 for home and 0.972 for foreign banks. On average, home banks survive 9 years, while foreign banks around 8 years.[5] At the steady state, the holding of global asset represents 16% of the total assets of the home banks, which matches the data for total lending by Swiss banks to U.S. counterparties from the year 2002 until 2008, and constitutes 17% of Swiss banks' total assets. In Appendix C, I evaluate the deterministic steady state of the home economy that results from this calibration and I compare it to Swiss data from 2002 until 2008. I assume a negative i.i.d. shock that occurs in foreign.

4.2 No policy response

Figure 3 shows 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 dash-dotted line. The second model has financial frictions but no trade in assets, and is the blue solid line. The financial frictions are à la Gertler and Kiyotaki (2010). The third model is with financial frictions and a global interbank market (financial openness); it is the red thin dashed line. The comparison of these models shows how the transmission mechanism across countries changes given the different assumptions. In the first two models, there is only international spillover due to the trade of intermediate goods. In the third model, I add the international financial mechanism. The comparison helps us understand the insurance and the transmission role of the interbank market. The size of the shock triggers a 30% decrease in the net worth of foreign banks and 7% of the net worth of home banks roughly the rates that we saw during the latest financial crisis. In Appendix E I show the complete set of impulse responses functions: foreign economy variables are in Figure 5, while home variables are in Figure 6.

When there is a decrease in the foreign quality of capital, and there are no financial frictions (i.e. no banks) in the economy, all the resources are channeled to recovering from the initial shock. Investment and asset price go up. Households

[5] Data from the SNB, for Switzerland, and from the FDCI, for the United States, on the number of financial institutions show that, over the last 13 years, the number of Swiss institutions has been more stable and decreasing less than those in the United States.

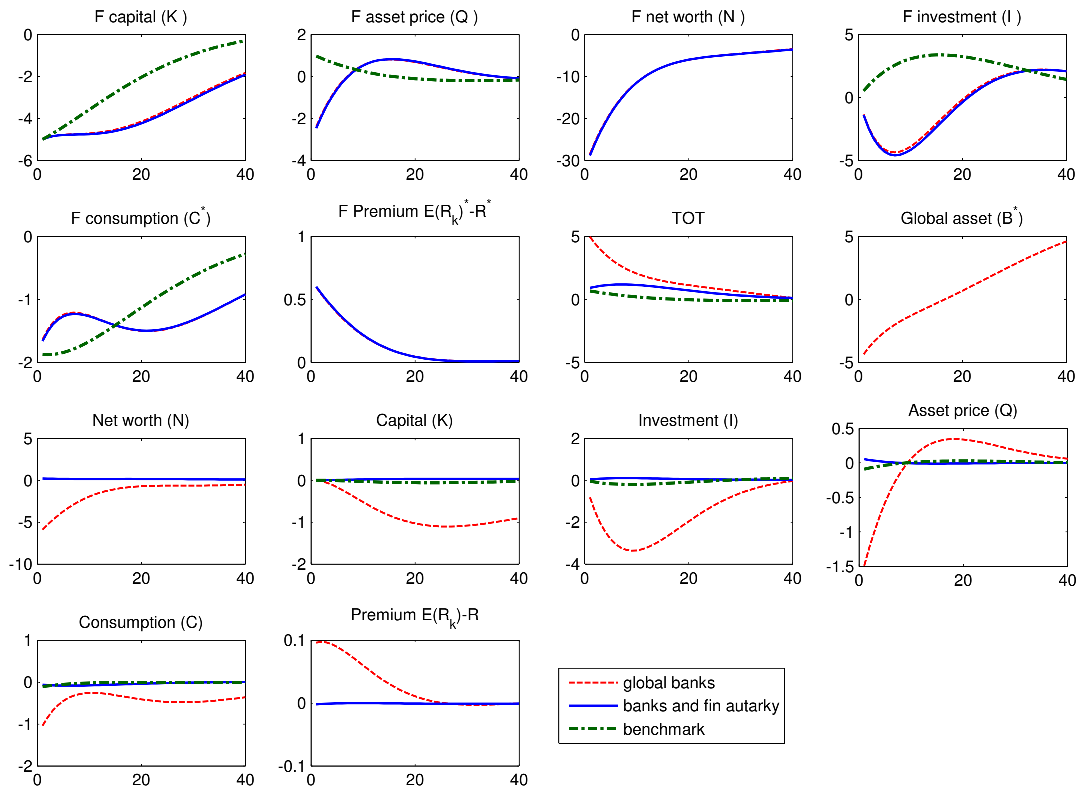

Figure 3. Impulse Responses to a 5% Decrease in Ψ_t^*, Model Comparison

cut down on consumption on impact because of lower labor income. Final domestic demand and production in foreign fall because of the negative shock.

The foreign economy cuts back not only the demand for local goods, X_t^{*F}, but also imports, X_t^{*H}. There are fewer foreign goods in the economy because of the shock. As a result, every unit of foreign good is more expensive and the terms of trade slightly improve (deteriorate) for foreign (home). The trade balance is defined by Equation (41) and equals zero in every period because there is no international borrowing/lending.

Foreign demand of home goods decreases but the home economy starts demanding more of domestic products because they are relatively cheaper. Home increases its production, X_t, while substituting foreign for domestic goods. Nevertheless, consumption and investment decrease because the interest rate is higher. In the model without financial frictions and in financial autarky, there is no international co-movement either in asset prices or in production. However, there is co-movement in total demand and consumption, while the terms of trade deteriorate for the home economy.

Adding financial frictions but no global banks to the model results in a similar model to Gertler and Kiyotaki (2010). There are banks and they are financially constrained; when their asset (capital) goes down, banks face a decrease in their net worth. Because banks are more constrained on how much they can borrow, there is a firesale of asset that prompts its price, Q_t^*, to go down.

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

Foreign production and consumption shrink. There are less foreign goods and they are relatively more expensive, similar to the model without financial frictions, the terms of trade slightly improve for foreign. Home goods are cheaper, its production increases and so does investment. Home businesses increase their demand for loans, banks are less constrained, their net worth goes up. Consumption falls because of the reduction in total wages. Similarly to the previous model, asset prices and production do not co-move across countries. Although there is a larger spillover to the home economy with financial frictions than without them, home banks get an increase on their net worth after a negative quality of capital shock in foreign.

When I allow for a global asset, home banks lend to foreign banks. In the global interbank market foreign banks borrow internationally; they diversify their liabilities and pool a country specific shock. These asset market characteristics have been discussed by Cole and Obstfeld (1991) and Cole (1993).

The decrease in the value of assets and securities in foreign prompts foreign banks to be more financially constrained. The reaction is similar to the model without global banks and is shown by the solid-blue and the thick dashed-red line in Figure 3. The mechanism that takes place for foreign variables is the same in both models with financial frictions. However, final domestic demand is less affected by the shock when there are global banks because foreign can partially pool the country specific shock.

There is asset market integration: the asset price in foreign falls and so does the asset price of the global asset. Home banks face a reduction in their net worth because of a country specific shock in foreign. Home financial intermediaries are more financially constrained and reduce lending to domestic businesses. Investment and the price of capital shrink. The global banks transmit the crisis from foreign to home.

Two types of spillovers disturb the home economy: the demand and the global asset effects. The demand effect prompts an increase in production because the home exchange rate is depreciating. The global asset effect generates a tightening of the home borrowing constraint because there is a decrease in the value of international lending. The global asset effect predominates and the net worth of home banks falls and households cut down on consumption. Global banks imply financial openness, the current account is now defined in Equation (42).

In a model with global banks and financial frictions, home and foreign consumption, asset price, and total demand co-move, while production does not. The asset markets across countries are integrated because of the equalization of returns of the asset market at home and abroad.

The results are different from the work of Dedola, Karadi, and Lombardo (2013). In their model, in response to a country-specific quality of capital shock with integration in the capital but not in the deposit market, assets and net worth of home and foreign move in different direction. This is the case because home loans increase to compensate for the fewer loans from foreign that suffered the negative shock. The leverage and the spread are equalized across countries. This would imply UBS increasing loans in the United States after a quality of capital shock in the United States, which is exactly the opposite of what happened during the latest financial crisis. Moreover, the reaction of the home real variables is almost negligible.

The qualitative behavior of the model matches the VAR evidence shown in Figure 2. In the data, a decrease in the U.S. loans prompts a decrease in the domestic asset price that is then transmitted to the Swiss economy. Total final demand, foreign U.S. dollars denominated loans, net interest payments, and asset prices fall.

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

4.3 Policy response

I analyze the three credit market interventions presented above: direct intervention in the loan market, direct intervention in the interbank market, and equity injections. In this part, all the policies are carried out only by the foreign central bank. One of the reasons that motivated the Fed to intervene was the abnormal credit spread in several markets. In this sense, the central bank determines the fraction of private credit to intermediate by following the difference between the risky and the risk free interest rate and its stochastic steady state value, as in Equation (45).

Figure 4 shows a small set of variables with the results; Figures 7 and 8 in Ap-

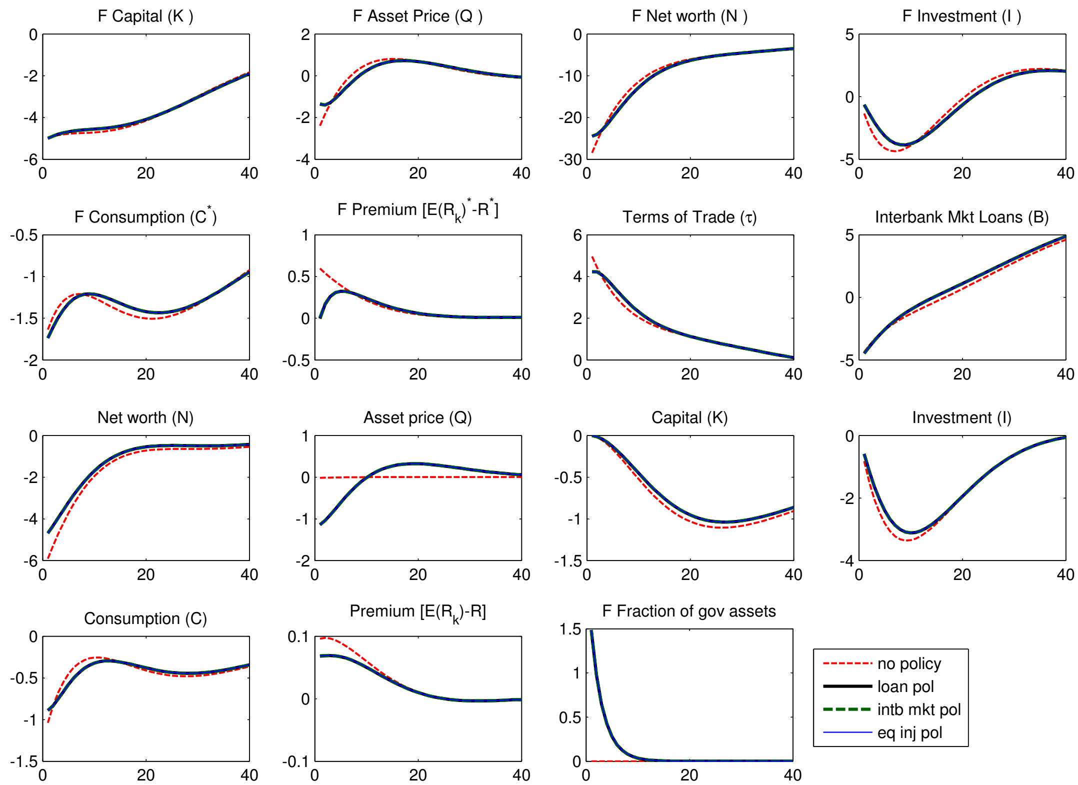

Figure 4. Impulse Responses to a 5% Decrease in Ψ_t^*, Unconventional Policies by F Central Bank

pendix E show more variables. The dashed red line is the model with financial frictions and financial openness without policy, the same as in the previous chapter. The solid thick black line is the model with direct intervention in the loan market, the dashed green line is with interbank market policy, and the solid thin blue line is with equity injections. The policy parameter ν_g^* is set to be 2000 and $\rho_{\tau_g^*} = 0.66$. The costs of issuing government loans follow Gertler, Kiyotaki, and Queralto (2012) and the fraction of government expenditure at the steady state matches the data for the United States and Switzerland.

The central bank intervention prompts a higher price of the domestic asset than under no intervention. The initial intervention is around 1.5% of total foreign assets. Higher asset price implies that foreign banks are less financially constrained. The Foreign banks' net worth falls 5% less than under no-policy. The asset price is also the price of investment, therefore, investment contraction is lower with the policy.

Consumers pay the cost of the policy.

Because of asset market integration, the price of the global asset also falls less. Home banks are less financially constrained than under no policy, the net worth of home banks drops only 4% on impact. Banks lend more to domestic firms; as a result, the home asset price decreases by less with the foreign policy and the fall in investment is smoothed.

In conclusion, with direct intervention in the foreign loan market the foreign and the home economy get a smoother impact of the crisis. Although home banks do not have direct access to the policy, home profits through the higher prices in the interbank market. Home consumption and home total demand drop less than under no-policy.

The reaction of the model with direct intervention in the interbank market is similar to the model with intervention in the loan market (the two lines in the Figures overlap). Under the interbank market intervention, government lending complements home global loans. Foreign and global asset prices are higher than without intervention.

Injecting equity into foreign banks, up to a first order approximation, is also similar to intervening in specific credit markets. Foreign banks decide how to allocate the funds, and they do it in the same way as the previous policies. The three policies react to the same interest rate spread. The spillover to the home economy after injecting equity into foreign banks is similar to that under direct intervention policies.

The first order approximation of the model is useful when studying the impact of an unexpected policy, however, it is not an adequate setup to study welfare. In the next subsection I evaluate the welfare implications of these policies by looking at the second order approximation of the model.

4.4 Welfare comparison

I introduce consumers' welfare to rank the policies presented above. The welfare criterion considered here is the one used by Gertler and Karadi (2011) and developed by Faia and Monacelli (2007). The households' welfare function is given by

$$Welf_t = U(C_t, L_t) + \beta E_t Welf_{t+1}, \tag{49}$$

where the utility function is defined in Equation (6). Welfare is defined as the lifetime utility of the consumers. I compare the different policies using the consumption equivalent, i.e. the fraction of household consumption that would be needed to equate the welfare under no-policy to the welfare under policy intervention.

	Det	Stochastic Steady State Ψ^*							
		No policy		Loan mkt		Intb mkt		Eq Inj	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
K	6.0671	6.0569	0.0016	6.0260	0.0021	6.0261	0.0021	6.0261	0.0021
C	0.4697	0.4714	0.0036	0.4695	0.0012	0.4696	0.0012	0.4696	0.0012
L	0.2295	0.2286	0.0031	0.2290	0.0009	0.2290	0.0009	0.2290	0.0009
K^*	6.6389	6.6013	0.0063	6.6038	0.0063	6.6029	0.0062	6.6027	0.0062
C^*	0.4430	0.4420	0.0022	0.4421	0.0022	0.4421	0.0022	0.4421	0.0022
L^*	0.2627	0.2628	0.0012	0.2628	0.0013	0.2628	0.0013	0.2628	0.0013
N	1.9806	2.0349	0.0196	1.9514	0.0059	1.9520	0.0058	1.9521	0.0058
D	5.1049	5.2876	0.0197	5.1644	0.0050	5.1643	0.0050	5.1643	0.0050
N^*	1.6402	1.6228	0.0183	1.6526	0.0189	1.6539	0.0186	1.6540	0.0186
D^*	4.9489	4.9163	0.0035	4.9065	0.0033	4.9041	0.0033	4.9038	0.0033
TOT	0.8274	0.8139	0.0149	0.8223	0.0057	0.8223	0.0056	0.8223	0.0057
Ψ^*	1.0000	0.9999	0.0013	0.9999	0.0013	0.9999	0.0013	0.9999	0.0013
B	1.1942	1.5362	0.1474	1.2815	0.0384	1.2820	0.0385	1.2822	0.0386
V^*	2.6829	2.6627	0.0063	2.6709	0.0062	2.6705	0.0061	2.6704	0.0061
φ_g^*				1.0001	0.0003	1.0001	0.0003	1.0001	0.0003
CE				-0.8695		-0.8700		-0.8696	
CE*				0.0170		0.0138		0.0132	

Table 2. Deterministic and Stochastic Steady States Comparison. Policy in F, $\nu_g^* = 100$

Note: All the variables are in levels except for the consumption equivalents which are in percentages.

The stochastic steady state is defined as the mean of the second order approximation of the model to a Monte Carlo simulation of the quality of capital shock.[6] The shock follows a Poisson process. The advantages of having a Poisson distributed instead of a Normal distributed shock are twofold. First, I only study negative shocks, which is the nature of the quality of capital shock. According to Equation (45) the government intervention is positive only with negative shocks; with positive shocks, the intervention would be negative because the spread would be negative. Positive quality of capital shocks would correspond to a transfer from the banking sector to the government. Second, the quality of capital shock does not occur in every period; instead, I set up the parameters to have a relative 'big' quality of capital shock every 28 years. The occurrence of the shock matches Reinhart and Rogoff (2008)'s estimate for banking crises in advanced economies; they report 7.2 banking crises between 1800 and 2008, as a world GDP weighted average. The size of the

[6] I simulate the model for 500 periods, 5,000 times, and drop the first 50 observations. I end up with 450 periods that equals 112 years.

shock is 0.015 and corresponds to a decrease in output at the first order of the economy directly hit by the shock of 1.2% from the steady state level; this corresponds approximately to the drop in output from the peak of all banking crises noted by Boissay, Collard, and Smets (2013). In Appendix D, for comparison with the rest of the literature, I show the theoretical moments of the model, with the same standard deviation of the shock presented in this section and I discuss the results. This is an anticipated policy: there is no surprise regarding the intervention of the government; the agents know that every time there is a quality of capital shock in foreign the policy maker intervenes. This generates a distortion: firms reduce their level of capital knowing that the asset price will be higher and the terms of trade lower (if production is lower, the terms of trade appreciate and households can work less and consume more). Table 2 presents the results of the deterministic and the stochastic steady states of the model with and without policies. This table only considers quality of capital shocks in foreign and policies carried out by the foreign central bank. Column 2 shows the deterministic steady state, while the rest of the table presents the stochastic steady state values. The policy parameters are $\nu_g^* = 100$ and $\rho_{\tau_g} = 0.66$. Columns 3 and 4 are the mean and the standard deviation of the model without policy.

Quality of capital shocks in foreign prompt a lower stock of foreign capital with a decrease in its price. Foreign banks are more financially constrained, and their value, V^*, falls. The lower price of the international asset and their lower value allow foreign banks to increase borrowing from home banks and to decrease deposits. Foreign households have a lower financial income, so they start to work more even though they face lower salaries. They cut down consumption. The exchange rate depreciates for foreign because there is a higher flow of interbank market borrowing; when banks pay the return on the loans the demand for foreign currency falls in comparison to the demand for the home currency.

Foreign real exchange rate depreciates, home real exchange rate appreciates. The net interest payments for home go up. In comparison to the deterministic steady state, home households consume more and work less. Home consumers are better off. Households increase bank deposits; this funds the new loans that are made to foreign banks. Home banks substitute domestic capital with interbank market loans.

Columns 5 to 10 of Table 2 show the mean and the standard deviation for the three different policies presented above. The three policies have similar welfare gains. The consumption equivalent gains (last two rows) show improvement in the case of any of these policies for foreign households but worsening for home ones. Three characteristics are important. First, the policies reduce the volatility of the variables with respect to the no policy case, as in Dedola, Karadi, and Lombardo (2013). Second,

	Det	Stochastic Steady State Ψ, Ψ^*, A, A^*, G, and G^* shocks							
		No policy		Loan mkt		Intb mkt		Eq Inj	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
K	6.0671	6.0269	0.0247	5.9938	0.0248	5.9960	0.0247	5.9960	0.0247
C	0.4697	0.4691	0.0110	0.4672	0.0112	0.4673	0.0112	0.4673	0.0112
L	0.2295	0.2293	0.0138	0.2297	0.0139	0.2297	0.0139	0.2297	0.0139
K^*	6.6389	6.5836	0.0311	6.5843	0.0313	6.5853	0.0311	6.5853	0.0311
C^*	0.4430	0.4418	0.0144	0.4418	0.0145	0.4419	0.0144	0.4419	0.0144
L^*	0.2627	0.2627	0.0205	0.2627	0.0204	0.2627	0.0205	0.2627	0.0205
N	1.9806	1.9743	0.0632	1.8914	0.0641	1.8930	0.0641	1.8930	0.0641
D	5.1049	5.1232	0.0166	5.0024	0.0190	5.0023	0.0190	5.0024	0.0190
N^*	1.6402	1.6176	0.0924	1.6466	0.0925	1.6490	0.0924	1.6490	0.0924
D^*	4.9489	4.9111	0.0202	4.9003	0.0204	4.8989	0.0202	4.8988	0.0202
TOT	0.8274	0.8240	0.0314	0.8324	0.0320	0.8325	0.0319	0.8325	0.0319
Ψ^*	1.0000	0.9999	0.0013	0.9999	0.0013	0.9999	0.0013	0.9999	0.0013
B	1.1942	1.2559	0.0748	1.0466	0.0989	1.0458	0.0990	1.0459	0.0990
V^*	2.6829	2.6604	0.0299	2.6680	0.0301	2.6683	0.0299	2.6683	0.0299
φ_g^*				1.0001	0.0006	1.0001	0.0006	1.0001	0.0006
CE				-0.8802		-0.8802		-0.8801	
CE*				0.0116		0.0141		0.0140	

Table 3. Deterministic and Stochastic Steady States Comparison, Technology, Government Expenditure, and Quality of Capital Shocks

Note: All the variables are in levels except for the consumption equivalents which are in percentages.

by targeting the interest rate spread, the interventions reduce the stock of capital in foreign and increase the price of the assets. A higher price prompts a higher value of foreign banks than without policy. Banks increase domestic deposits and reduce borrowing from home banks; the borrowing constraint is less binding. Lower foreign capital implies lower labor. The net interest payments received by home go down. The terms of trade improve foreign welfare. Third, the level of policy intervention is almost zero at the stochastic steady state.

The most effective domestic policy for foreign is the loan market intervention; it presents the highest consumption equivalent for foreign households. This policy prompts the highest price of capital which helps relaxing the financing constraint of the banks. By injecting credit directly into the market in troubled times, the foreign central bank helps the domestic economy, while it hurts home households.

For robustness, I examine the model taking into account quality of capital, technology, and government expenditure shocks in both countries. The distribution of technology and government shocks follow Schmitt-Grohé and Uribe (2005). Technology shocks have an autoregressive coefficient of 0.8556 and a standard deviation of 0.0064; the autoregressive coefficient of government expenditure shocks and the standard deviation are 0.87 and 0.016, respectively. The results are summarized in Table 3. I assume that all the shocks except for the quality of capital shocks follow a Normal process. Under this scenario, the results of intervening are very similar to the previous case. The policies carried out by the foreign central bank are effective in improving domestic consumers' welfare but the gains for foreign households are smaller than in the case where there are only foreign quality of capital shocks.

5 Conclusion

I have presented a two-country DSGE model with financial intermediaries that captures the international transmission mechanism of the latest financial crisis. Banks in both countries are borrowing constrained on obtaining funds from households. Home can invest in the foreign economy through banks using a global asset. The return of the international asset is equal to the return on capital of the foreign economy because there are no financial frictions in the interbank market.

Comparing a model with financial frictions and in financial autarky with one with a global interbank market suggests that the latter generates a higher co-movement of the crisis that matches qualitatively the behavior seen in the data, as shown in the VAR analysis. When a quality of capital shock hits the foreign economy, foreign and home economies experience a crisis both in real and financial variables. The global interbank market prompts the international transmission. The net worth of home banks drops because the price of the international asset falls. Home banks face a reduction in their balance sheets and they are more constrained to lend to domestic non-financial firms. The price of 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.

Banks that intermediate funds across borders and in different currencies entail relevant challenges in terms of policy and regulation. I study the introduction of unconventional policies, in particular, direct lending of the foreign central bank to non-financial firms, direct lending in the interbank market, and equity injections into banks. Up to the first order approximation, the policies are effective for the banks in mitigating the effects of the crisis not only in the domestic country, but also abroad. When the home central bank intervenes foreign variables are hardly affected, but the net worth of home banks falls less. Because of the equalization of loan returns across countries, when the foreign central bank intervenes to reduce the abnormal excess return, the price of foreign and global assets falls less than under no policy. Home banks are less financially constrained. On impact, there is crowding out of consumption in the country that carries out the policy because of the costs of issuing the intervention. I also evaluate the second order approximation of the model. The quality of capital shock follows a Poisson distribution. When only the foreign central bank intervenes, foreign consumers have a welfare improvement as a result of the policies. Home consumers are worse off. The result is a consequence of the terms of trade effect.

The paper focuses on one aspect of the unconventional policies that policy makers have carried out during the last few years. Banks that intermediate funds across borders and in different currencies imply relevant challenges in terms of policy and regulation. In future research, I am planning to study different features of the unconventional policies. In particular, the Fed had coordinated actions with other central banks, because of global banks. The Fed provided U.S. dollars to other central banks, such as the Swiss National Bank and the Bank of England. Then, these central banks provided liquidity to the banks in their jurisdiction, to continue lending to U.S. institution, thereby improving liquidity condition in U.S. These arrangements are called foreign liquidity swaps.

In the model, home can only invest in foreign through the banks. I only look at the net foreign asset position. In reality, the FX swaps and the interbank market, among other derivatives, make the relations across banking systems much more complicated. I believe that this simple relationship between global banks helps us to understand some aspects of the international transmission of the crisis.

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A Appendix: Data and Sources

U.S. loans 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).

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

Swiss final domestic demand 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).

Swiss loans denominated in U.S. dollars 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.

Swiss net interest payments 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.

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

B Appendix: Definition of Equilibria

Frictionless Economy In a model without financial frictions, the competitive equilibrium is defined as a solution to the problem that involves choosing twenty two quantities (Y_t, X_t, L_t, C_t, I_t, X_t^H, X_t^{H*}, K_{t+1}, W_t, Z_t, S_t, Y_t^*, X_t^*, L_t^*, C_t^*, I_t^*, K_{t+1}^*, X_t^F, X_t^{F*}, W_t^*, Z_t^*, S_t^*), two interest rates (R_t, R_t^*), and five prices (Q_t, P_t^H, Q_t^*, P_t^{F*}, τ_t) as a function of the aggregate state (I_{t-1}, K_t, A_t, Ψ_t, I_{t-1}^*, K_t^*, A_t^*, Ψ_t^*).

There are twenty nine variables and twenty nine equations: Eq. (1)-(5), (8) - (14), and Eq. (26) for home, where Eq. (10) has two equations, and equivalent for foreign, and for Eq. (41) which is unique.

Economy with Financial Frictions The competitive banking equilibrium without government intervention is defined as a solution to the problem that involves choosing the same twenty two quantities as in the frictionless economy (Y_t, X_t, L_t, C_t, I_t, X_t^H, X_t^{H*}, K_{t+1}, W_t, Z_t, S_t, Y_t^*, X_t^*, L_t^*, C_t^*, I_t^*, K_{t+1}^*, X_t^F, X_t^{F*}, W_t^*, Z_t^*, S_t^*), plus the fourteen variables related with banks (N_t, D_t, B_t, Ω_t, μ_t, ν_t, ϕ_t, N_t^*, D_t^*, B_t^*, Ω_t^*, μ_t^*, ν_t^*, ϕ_t^*), five interest rates (R_t, R_t^*, R_{kt}, R_{kt}^*, R_{bt}^*), and six prices (Q_t, Q_{bt}^*, P_t^H, Q_t^*, P_t^{F*}, τ_t) as a function of the aggregate state (I_{t-1}, K_t, A_t, Ψ_t, I_{t-1}^*, K_t^*, A_t^*, Ψ_t^*). There are forty seven variables and forty seven equations. Eq. (1)-(5), (8)-(14), for home, where Eq. (10) has two equations, and equivalent for foreign. Eq. (21), (23)-(26), (31)-(33) and similar for foreign; and Eq. (27), (29), (36), (43), (42).

C Appendix: Deterministic Steady State

In Table 4 I show the comparison between the average of Swiss data for 2002-2008 and the deterministic steady state of the home economy. The first part of the table presents the ratios of the main variables with respect to GDP, while the second part shows the ratios with respect to the final domestic demand. In both cases the ratios of the deterministic steady state of the real variables match the data. There are two caveats. First, the net exports of the model are negative, while in the data they are positive. To model a small economy with a big financial sector, I need a net importer home country. If I only included the data for goods, the net exports of Switzerland would be negative. Second, the financial variables of the model (total assets and assets from home banks with foreign counterparties) almost double the data. However, the ratio of global assets over the total assets matches the data, which is most relevant for the results.

The deterministic steady state also matches the ratio between the Swiss and the U.S. economy. In particular, for the period 2002-2008, the U.S. GDP is almost 29 times bigger than the Swiss GDP. In the model, foreign production is 27 times bigger than home production.

		Data	Model
Panel A: *Ratios w.r.t. GDP*			
$X^{H*}\frac{1-m}{m}$ - X^F	Net exports	0.0777	-0.0516
C	Consumption	0.5933	0.6945
I	Investment	0.2146	0.2243
G	Gov Consumption	0.1140	0.1300
B + K	Total Assets	5.7288	10.7368
B	Global Asset	1.0246	1.7658
Panel B: *Ratios w.r.t. Final Domestic Demand*			
$X^{H*}\frac{1-m}{m}$ - X^F	Net exports	0.0848	-0.0492
C	Consumption	0.6435	0.6622
I	Investment	0.2329	0.2138
G	Gov Consumption	0.1236	0.1240
B + K	Total Assets	6.2245	10.2373
B	Global Asset	1.1135	1.6836

Table 4. Comparison between Swiss Data and Deterministic Steady State

Note: The Swiss data is HP filter and evaluated between 2002 and 2008. See sources in Appendix A.

D Appendix: Unconditional Welfare

For comparison with the previous literature, I look at the unconditional moments of the second order approximation of the model. The results are in Table 5. Given that the volatility of the shock matches the volatility generated by the Poisson distribution, the size of the disturbance is very small. This prompts a small reaction of the variables. In this case, it is the ergodic distribution of the variables given positive and negative shocks, which prompt negative and positive intervention, respectively. The government intervenes in every period using its unconventional policy. In comparison with the conditional moments, two aspects are relevant. First, the policies do not help to reduce the volatility of the variables. Second, the ranking of the policies according to the consumption equivalent of foreign consumers is the opposite.

In the unconditional stochastic steady state, the interbank market policy crowds out home loans to foreign. The difference in the interbank market quantities affects the terms of trade. Foreign experiences a larger appreciation with respect to the no-policy model with the interbank market policy than with the intervention in the loan market. The welfare gain from no policy in consumption equivalents (last row of Table 5) is positive for both policies and twice higher for the interbank one because of the terms of trade effect.

	Det	Stochastic Steady State Ψ^*							
		No policy		Loan mkt		Intb mkt		Eq Inj	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Y	0.7093	0.7124	0.0047	0.7124	0.0047	0.7123	0.0047	0.7123	0.0047
K	6.0671	6.0702	0.0018	6.0702	0.0018	6.0701	0.0018	6.0701	0.0018
C	0.4697	0.4723	0.0058	0.4723	0.0058	0.4722	0.0058	0.4722	0.0058
L	0.2295	0.2285	0.0048	0.2285	0.0048	0.2285	0.0048	0.2285	0.0048
Y^*	0.7612	0.7611	0.0022	0.7611	0.0022	0.7611	0.0022	0.7611	0.0022
K^*	6.6389	6.6393	0.0067	6.6393	0.0067	6.6393	0.0067	6.6393	0.0067
C^*	0.4430	0.4429	0.0024	0.4429	0.0024	0.4429	0.0024	0.4429	0.0024
L^*	0.2627	0.2628	0.0013	0.2628	0.0013	0.2628	0.0013	0.2628	0.0013
N	1.9806	2.0399	0.0317	2.0400	0.0317	2.0381	0.0317	2.0379	0.0317
N^*	1.6402	1.6382	0.0187	1.6381	0.0187	1.6382	0.0187	1.6382	0.0187
TOT	0.8274	0.8095	0.0231	0.8095	0.0232	0.8100	0.0232	0.8101	0.0232
Ψ^*	1.0000	1.0000	0.0013	1.0000	0.0013	1.0000	0.0013	1.0000	0.0013
B	1.1942	1.4598	0.2355	1.4601	0.2356	1.4500	0.2356	1.4491	0.2356
V^*		2.6785	0.0068	2.6785	0.0068	2.6786	0.0068	2.6786	0.0068
φ_g^*				1.0001	0.0000	1.0001	0.0000	1.0001	0.0000
CE				0.0011		-0.0298		-0.0325	
CE*				-0.0002		0.0014		0.0015	

Table 5. Unconditional Moments. Deterministic and Stochastic Steady States Comparison

Note: All the variables are in levels except for the consumption equivalents which are in percentages.

E Appendix: Additional Graphs

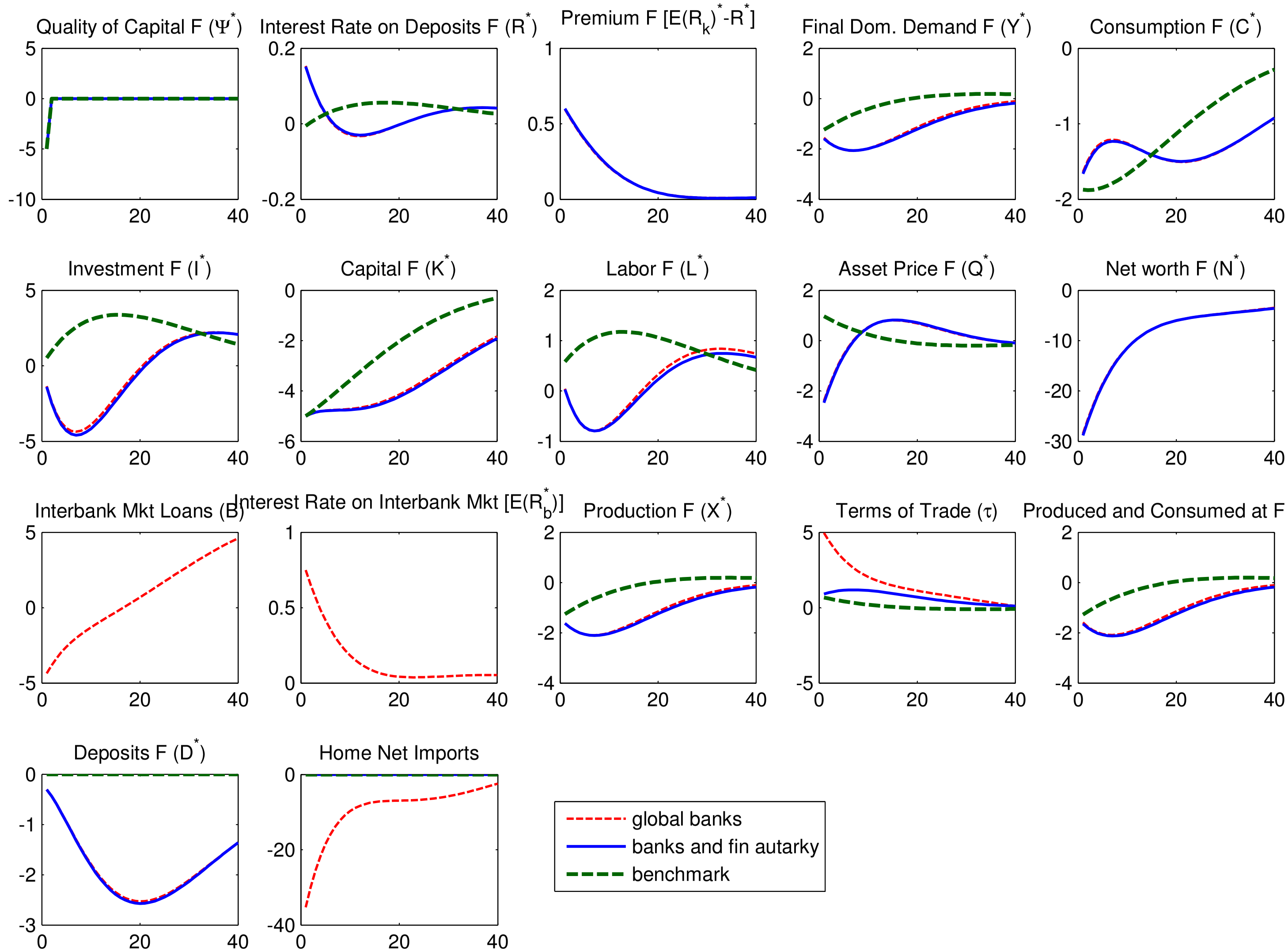

Figure 5. Impulse Responses to a 5% Decrease in Ψ_t^*, Model Comparison, Large Set of Foreign Variables

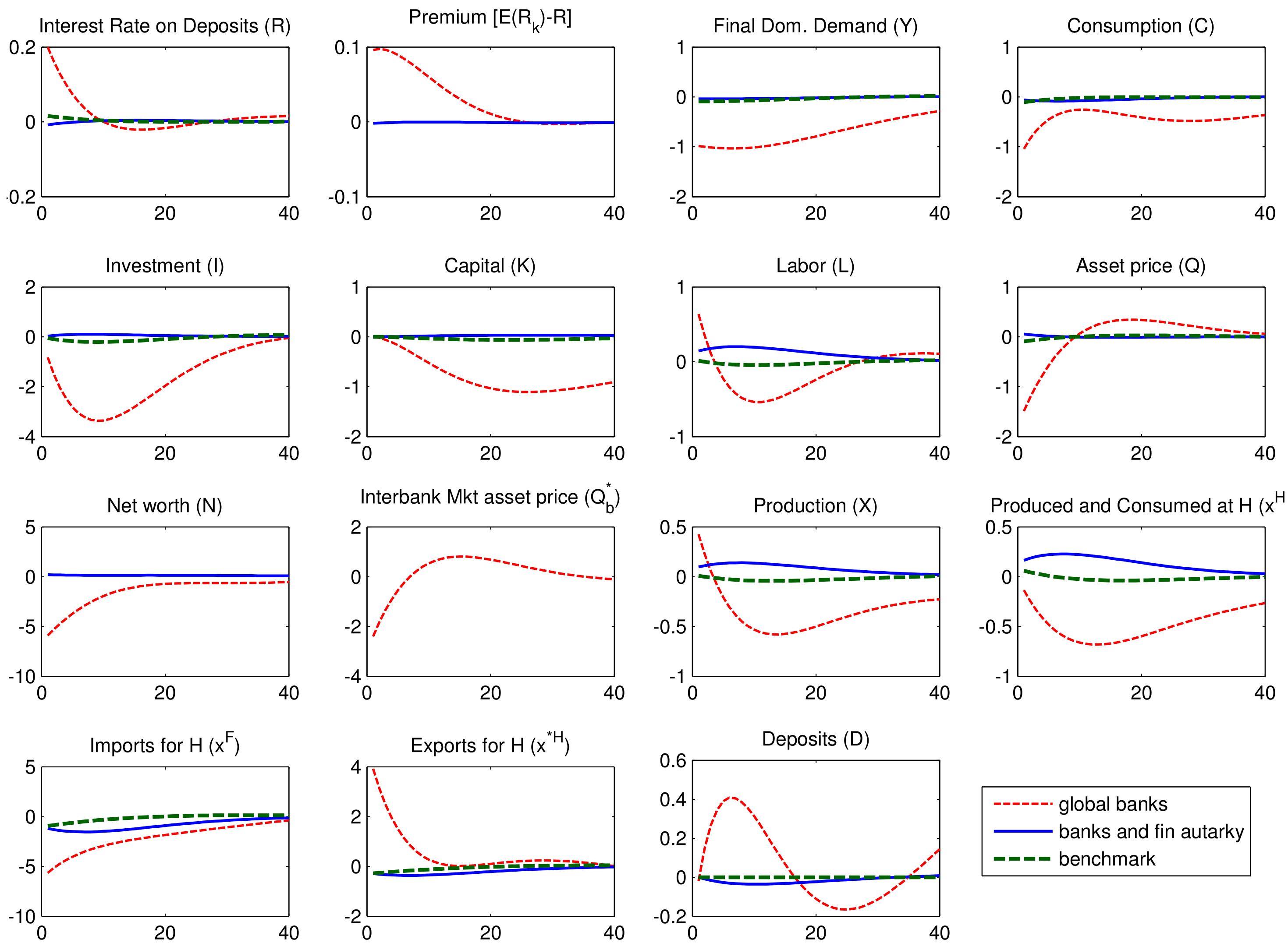

Figure 6. Impulse Responses to a 5% Decrease in Ψ_t^*, Model Comparison, Large Set of Home Variables

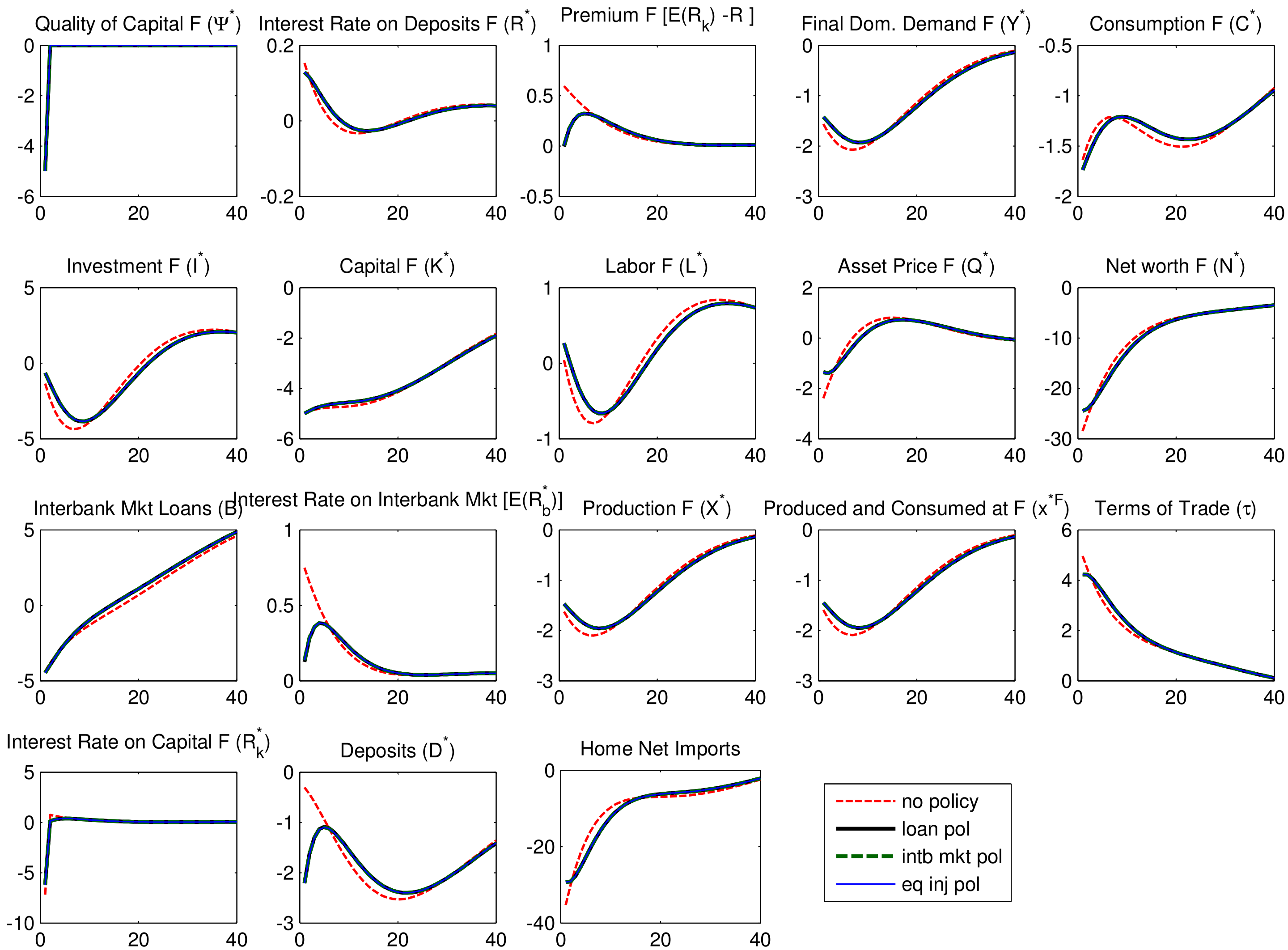

Figure 7. Impulse Responses to a 5% Decrease in Ψ_t^*, Unconventional F Policy Comparison, Large Set of Foreign Variables

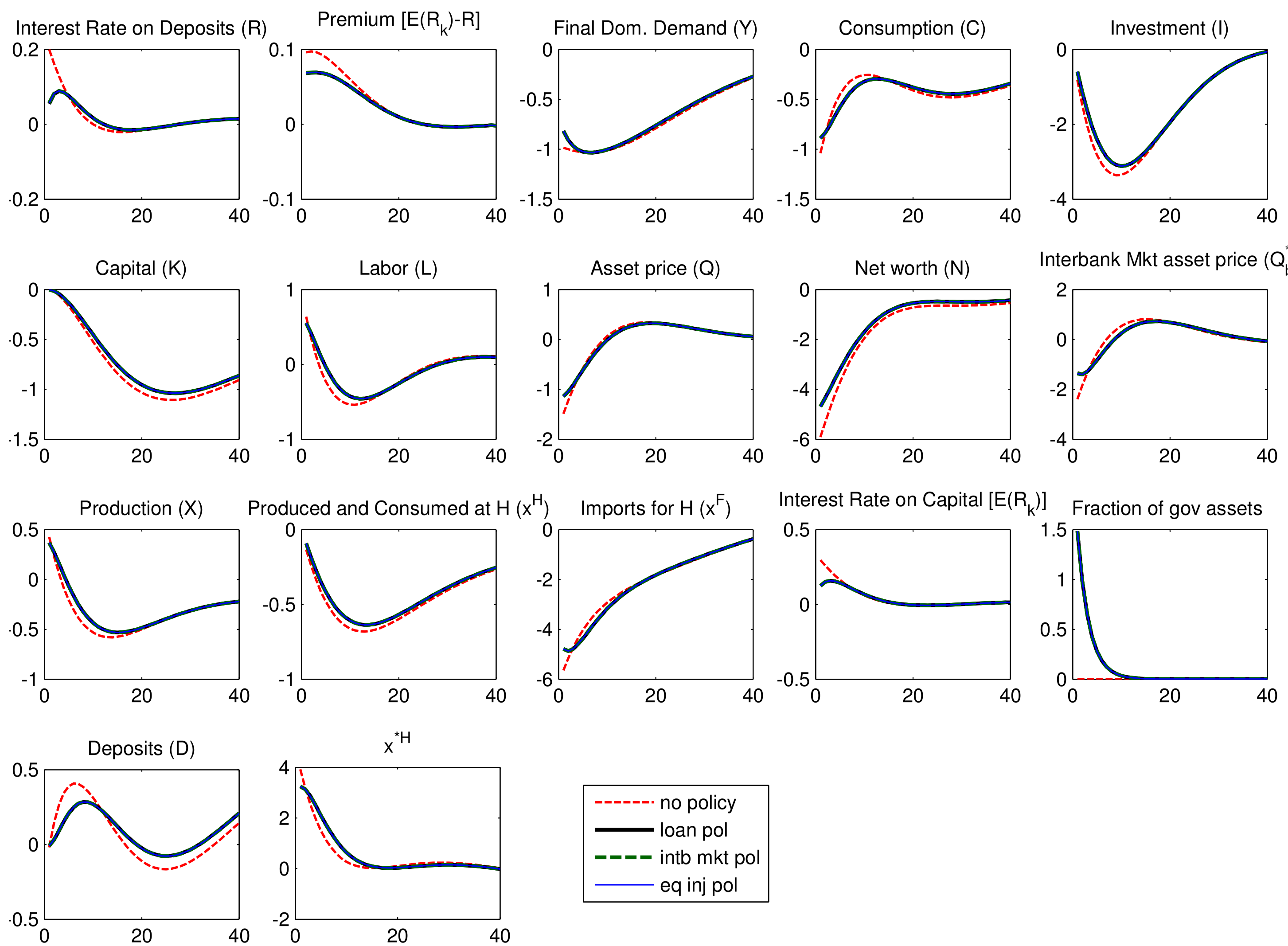

Figure 8. Impulse Responses to a 5% Decrease in Ψ_t^*, Unconventional F Policy Comparison, Large Set of Home Variables