Securitization and cross-border spillovers from macroprudential policy*

Dawid Żochowski[†]

European Central Bank

August 6, 2017

Abstract

This paper puts forward a two-country two-period general equilibrium model with fragmented mortgage and capital markets and heterogenous banks. I extend Goodhart et al. (2013) model by allowing for securitisation and by varying risk aversion across banks in two countries. In such a set-up I test the cross-border propagation from capital and loan-to-value (LTV) regulation. I find that the re-optimisation of bank balance sheets in response to a macroprudential policy innovation is crucial in determining the magnitude of cross-border spillovers. I also find that by means of securitisation banks may shift risk across borders in response to rebalancing the macroprudential policy stance between the two countries, thereby weakening the effectiveness of the policy (securitisation channel). In particular, an uncoordinated LTV policy may lead to unintended results as banks increase their originate-to-distribute activity in response. In this way an asymmetric macroprudential policy innovation is leaked across borders.

Keywords: General equilibrium; macroprudential policy; systemic risk, cross-border spillovers.

JEL-Classification: G38, L51.

---

*DISCLAIMER: This paper should not be reported as representing the views of the European Central Bank (ECB). The views expressed are those of the author and do not necessarily reflect those of the ECB.

[†]E-mail dawid.zochowski@ecb.europa.eu

1 Introduction

In the run-up to the global financial crisis that erupted in mid-2007 cross border credit risk sharing has increased substantially and rapidly. According to the BIS consolidated banking statistics banks' foreign claims rose to $24.7 trillion in March 2008 after they had doubled since 2005 (see Figure 1). They have receded since.

This internationalisation of credit risk took various forms. European banks were buying Residential Mortgage Backed Securities issued in the U.S. French and German banks were exposed to sovereign bonds issued by Greek, Spanish or Italian governments. Furthermore, many banks expanded their foreign activities by acquiring foreign subsidiaries or starting greenfield investments. In particular in the euro area, an integrated money market facilitated an increase in cross border exposures, as during the pre-crisis period it was relatively easy to fund them via short-term money market liabilities. All this took place in the environment where prudential regulations and supervisory practices were not aligned across jurisdictions. This paved the way for regulatory arbitrage and, in some cases, resulted in excessive risk taking in some countries or by some banks. The most important channels of this risk diversification process were cross-border lending and securitisation.

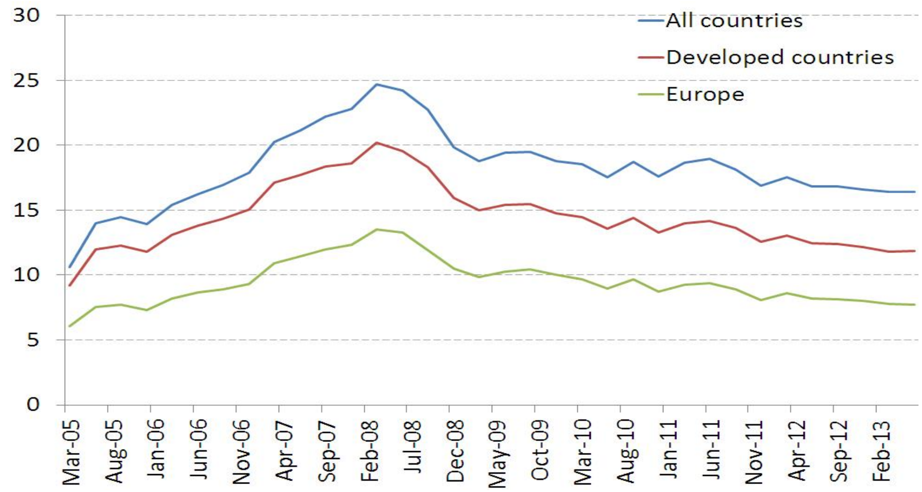
Against this background, this paper extends a simplified version of the framework by Goodhart et al. (2013) in two dimensions. First, it extend the model into a two country set-up in order to identify cross boarder channels of propagation of various macroprudential instruments. Second, it introduces monetary policy shocks in order to test the interaction between the macroprudential instruments and the monetary policy. Following Goodhart et al. (2013) the main frictions in the model are two types of defaults. First, the household can default on the mortgage and, second, the financial intermediary may default on its interbank claim. This may also lead to credit supply shocks. It is important to stress that in both cases default is a result of utility optimisation, i.e. appears in (bad) equilibrium. For tractability of cross-boarder propagation channels, we refrain from modelling fire-sales and liquidity squeezes in this version of the model.

There is a growing literature that analyses the efficacy of various macroprudential instruments within a general equilibrium framework[1], however, little papers allow for an endogenous default on the mortgage contract. In fact, following Kiyotaki and Moore (1997) the literature tends to assume that borrowers always pledge enough collateral to shelter the lenders from the adverse implication of a default. Furthermore, little papers develop a two country framework or, more broadly, introduce heterogeneity within the banking sector and look into cross-sectional propagation of macroprudential instruments. To the best of our knowledge, only Brzoza-Brzezina et al. (2013) test the relative effectiveness of LTV and capital regulations in a two-economy macrofinancial DSGE model under the asymmetric shock to the core and the periphery. They find that LTV policy is more efficient than capital regulation. However, they do not assess the implications of joint regulations nor they discuss cross boarder spillover from macroprudential policies.

The empirical literature on cross-border propagation from macroprudential policies is also rather scarce, however, there area some evidence that the spill-overs are not negligible. Analysing lending activity of 155 large multinational banks operating across 16 countries Ongena et al. (2013) show that banks who are tightly regulated at home apply lower lending

[1] See for instance Angelini et al. (2011), Darracq-Paries et al. (2011), Christensen et al. (2011), Angeloni and Faia (2011).

Figure 1: Consolidated foreign claims of reporting banks - ultimate risk basis [USD trillion]



Source: BIS

standards abroad. Aiyar et al. (2011) provide evidence for regulatory arbitrage showing that UK-regulated banks reduced lending in response to tighter capital requirements, but resident foreign branches increased lending at the same time. Yet while this 'leakage' was material, it was not full - it offset about one-third of the initial impulse from the regulatory change. Furthermore, in a recent discussion paper Kincaid and Watson (2013) claim that the benefits from international coordination of macro-prudential policies should be greater than the gains from macroeconomic policy coordination because of financial sector specific externalities. They also note what is one of the outcome of this model, namely that macro-prudential measures applied solely to domestic financial institutions may be undermined by cross-border flows in the absence of coordination. In addition, a progress report to G20 ((FSB, 2011)) underlined that a key concern for the efficiency of macroprudential tools is the potential for cross-border regulatory arbitrage. Finally, Canuto and Cavallari (2013) note that cross-border capital flows and macroeconomic policy spillovers may bring implications in terms of higher volatility of activity on the real side, more complicated monetary policy management and augmented financial-sector risks.

This paper finds that an active response of bank agents via the adjustment of banks balance sheets plays a crucial role in the propagation of the macroprudential policy. In particular, the macroprudenital policy shock may be leaked cross-border via the securitisation and interbank channel. Hence, the efficacy of the asymmetric policy innovation may be weakened, as banks may switch to originate-to-distribute type of activity. Furthermore, this paper shows that the cross-boarder spillover from macroprudenital policy is not straightforward and may depend on the risk aversion of the banks. In general, risk-loving banks will more actively adjust their balance sheets and via cross-boarder securitisation channel may affect the supply of mortgages aborad. In particular, I identify strong cross-boarder leakages from the application of the LTV regulation in a risk-loving environment. Since in the case of the LTV regulation the constrain binds the borrower but not the lender, the risk-loving bank tends to adjust the cross-border composition of its balance sheet exposures by increasing the exposure to home mortgages in a country where a prudent bank operates. While this regulation, as intended decreases the amount of mortgages issued in the region where the risk-loving bank operates, it leads to an increase in the amount of mortgages issued in the region where a risk averse bank operates. Hence, the LTV regulation in response to an asymmetric shock may be 'leaked' across borders.

Given that the mortgage market is national, such a set-up can be interpreted as a monetary union with a fragmented (national) banking sectors. Hence, this framework may be useful in assessing the impact of a mix of macroprudential policy instruments on various countries in the euro area in the context of the implementation of a Single Supervisory Mechanism.

The remainder of this paper is organised as follows: section 2 outlines the model, while section 3 discusses agents' optimisation problems in detail. Using a calibrated version of the model to a theoretical two country/region economy section 4 describes the effects of various macroprudential policy interventions. Lastly, section 5 concludes.

2 Model

This sub-section describes the main building blocks of the model in a narrative way. It is followed by sub-sections describing the model in a formal way.

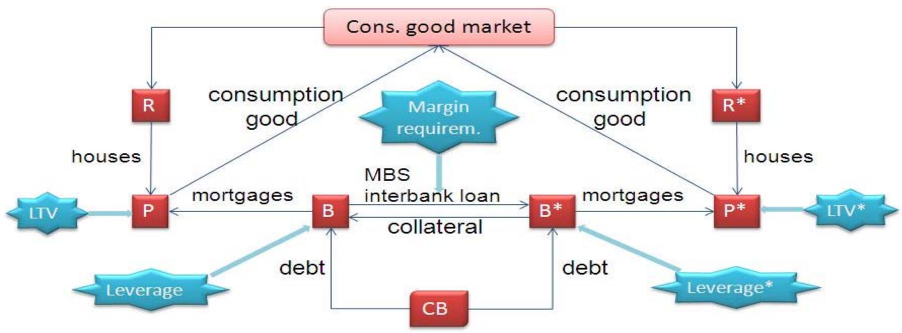
The model outlined in this section is an extension of the Goodhart et al. (2013) framework in a two country set-up. Consequently, I adopt the same notation. In addition, using the notation adopted in the 'open economy' literature, all agents in a foreign country are denoted with a *-superscript. Each country consist of three local agents: a household poor-in-houses (P), a household reach-in-houses (R) and a commercial bank (B) that extends mortgages and can securitise them. Moreover, a central bank, common to two countries, sets a lending rate and provides commercial banks with necessary funding.

There are two consumption goods in the economy: a durable houses and non-durable food, which are perishable and yield nothing. (P is endowed only with food, while (R is endowed only with houses. In the first period, both types of households are allowed to exchange food against houses. P funds its house purchases both with the proceeds from the sale of food portions and with a mortgage from the commercial bank B. The houses bought in the first period serve as collateral for the mortgages. There are two main linkages between the two countries (see Figure 2). First, all households exchange food in one common international market, whereas housing markets are national. Second, banks securitise and trade the mortgages they extended and can also use these securities in the interbank repo contracts. Within the calibrated version of the model presented in Section 3.3, the home bank B securitises the mortgages issuing mortgage-backed securities (MBS) and sells them to the foreign bank B^*. These MBS serve as collateral for a defaultable interbank loan extended to B^*. Both banks can also fund their operations using central bank funding. The interest rate on central bank debt is exogenous and acts as an instrument of conventional monetary policy in this model.

The only heterogeneity which is introduced between the two countries/regions is a difference in the risk-aversion of the two banks: The home bank B is more risk-averse than the foreign bank B^*.

Furthermore, markets are perfectly competitive, there is no asymmetric information and agents are rational. Asset markets are incomplete since agents are not allowed to meet in the first period and trade assets that allow for every conceivable contingency for all future states. The main friction in the model is the fact that the household can default on its mortgage and

Figure 2: Schematic overview



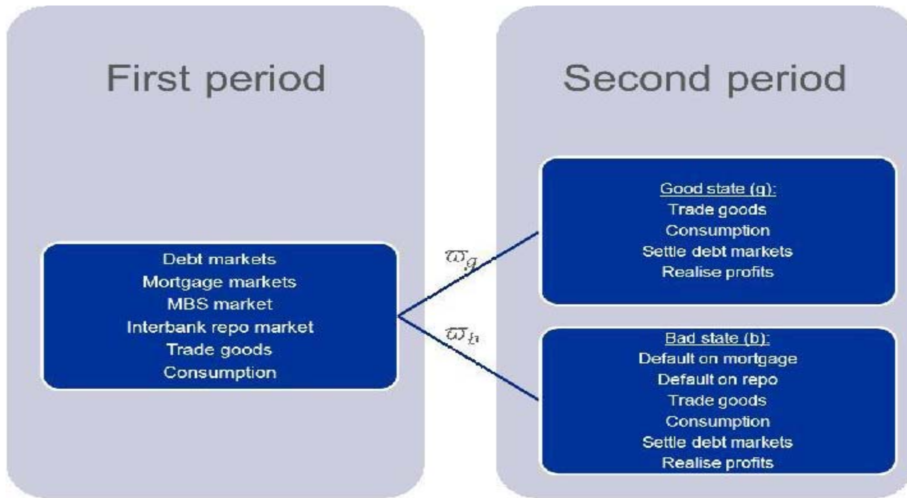
Source: Own scheme

that the banks can default on their repo contract. Defaults occur in the bad state and are endogenous, i.e. they are outcomes of agents' optimisation.

Figure 3 illustrates the dynamic features of the model. There are two periods in the model, between which financial institutions need to roll-over their debt. In the first period, the households P, $P*$, R, and $R*$ trade in goods and consume, mortgages are issued and securitised, interbank loan and debt contracts are initiated. In the second period there are two possible states of the nature, a bad state (b) or a good state (g). In the second period, agents P and $P*$ decide whether to default on their mortgages, $B*$ decides whether to default on the interbank loan, all households trade in goods and consume, debt in the financial sector is repaid and financial institutions realize their profits. In the calibrated version of the model presented in Section 3.3, the two final states differ only with respect to agent P's and $P*$'s endowments. Low endowments mimic a negative productivity shock.

Agents P and $P*$ default on their mortgages if the value of the house they bought in the first period is lower in the second period than the mortgage repayment. Following Goodhart et al. (2013) the default is therefore an endogenous decision stemming from the utility optimization. In the calibrated version of the model presented in Section 3.3 the default condition is satisfied in the bad state and hence P and P default on their mortgages. While the decision to default on the mortgage is a binary decision, the recovery value of the mortgage is a continuous variable. Following the default the underlying collateral, i.e. the houses that were bought in the first period by P and $P*$, are seized by the banks. Banks can also recover some value of the mortgages by selling the collateral in the second period on the housing market. The default condition on the repo contract is similar. The bank decides to default on the interbank loan if the value of the collateral (MBS) is lower than the loan obligation in the second period.

Figure 3: Overview of the model dynamics and markets



Source: Own scheme.

3 Optimisation and Equilibrium

3.1 Agents' optimisation problems

In the remainder of this paper the following labeling is used: agents are denoted with capital letters and superscripts. Goods, periods, and states are denoted with subscripts. For example, $c^P_{1,h}$ is agent P's first period consumption of housing.

Agent *P*'s and *P's optimization problem.** The following maximization problem is identical for P and P*. In order to keep the description brief, only the one for P is reported. Household P obtains utility from consuming food and housing. However, he is only endowed with food in all periods and states and with money in the first period. His food endowment is given by $\overline{e}^P = (e^P_{1,f}, e^P_{g,f}, e^P_{b,f})$, for period 1, state g, and b. Hence, he wishes to obtain houses, the good that he is not endowed with. Therefore, P sells food and buys houses. In order to finance his housing purchases in the first period, P takes a mortgage M^P_1 from bank B. P therefore combines self-financing (money endowment and proceeds from the sale of the food) and debt financing (mortgage) in order to purchase houses. His first period budget constraint in following:

$$p_{1,h}c^P_{1,h} \leq E^P_1 + M^P_1 + p_{1,f}q^P_{1,f} \tag{1}$$

where $p_{1,h}$ is the unit price of housing and $p_{1,f}$ the unit price of food in the first period. $c^P_{1,h}$ is P's consumption of housing and $q^P_{1,f}$ are his food sales in the first period. In the second period, once the the final state of the nature is determined, P decides whether to default or not to default on his mortgage. He defaults if the underlying collateral is worth less than the mortgage repayment. Put differently, he defaults if the second period value of his first period houses is lower than the mortgage repayment, i.e. $p_{s,h}c_{1,h}(1-\delta) \leq M^P_1(1+\rho^M)$, where ρ^M is the interest on the mortgage, $p_{s,h}$ is the unit price of housing in state $s \in \{g, b\}$ and δ is the rate of depreciation of houses between the two periods. In the calibrated version of the model in Section 3.3, default occurs in state b. P's budget constraint for this state is therefore given by the following condition:

$$p_{b,h}c_{b,h}^P \leq E_b^P + p_{b,f}q_{b,f}^P \tag{2}$$

In contrast, P will repay his mortgage in state g and his budget constraint must satisfy:

$$M_1^P(1+\rho^M) + p_{g,h}c_{g,h}^P \leq E_g^P + p_{g,f}q_{g,f}^P \tag{3}$$

Household P's problem is then to maximizes his expected first period utility $\overline{U}^P$, subject to budget constraints (1)-(3). Hence, his expected utility takes the form:

$$\overline{U}^P = U^P(c_{1,f}^P, c_{1,h}^P) + \beta\omega_g[U^P(c_{g,f}^P, (1-\delta)c_{1,h}^P + c_{g,h}^P)] + \beta(1-\omega_g)[U^P(c_{bs,f}^P, c_{bs,h}^P)] \tag{4}$$

where $0 < \delta < 1$ is the rate of depreciation rate on the durable goods, i.e. houses, $0 < \beta < 1$ is a discount rate, and $0 < \omega_g < 1$ is agent P's belief about the probability that state g materialises in the second period. The depreciation rate, the discount factor, and the beliefs about the probabilities of future states are the same among all agents. This equation reflects also the durable and non-durable character of the two goods: while P still consumes houses, discounted by the depreciation rate, in state g (no default), food cannot be transferred across periods. In state b when P defaults on his mortgage, the bank seizes collateral, i.e. P's first period house purchases, since they serve as collateral for the mortgage. The houses are then acquired by the bank in state b.

Agent R's and R^*'s optimization problem. The following maximization problem is identical for R and $R*$. In order to keep the description brief, only the one for R is reported. Household R is the trading counterparty to P. He is only endowed with houses in the first period, $e_{1,h}^R$, i.e. his endowment is $\overline{e}^R = (e_{1,h}^R, 0, 0)$. Hence, he is interested in buying food. In contrast to P, household R is not facing any financing problems and instead wishes to save some of his income from housing sales in the first period. Hence, his first period budget constraint must satisfy:

$$p_{1,f}c_{1,f}^R + cash^R \leq E_1^R + p_{1,h}q_{1,h}^R \tag{5}$$

where $cash^R$ represents his first period savings and all other variables are in line with the notation for agent P. His savings will be available in the second period in both states. Hence, his second period budget constraints are given by:

$$p_{s,f}c_{s,f}^R \leq cash^R + E_s^R + p_{s,h}q_{s,h}^R \text{ for } s \in \{g, b\} \tag{6}$$

R can transfer the durable goods, i.e. houses, from the first to the second period. After depreciation, R can again sell houses in the second period and consume the rest.

Agent R's problem is then to maximizes his first period expected utility $\overline{U}^R$,, subject to the budget constraints (5) and (6), which takes the form:

$$\overline{U}^R = U^R(c_{1,f}^R, c_{1,h}^R) + \beta\sum_s \omega_s[U^R(c_{s,f}^R, (1-\delta)c_{1,h}^R - q_{s,h}^R)] \text{ for } s \in \{g, b\} \tag{7}$$

Agent B's optimization problem. The commercial bank B is endowed with initial capital E_1^B. In addition, it can borrow D_1^B from CB in the first period. B's first period leverage ratio is defined as $\frac{D_1^B}{E_1^B}$. B extends mortgages M_1^B to household P. Moreover, it securitises a proportion σ_1^B of these mortgages issuing mortgage backed securities MBSs and sells them to the foreign bank B^* at the price P_1^M. At the same time, B can extend an inter-bank loan L_1^B to B^* to B^* for which the MBS serve as collateral in case of a default on this loan. B's first period budget constraint must therefore satisfy:

$$M_1^B - P_1^M \sigma_1^B M_1^B + L_1^B \leq D_1^B + E_1^B \tag{8}$$

Including an interaction term σ_1^B on M_1^B implies that B takes into account that the more mortgages it extends to P, the more it can securitise. After the state of the nature in the second period crystalises, financial institutions have to roll-over their debt. The roll-over of debt separates interest rates for the two periods, it takes the following form for the two states:

$$D_1^B(1 + r_1) \leq D_s^B \text{ for } s \in \{g, b\} \tag{9}$$

i.e. old debt is paid back at the interest r_1 using new debt D_s^B. Recall that in state g household P does not default on his mortgage, but repays his debt completely. The same holds for the foreign bank B^* with respect to the interbank-loan. B's final profit in state g is therefore given by:

$$\pi_g^B = M_1^B(1 - \sigma_1^B)(1 + \rho^M) + L_1^B(1 + \rho^L) - D_g^B(1 + r_g) \tag{10}$$

, i.e. B's proceeds consist of the repayment on the mortgages that were not securitized, plus the repayment of the inter-bank loan, where ρ^L is the interest on the loan, less the debt that has to be repaid to the CB at the interest rate r_g. In a bad state, P defaults on his mortgage, which may trigger the default of B^* on the inter-bank loan. This is because the underlying collateral, i.e. the first period house purchases of households P and P^*, are seized by the financial institutions after a default on the mortgage. Financial institutions sell these houses on the market in the second period. Depending on the second period house prices for state b, B is able to recover a proportion $V_b^M = \frac{p_{b,h} c_{1h}^P}{(1+\rho^M) M_1^P}$ of the total repayment. Moreover, B receives the first period MBS sales if B^* defaults on the interbank-loan. The recovery on the inter-bank loan is therefore given by $V_b^{Repo} = (\frac{V_b \sigma_1^B M_1^B (1+\rho^M)}{L_1^B})$. Hence, B's profits after in a bad state are given by:

$$\pi_b^B = V_b M_1^B(1 - \sigma_1^B)(1 + \rho^M) + L_1^B V_b^{Repo} - D_b^B(1 + r_b) \tag{11}$$

, i.e. B's proceeds consist of the recovery on the mortgages that were not securitized and the recovery on the inter-bank loan, less the debt repayment to the CB.

Hence, agent B's optimisation problem is to maximize the expected payoff function $\overline{P}^B$, subject to constraints (8)-(11), which takes the form:

$$\overline{P}^B = \beta \sum_s \omega_s P^B(\pi_s^B) \text{ for } s \in \{g, b\} \tag{12}$$

Agent B^* optimization problem. The foreign bank B^* is endowed with initial capital $E_1^{B^*}$. In addition, it can borrow $D_1^{B^*}$ from the CB in the first period and also it can take an inter-bank loan $L_1^{B^*}$ from the home bank B. B^*'s first period leverage ratio is defined as $\frac{D_1^{B^*} + L_1^{B^*}}{E_1^{B^*}}$. In the first period, B^* issues mortgages $M_1^{B^*}$ to household P^*. Moreover, it buys

$\overline{M}_1^{B^*}$ of mortgage backed securities at the price P_1^M from B. B^* first period budget constraint must therefore satisfy the following inequality:

$$M_1^{B^*} + \overline{M}_1^{B^*} P_1^M \leq D_1^{B^*} + E_1^{B^*} + L_1^{B^*} \tag{13}$$

Once the state crystalises in the second period, financial institutions roll-over their debt:

$$D_1^{B^*}(1 + r_1) \leq D_s^{B^*} \text{ for } s \in \{g, b\} \tag{14}$$

, i.e. old debt is paid back at the interest r_1 by taking on new debt $D_s^{B^*}$. Recall that households P and P^* do not default on their mortgages in state g, but repay their debt completely. In the calibrated version of the model presented in Section 3.3, foreign bank B^* also does not default on its inter-bank loan in state g. Hence, the following condition holds: $L_1^{B^*}(1 + \rho^L) < \overline{M}_1^{B^*}(1 + \rho^M)$, i.e. the repayment on the inter-bank loan is less than the value of the underlying collateral, i.e. the proceeds from the MBS that B^* bought in the first period. B^* final profit in state g is therefore given by:

$$\pi_g^{B^*} = M_1^{B^*}(1 + \rho^{M^*}) + \overline{M}_1^{B^*}(1 + \rho^M) - L_1^{B^*}(1 + \rho^L) - D_g^{B^*}(1 + r_g) \tag{15}$$

, i.e. B^* profits consist of the repayment on the mortgages that it extended to P^*, the return on the *MBS*, less the repayment of the inter-bank loan, where ρ^L is the interest on the loan, and the debt that has to be repaid to the *CB* at the interest rate r_g.

In contrast, in the bad state, P^* defaults on his mortgage, which triggers a defaults of B^* on the inter-bank loan. This is because $L_1^{B^*}(1 + \rho^L) > V_b\overline{M}_1^{B^*}(1 + \rho^M)$, i.e. the value of the underlying collateral is less than the repayment on the inter-bank loan. As a result, B^*'s profits in the bad state are given by:

$$\pi_b^{B^*} = V_b^* M_1^{B^*}(1 + \rho^{M^*}) - D_b^{B^*}(1 + r_b) \tag{16}$$

, i.e. B's profits consist of the recovery value of the mortgages that were extended to household P^* (where $V_b^* = \frac{p_{b,h}^* c_{1h}^{P^*}}{(1+\rho^{M^*})M_1^{P^*}}$), less the debt repayment to the CB.

The optimisation problem of the foreign bank B^* is then to maximize the expected payoff function $\overline{P}^{B^*}$, subject to conditions (13)-(16), which takes the following form:

$$\overline{P}^{B^*} = \beta\omega_g P^{B^*}(\pi_g^{B^*}) + \beta\omega_b[P^{B^*}(\pi_b^{B^*}) - \tau[L_1^{B^*}(1 + \rho_L) - V_b\overline{M}_1^{B^*}(1 + \rho^M)]] \text{ for } s \in \{g, b\} \tag{17}$$

A new element in the objective function of the foreign bank B^* compared to the domestic bank B is a linear default penalty τ.[2], since corner-solutions exists as long as $\rho^M \neq \rho^L$.[3]. B^* needs to pay this default penalty for every unit of default, i.e. τ times the difference between the amount owed, $L_1^{B^*}(1 + \rho_L)$, and the recovery value of the collateral, $V_b\overline{M}_1^{B^*}(1 + \rho^M)$.

[2]The modelling of the default penalty follows Dubey et al. (2005). The idea behind this additional cost is that the default is costly as a result of, for example, the loss of reputation in the case of the default on the loan.

[3]For example, the foreign bank B^* will always demand more *MBS* as long as $\rho^M > \rho^L$.

3.2 Markets and equilibrium

This a two period rational expectations model with uncertainty about the state of the nature in the second period. Hence, an optimal solution for this model is reached by maximising agents' optimization problems subject to constraints and by clearing of all markets[4]. Each market clears when supply equals demand. Good markets clear if the supply is equal to the demand in the first and the second period. The first and second period international food market clears when:

$$c^R_{s,f} + c^{R^*}_{s,f} = q^P_{s,f} + q^{P^*}_{s,f} \text{ for } s \in \{1, g, b\} \tag{18}$$

In contrast to the food market, housing markets are national. First period housing markets clear if:

$$c^P_{1,h} = q^R_{1,h} \tag{19}$$

$$c^{P^*}_{1,h} = q^{R^*}_{1,h} \tag{20}$$

Second period housing markets clear accordingly, taking into account that the underlying collateral of the mortgage is sold by the financial institutions in state b:

$$\begin{aligned} c^P_{g,h} &= q^R_{g,h} && (21)\\ c^{P^*}_{g,h} &= q^{R^*}_{g,h} && (22)\\ c^P_{b,h} &= q^R_{b,h} + (1-\delta)c^P_{1,h} && (23)\\ c^{P^*}_{b,h} &= q^{R^*}_{b,h} + (1-\delta)c^{P^*}_{1,h} && (24) \end{aligned}$$

Moreover, mortgage, securitization, and inter-bank loan markets also have to clear. The mortgage market clears if the mortgage demand by household P is equal to the supply by the home bank B, and similarly for the foreign country, that is:

$$M^P_1 = M^B_1 \tag{25}$$

$$M^{P^*}_1 = M^{B^*}_1 \tag{26}$$

The mortgage-backed-security market and the inter-bank loan market clear if:

$$\begin{aligned} \overline{M}^{B^*}_1 &= \sigma^B_1 M^B_1 && (27)\\ L^B_1 &= L^{B^*}_1 && (28) \end{aligned}$$

Debt market clearing requires that:

$$D^B_s + D^{B^*}_s = M^{CB}_s \text{ for } s \in \{1, g, b\} \tag{29}$$

In this model, monetary policy is understood as the central bank changing the exogenously given money endowments M^{CB}_s and thereby changing the price of debt (r_1,, r_g, or r_g), which is taken as given by B and B^*.

[4]Nominal determinacy of interest rates, inflation, and commodity allocations is guaranteed by positive second period liquid wealth of the agents Dubey and Geanakoplos (2006). The equilibrium that is reported in Table 1 in the Annex is locally unique, which allows for performing comparative static exercises. The effects of monetary policy can be tracked because of this determinacy. Monetary policy in this economy is non-neutral because it has an impact upon the relative allocation of goods and assets.

3.3 Numerical example

Given the number of equations arising from the first order conditions, the model cannot be solved analytically. This subsection discusses a numerical solution, which will serve as an initial equilibrium to analyse deviations caused by policy innovations (see Section 4.

Table 5 in Appendix reports the values assumed for the exogenous variables. Households and banks have constant relative risk aversion utility functions that are separable in goods for households. Household P's first period utility is given by $U^P(c^p_{1f,}c^P_{1h}) = \frac{1}{1-\gamma^P}(c^P_{1f})^{(1-\gamma^P)} + \frac{1}{1-\gamma^P}(c^P_{1h})^{(1-\gamma^P)}$, and B's payoff in state g $P^B(\pi^B_g) = \frac{1}{1-\gamma^B}(\pi^B_g)^{(1-\gamma^B)}$. The coefficients of risk-aversion for households and banks are following: $\gamma^{P,P^*} = 2.2$, $\gamma^{R,R^*} = 2$, $\gamma^B = 2$ and $\gamma^{B^*} = 0.1$. As already indicated, the difference in the attitude towards risk-aversion between the home and foreign bank is the only difference between the two countries.

The uncertainty in the model is introduced via the stochastic nature of the determination of the good or bad state, which leads to the fluctuations of endowments of households P and P^* in the second period. Household R and R^*, endowed with $\overline{e}^{R,R^*}_{1,h} = 1$, are not facing any uncertainty in their endowments in the second period. In contrast, agents P's and P^*'s food endowments, $\overline{e}^{P,P^*} = (10, 15, 5)$, and wealth endowments, $\overline{E}^{P,P^*} = (E^{P,P^*}_1, E^{P,P^*}_g, E^{P,P^*}_b) = (0, 3, 0.5)$, depend on the realization of the state of the world. An adverse productivity shock in the bad state is mimicked by materially lower endowments in that state of the economy.

Taking account of the duration of big financial crises, most notably the Great Depression and the Great Recession, one period in this model should be understood as five years. The likelihood of a crisis - the bad state of the economy - is set to 0.1, which corresponds to one financial crisis every 50 years. Because of that, one period depreciation rate amounts to 15% and the discount rate equals 0.85. Similarly, keeping the duration of one period in mind, five-year interest rate is set to $r_1 = 0.12$, $r_g = 0.12$, and $r_b = 0.2$. It increases in the bad state of the world, which reflects higher funding costs in a crisis.

Table 5 in Appendix reports the initial equilibrium. The variation of the relative house prices mimics a boom-bust cycle in the housing market. The relative house prices fall substantially during the crisis, which forces households P and P^* to default. In particular, the default condition is satisfied in line with equation 2. The initial equilibrium also satisfies budget constraints of all households. Furthermore, households cannot short-sell assets, i.e. they cannot dispose of their future endowments. Since the foreign bank B^* is risk-loving, it chooses higher leverage that the home bank B. As a result, its balance sheets and the amount of extended mortgages are larger than the balance sheet and loan portfolio of a home bank.

4 Policy interventions

Using the calibrated version of the model, in this section I perform several policy interventions in order to test the response of the model around the identified equilibrium. In particular, I am interested in the differences in the cross-border propagation from various macroprudential policy instruments, including the capital ratio and the loan-to-value ratio, In addition, I demonstrate how a multi-instrument regulation could work by the application of both macro-prudential tools at once. Policy interventions are conducted in the first period in the spirit of leaning against the wind, i.e. the build-up of imbalances and risks.

4.1 Capital regulation

In this section I test the impact of capital regulation around the equilibrium.

Table 1 reports the response of the economy to a 1% reduction in B's initial leverage ratio $(\frac{debt_1}{equity_1} = \frac{D_1^B}{E_1^B})$ and in B^*'s leverage ratio $(\frac{debt_1}{equity_1} = \frac{D_1^{B^*}+L_1^{B^*}}{E_1^{B^*}})$.

A decrease in the leverage ratio applied to the home bank B forces him to slim its balance sheet. This leads to both a reduction in the supply of mortgages to P as well a decrease in his interbank exposure towards B^*. This adjustment in the balance sheet structure of the home bank has an impact on the balance sheet of the foreign bank B^*, too. Since he borrows less from the home bank, he has to reduce his demand on MBSs. Moreover, the interbank borrowing of bank B^* drops by more than the reduction in the amount of MBS he acquires. As a result, the bank is able to extend less mortgages to P^*. As a consequence, the leverage ratio of B^* also drops. Overall, the securitisation allows the home banks to channel the reduction in lending to the foreign bank. In spite of the fact that the regulation is only binding on the home bank, the foreign bank B^* is also forced to reduce its lending.

In terms of the welfare implications, considering the welfare effects for banks, lowering the leverage for the home bank leads to an improvement in the welfare of both banks, as they both are less prone to credit losses in the bad state.

A decrease in the leverage ratio of the foreign bank B^* has similar, albeit less pronounced effects. B^* reduces lending and acquires less MBSs from the home bank. Consequently, his interbank borrowing is also reduced. From the home bank B perspective, lower interbank lending allows the bank to extend more mortgages, which increase almost one to one with the decrease in the interbank exposure. As a result the size of the balance sheet of the home bank decreases, albeit only marginally.

Finally, lower leverage of the foreign bank makes it more immune to credit losses in the bad state. However, the home bank welfare is reduced, as, due to higher exposure to mortgages, it is now more prone to credit losses in the bad state.

Note that the tightening of capital requirements of B^* leads to an increase of lending by B, while the tightening of capital requirements for B leads to a decrease in lending by B. To understand this asymmetry in the cross boarder propagation of capital regulation, it is important to bear in mind that in the initial equilibrium B^* extends more mortgages than B. Moreover, it also partly funds its purchases of MBS by borrowing from B in the interbank market. This leads to a substitution effect on the balance sheet of bank B, whereby the bank extends more cross-border interbank loans at the expense of lower exposure to local mortgages. All this is due to the higher risk appetite of B^* and ultimately leads to shifting lending from the home to the foreign economy. Note that, should the banks be indifferent in the risk aversion, their leverage would be the same and there would be no cross border lending, as the two economies are symmetric. One could also interpret this initial equilibrium as asymmetric boom in the housing market in the foreign economy. When B^*'s leverage is reduced, the new equilibrium is closer to what one would expect under homogenous risk aversion (the same size of the balance sheets), namely the lending in the foreign economy drops and in the home economy increases. This is because the initial substitution effect on the balance sheet of the home bank (more cross-border and less domestic lending) is being reverted. As B lends now less to B^* it releases equity and, given that the bank maintains its leverage unchanged, it allows him to lend more to domestic borrowers. In contrast, when B is subject to the leverage tightening, it reduces both lending to local, P, and foreign, B^*, borrowers. However, it does not lead to any substitution effect on the balance sheet of B^*, as interbank loan is a liability for this bank. Hence, a reduction in interbank lending by B limits B^*'s funding and de facto acts as a leverage constraint. Lower leverage means that the bank reduces its domestic and foreign exposures. This is why the reduction in the leverage of B leads also to a reduction in lending in the foreign economy. This asymmetry is determined by the initial equilibrium in which the foreign bank is the net cross-border borrower, i.e. it vacuums funding from B (via interbank market) to also fund its domestic lending. In this model this constellation is an outcome of the two assumptions: market fragmentation and the heterogeneity in the risk aversion.

Table 1: 1% decrease in B's or B^*'s leverage ratio

	Leverage ↓	Leverage* ↓
Mortgages extended to P	-0.62%	0.41%
Mortgages extended to P*	-0.35%	-0.70%
Mortgages securitised	-0.42%	-1.09%
Repos	-0.55%	-2.04%
Leverage ratio B	-1.00%	-0.08%
Leverage ratio B*	-0.45%	-1.00%
Welfare B	0.64%	-0.87%
Welfare B*	0.16%	1.47%

All in all, this example shows that the securitisation channel plays an important role i cross-boarder propagation of macroprudential policy impulses. Overall, an increase in the capital requirements is more easily transmitted from a risk averse banking sector to the risk-liking banking sector. According to the model, the foreign bank initial leverage is also substantially reduced as a consequence of lower interbank borrowing. As a result, the two banks are less interconnected and, therefore, more immune to spill-overs from default. While lowering of the leverage ratio of the foreign bank B^* reduces mortgage lending to P^*, as intended, it also leads to unintended consequences in the form of the increase of lending in the home country. In sum, the leverage ratio may be a powerful cross-border macroprudential policy instrument. However, its application in the monetary area may be challenging, as through the adjustment of the structure of banks' balance sheets it may cause, the effects of the regulation have both offsetting and reinforcing effects for the monetary union as a whole. In general, if risk averse banks are forced to reduce their leverage, risk liking banks will also reduce it. However, if the leverage restriction is imposed on a risk liking banks, while they will reduce lending, risk averse banks will increase it.

4.2 Loan-to-value ratio

In this section the loan-to-value ratio is imposed separately on home and foreign mortgages in the first period. Table 2 shows the response of the economy in a reaction to a 1% reduction in the home loan-to-value ratio ($\frac{M_1^P}{p_{1,h}c_{1,h}}$) or the foreign loan-to-value ratio ($\frac{M_1^{P^*}}{p^*_{1,h}c^*_{1,h}}$).

A decrease in the LTV ratio in the home country reduces the initial demand for mortgages. In view of this B reacts by lowering the supply of MBSs to hold more mortgages on its balance sheet. Consequently it reduces also its interbank lending. As the foreign bank B^* has now less opportunities to invest in MBSs, it extends more mortgages, albeit only marginally. However, due to a substantial reduction of cross-border securitisation and interbank exposure, both banks' leverage is reduced.

In terms of welfare effects, the home's bank credit risk is reduced thanks to the tighter LTV regulation. Moreover, since his exposure to the counterparty risks from the repo contracts is also lower, all this improves the overall welfare of B. To the contrary, due to lower interbank exposure B^* has now less opportunities to benefit from defaulting on his interbank liability. As a result, his welfare drops.

Increasing the restrictiveness of the LTV regulation in the foreign country leads to effects which, to a large extent, are a mirror image of the above. In view of the lower demand for mortgages bank B^* reacts by increasing the demand for MBSs - the amount of mortgages securitised by the home bank and its interbank lending increases. As a result, the home bank extends more mortgages. However, since his securitisation activity increased markedly, the amount of mortgages held on the balance sheet drops, almost one to one with the increase in the interbank lending. Hence, similarly as in the case of the restrictions imposed on the leverage ratio of the foreign bank, the size of the balance sheet and, as a result, the leverage ratio of the home bank almost do not change. Moreover, the increase in the MBS exposure by the foreign bank more than compensates for the reduction in the bank's exposure to mortgages. Hence, the foreign bank's leverage ratio rises.

As regards the welfare implications, B^*'s welfare increases, as the bank is now better sheltered against the credit risk. Furthermore, due to higher interbank exposure, he can also benefit from defaulting on the repo contract. On the contrary, B is now more prone both to the domestic credit risk and counterparty credit risk. As a result, his welfare is reduced.

All in all, the LTV regulation is effective in the reduction of the risks in the system if applied to a risk averse bank because it reduces both the demand for mortgages in the home country and cross border interbank exposure. Nevertheless, stricter LTV regulation in the home country leads to higher lending in the foreign country. On the contrary, if applied to a risk-liking (foreign) banking sector, the LTV regulation may even prove to be counter-effective, as, in view of the lower local demand for mortgages, the foreign banking sector will seek an increase in the exposure to home mortgages boosting their supply in the country where the LTV regulation is not applied and, at the same time, the interbank linkages between the banks.

Table 2: 1% decrease in the LTV ratio on home or foreign mortgages

	LTV ↓	LTV* ↓
Mortgages extended to P	-1.43%	0.97%
Mortgages extended to P*	0.12%	-1.40%
Mortgages securitised	-14.31%	30.92%
Repos	-13.89%	30.51%
Leverage ratio B	-1.73%	0.14%
Leverage ratio B*	-5.23%	10.76%
Welfare B	1.40%	-1.46%
Welfare B*	-0.56%	2.43%

4.3 Combined regulation

Using the model several combinations of macro-prudential regulation can be explored. In this section I consider a specific case of loosening the leverage regulation and a concurrent tightening of the LTV ratio. I also discuss the implication of such a macropudential policy-mix on the stability of the banking sector.

First, consider a 1% increase in the leverage ratio of the home bank and a simultaneous 1% decrease in the LTV ratio in the foreign country. Since the home bank is subject to loosened capital requirements, it can extend more mortgages and increase his interbank lending (see Table 3). Nevertheless, the increase in the interbank exposure is primarily driven by the demand on MBS from the foreign bank. Due to a decrease in the LTV* ratio the demand for mortgages from P^* decreases. The risk liking bank is compensating that by increasing substantially its holding of securitised home assets and its interbank borrowing. That increase is even larger in the case when the leverage ratio of the home bank remains stable, as the higher leverage of the home bank allows the foreign bank to be even more exposed to home assets. It is worth noticing that both regulations are binding in this case.

On the face of it, the regulation leads to the expected results, namely the lending in the home country increases, while it is reduced in the foreign country. Nevertheless, the interbank cross-exposure and securitisation activity increase markedly. This makes the home bank more prone to the default of the foreign bank on his interbank exposure. This is why the home bank's welfare is reduced. The foreign bank's welfare increases, as he is less prone to the domestic credit risk and because he can, to a much larger extent, benefit from defaulting on the repo contract.

Table 3: 1% increase in the leverage ratio and 1% decrease in the LTV ratio

	Leverage ↑ and LTV* ↓	Leverage* ↑ and LTV ↓
Mortgages extended to P	1.90%	-1.45%
Mortgages extended to P*	-1.49%	1.13%
Mortgages securitised	45.39%	-7.82%
Repos	44.90%	-5.98%
Leverage ratio B	1.00%	-0.77%
Leverage ratio B*	16.26%	-1.95%
Welfare B	-3.23%	2.52%
Welfare B*	3.77%	-3.16%

Second, I test a macroprudential policy-mix, which is a mirror picture of the above, namely a 1% increase in the leverage ratio of the foreign bank and a 1% decrease in the LTV ratio in the home country. Looser capital requirements alow the foreign bank to extend more mortgages (see Table 3). Nevertheless, in view of the tighter LTV requirements P reduces his demand for mortgages. As the demand for mortgages in the home country drops, the home bank is now less inclined to securitise them. Lower supply of MBSs also reinforces the effect of looser capital requirements in the foreign country, whereby the supply of foreign mortgages can increase even more. Contrary to the example above, only the LTV regulation is binding. Initial leverage of B^* decreases in fact, albeit to a lesser extent as in the case where the leverage ratio remained unchanged (see Table 2).

Again, the regulation leads to, as expected, a reduction in mortgage lending in the home country and an increase in the mortgage lending in the foreign country. At the same time, due to a smaller cross-boarder securitisation activity, B is less exposed to the risk of a default of B^* on its interbank liability. Also, he is less exposed to the credit risk of P, who needs to pledge more assets in order to be granted a loan, in view of the reduction in the LTV ratio. Therefore, B's welfare increases. Inversely, B^*'s welfare is reduced as it is more exposed to the domestic credit risk and has less opportunities to benefit from the default on the repo contract.

5 Conclusions

This paper extends a simplified version of the framework by Goodhart et al. (2013) into a two country/region set-up within a monetary union in order to identify how monetary policy propagates between the two regions. Similarly as in the original set-up, the model is a stochastic, two period general equilibrium framework. In the second period the world can take two states, bad or good. The two economies do not differ between each other in terms of the endowment. The only difference is that the two banking sectors differ in terms of risk appetite. One bank is risk-averse, while the other one is risk-loving. Furthermore, the mortgage and capital markets are fragmented. In the model financial instability is introduces by endogenous defaults, which is an outcome of an optimisation behaviour of economic agents.

We find that the adjustments of banks' balance sheets in response to a macroprudential policy shock is crucial in cross-border propagation and that the effectiveness of macroprudential policy may be weakened through securitization. In particular, uncoordinated LTV policy may lead to sub-optimal results as banks may switch to originate-to-distribute business model. In this way securitization channel may "leak" across borders the impact of an asymmetric macroprudential policy shock, thereby weakening the efficacy of the policy. My findings are in line with Brzoza-Brzezina et al. (2013) that LTV ratio cap is a relatively more efficient tool in addressing an asymmetric shock than capital requirements. Yet, the overall efficacy of this tool needs to be assessed in the context of corss-border spillovers that may vary depending on banks attitude towards risk. In particular, the LTV regulation may even prove to be counter-effective, as, in view of the lower local demand for mortgages, the foreign banking sector will seek an increase in the exposure to home mortgages boosting their supply in the country where the LTV regulation is not imposed.

The findings of this paper call for coordination of macroprudential policies. This will be ensured for the macroprudential instruments envisaged under CRD IV and CRR, as according to the SSM Regulation these instruments are attributed to the ECB's Supervisory Board. Nevertheless, LTV ratio caps and margin and haircut requirements remain beyond direct SSM control. In view of my findings, in particular potentially strong cross-border spillovers from LTV regulation, in order to perform its task efficiently, the SSM should ensure a framework, in which it could coordinate the use of those macroprudential policy instruments that are beyond its direct influence.

References

Shekhar Aiyar, Charles W Calomiris, and Tomasz Wieladek. Does macropru leak? evidence from a uk policy experiment. *Bank of England working papers*, 445, 2011.

Paolo Angelini, Laurent Clerc, Vasco Cúrdia, Leonardo Gambacorta, Andrea Gerali, Alberto Locarno, Roberto Motto, Werner Roeger, Skander Van den Heuvel, and Jan Vlcek. Basel iii: Long-term impact on economic performance and fluctuations. *BIS Working Papers*, 338, 2011.

Ignazio Angeloni and Ester Faia. Capital regulation and monetary policy with fragile banks. *Journal of Monetary Economics*, 60(3):311–324, 2011.

Michal Brzoza-Brzezina, Marcin Kolasa, and Krzysztof Makarski. Macroprudential policy instruments and economic imbalances in the euro area. *European Central Bank, Working Paper Series*, 1589, December 2013.

Otaviano Canuto and Matheus Cavallari. Monetary policy and macroprudential regulation: Whither emerging markets. *Policy Research Working Paper 6310, World Bank*, 2013.

Ian Christensen, Meh Césaire, and Kevin Moran. Bank leverage regulation and macroeconomic dynamics. *Working Papers, Bank of Canada*, 11-32, December 2011.

Matthieu Darracq-Paries, Christoffer Kok-Soerensen, and Diego Rodriguez-Palenzuela. Macroeconomic propagation under different regulatory regimes: Evidence from an estimated dsge model for the euro area. *International Journal of Central Banking*, 7(4):49–113, December 2011.

Pradeep Dubey and John Geanakoplos. Determinacy with nominal assets and outside money. *Economic Theory*, 27(1):79–106, 01 2006.

Pradeep Dubey, John Geanakoplos, and Martin Shubik. Default and punishment in general equilibrium. *Econometrica*, 73(1):1–37, 01 2005.

FSB. Macroprudential policy tools and frameworks. *Progress Report to G20*, 2011.

C.A.E. Goodhart, A.K. Kashyap, D.P. Tsomocos, and A.P. Vardoulakis. An integrated framework for analyzing multiple financial regulations. *International Journal of Central Banking*, 9:109–143, January 2013.

G. Russell Kincaid and C. Maxwell Watson. The role of macro-prudential policies and implications for international policy coordination. *Discussion Draft*, August 2013.

Nobuhiro Kiyotaki and John Moore. Credit cycles. *Journal of Political Economy*, 105(2): 211–48, April 1997.

Steven Ongena, Alexander Popov, and Gregory F. Udell. 'when the cat's away the mice will play': Does regulation at home affect bank risk-taking abroad? *Journal of Financial Economics*, 108(3):727–750, 2013.

Appendix

Exogenous parameters

Endowment of goods	Bank capital and households' wealth	Interest rates	Risk aversion	Other parameters
$e^P_{1f} = 10$	$Eg^P = 3$	$r_1 = 0.12$	$\gamma^P = 2.1$	$\delta = 0.15$
$e^P_{gf} = 15$	$E^P_b = 0.5$	$r_g = 0.12$	$\gamma^R = 2.0$	$\beta = 0.85$
$e^P_{bf} = 5$	$E^B_1 = 2.2$	$r_b = 0.20$	$\gamma^{P*} = 2.1$	$\omega_g = 0.9$
$e^R_{1h} = 1$			$\gamma^{R^*} = 2.0$	$\tau = 1.0$
			$\gamma^B = 2.0$	
			$\gamma^{B^*} = 0.1$	

Initial equilibrium

Relative prices	Interest rates and recovery rates	Home economy	Foreign economy	Banks
$\frac{P_{1h}}{P_{1f}} = 202$	$\rho^M = 1.44$	$c^P_{1f} = 0.67$	$c^{P^*}_{1f} = 0.67$	$M^B_1 = 7.3$
$\frac{P_{gh}}{P_{gf}} = 315$	$\rho^{M^*} = 1.33$	$c^R_{1f} = 9.26$	$c^{R^*}_{1f} = 9.40$	$M^{B^*}_1 = 8.5$
$\frac{P_{bh}}{P_{bf}} = 35$	$V^M_b = 0.78$	$c^P_{1h} = 0.07$	$c^{P^*}_{1h} = 0.07$	$D^B_1 = 5.0$
$\frac{P^*_{1h}}{P_{1f}} = 207$	$V^{M^*}_b = 0.76$	$c^R_{1h} = 0.93$	$c^{R^*}_{1h} = 0.93$	$D^{B^*}_1 = 6.4$
$\frac{P^*_{gh}}{P_{gf}} = 321$	$\rho^L = 1.40$	$c^P_{gh} = 0.01$	$c^{P^*}_{gh} = 0.01$	$D^B_g = 5.6$
$\frac{P^*_{bh}}{P_{bf}} = 36$		$c^R_{gh} = 0.78$	$c^{R^*}_{gh} = 0.78$	$D^{B^*}_g = 7.2$
$P^M_1 = 1.0$		$c^P_{gf} = 1.06$	$c^{P^*}_{gf} = 1.03$	$D^B_b = 5.6$
		$c^R_{gf} = 13.86$	$c^{R^*}_{gf} = 14.05$	$D^{B^*}_b = 7.2$
		$c^P_{bh} = 0.13$	$c^{P^*}_{bh} = 0.12$	$\sigma^B_1 = 0.54$
		$c^R_{bh} = 0.72$	$c^{R^*}_{bh} = 0.73$	$\overline{M}^{B^*}_1 = 8.47$
		$c^P_{bf} = 0.69$	$c^{P^*}_{bf} = 0.68$	$L^B_1 = 3.78$
		$c^R_{bf} = 4.26$	$c^{R^*}_{bf} = 4.37$	$L^{B^*}_1 = 3.78$
		$cash^R = 7.5$	$cash^{R^*} = 8.3$	$\pi^B_g = 3.9$
				$\pi^{B^*}_g = 3.6$
				$\pi^B_b = 1.5$
				$\pi^{B^*}_b = 0.0$