The Macroeconomics of Deposit Insurance in a Two-country Model

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Abstract

This paper develops a macroeconomic framework to analyze the implications of different deposit insurance regimes in the Eurozone. I develop a two-country model with banks that are subject to endogenous and costly bank runs. The two countries are financially integrated as home banks can lend to foreign banks. I analyze the macroeconomic effect of having deposit insurance either at the national level or harmonized or fully joint for the two countries. I find that harmonized or joint deposit insurance increases steady-state consumption and output and reduces volatilities following macroeconomic shocks, thus leading to welfare gains. However, the two countries do not agree on the welfare ranking of harmonized versus joint deposit insurance.

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1 Introduction

1.1 Deposit Insurance in the Eurozone

Deposit insurance is an important topic for policy makers in the Eurozone. Before the financial crisis, deposit insurance was mainly left to the member states. There were only very minimal European-level rules; namely, member states were required to insure at least 20'000 EUR of deposits in case of a bank failure. Hence, there were major differences in deposit insurance coverage across Eurozone countries. Countries such as Spain, Greece or Ireland stuck to the lower limit of 20'000 EUR coverage, whereas France offered a coverage of 70'000 EUR and Italy above 100'000 EUR. The coverage in Germany was almost unlimited, but based on a voluntary and privately managed insurance scheme. There were also important differences in the financing of deposit insurance. Italy for example offered a high coverage, but had no deposit insurance fund and relied solely on ex-post contributions by banks to pay depositors of failed banks. Other countries, such as France and Germany had a deposit insurance fund, funded by ex-ante contributions by banks. The size of the deposit insurance fund, when existing, and the fees to be paid by banks were different across member states.

During the turmoil of the financial crisis, the differences in deposit insurance across countries were disruptive and amplified financial instability, as depositors attempted to shift their deposits from those banks perceived as less well insured to those perceived as better insured. The European Commission took some steps towards harmonizing deposit insurance in the European Union. In 2008, the minimal coverage was increased from 20’000 to 50’000 EUR, and it was further increased to 100’000 EUR in 2010. Deposit insurance in the EU was revised in 2014. The revision maintained the insurance coverage of 100’000 EUR but required member states to build up a fund. Thus, both the financing and coverage of deposit insurance is now harmonized across member states. The fund should equal 0.8% of outstanding deposits and be built up over a period of 10 years, by collecting ex-ante contributions from banks. The bank deposit insurance fees are risk-based, so more risky banks contribute more than safe banks.

1See Demirgüç-Kunt et al. (2008) and Demirgüç-Kunt et al. (2014) for a cross-country comparison of deposit insurance.

2Source: regulation 2014/49/EU
In November 2015, the European commission issued a proposal for a euro-area-wide deposit insurance scheme (EDIS). The proposal puts forward a plan to have a single deposit insurance fund for all Eurozone countries. The fund would cover deposits in any Eurozone country up to 100’000 EUR. Banks in member states would pay quarterly risk-based fees to the joint fund, and EDIS would progressively take over from the national insurance schemes. The proposal is currently under consideration and not yet implemented. There are two main rationales behind EDIS: first, a national deposit insurance fund could be vulnerable to large local shocks; second, a joint deposit insurance in the Eurozone could break the link between the banking sector and the sovereign. A sovereign with a weak fiscal position could be perceived as unable to bail out its banks, increasing the probability of bank runs. Similarly, an unstable banking sector could put pressure on the government finances and make it less creditworthy.

1.2 Motivation

The rationale for deposit insurance has long been studied in economics, starting with the seminal paper of Diamond and Dybvig (1983). However the macroeconomic impacts of bank runs and deposit insurance have received less attention; this paper aims to fill this gap. This paper develops and international macroeconomic framework in which deposit insurance can be analyzed. In particular, we discuss how different deposit insurance regimes, either national, harmonized or joint would impact the economy and its response to shocks.

I develop a two-country model with a financial sector. The two countries are financially integrated in the sense that home banks can lend to foreign banks. In each country, banks are subject to idiosyncratic risk and can suffer costly bank runs when asset values are low. In this setting, I introduce deposit insurance: government collects fees from banks and pays depositors of failed institutions. I then analyze the steady state and dynamic response of the model when deposit insurance is fully national (as it was before the financial crisis), and compare it with harmonized deposit insurance (following the 2014 reform), or fully joint deposit insurance (as per the proposal of 2015).

I find that a harmonized or a joint deposit insurance both greatly improve

\[3\text{See: European Commission web site on EDIS}\]
consumption and output in steady state relative to national deposit insurance, both for Home and for Foreign. The reason is that a harmonized or joint deposit insurance make banks in both countries less vulnerable to runs. Moreover, harmonized or joint deposit insurance also help mitigating the response of the economy to shocks, hence improving welfare. This paper is organized as follows: section 2 reviews the literature, section 3 explains and derives the model, section 4 presents the calibration we use for the model, section 5 shows the quantitative analysis of the model and the results from the steady-state (5.1), dynamic (5.2), welfare (5.3) and transition (5.4) analysis. Finally, section 6 concludes.

2 Literature Review

A first important contribution on bank runs and the role of deposit insurance is Diamond and Dybvig (1983). The paper develops a three-period model with multiple equilibria and bank runs. They show that government-provided deposit insurance has beneficial effects as it can eliminate the bank run equilibria. Diamond and Rajan (2000, 2001) further show that bank fragility is an essential and desirable characteristic of the bank, as it disciplines bankers and enables more lending. My paper differs from these contributions in that it studies deposit insurance in a macroeconomic, infinite horizon setup, which enables quantitative analysis.

Angeloni and Faia (2013) develop a macroeconomic model with fragile banks and study the impact of procyclical capital regulation. More recently, Gertler and Kiyotaki (2015) develop a macroeconomic infinite horizon model where banking instability is due to both financial accelerator effects and bank runs. The existence of a bank run equilibrium depends on macroeconomic conditions and endogenous liquidation price of bank assets. My modeling of a bank run builds on Angeloni and Faia (2013) and Gertler and Kiyotaki (2015), but I go further by introducing idiosyncratic risk on banks, extending the model to two countries and studying the role of deposit insurance.

This paper also builds on the literature on financial frictions and financial accelerator. Bernanke et al. (1999) develop a model of financial intermediation with asymmetric information, where the friction generates countercyclical external finance premium and amplification of the cycle. Gertler and Kiyotaki (2010) develop a macroeconomic model with financial intermediation and interbank loans, where

Finally, this paper is related to the literature on open economies with financial integration and contagion. Dedola et al. (2013) develop a two country model with banks and financial integration. In Nuguer (2016), the presence of global banks amplifies the contagion across countries. Devereux and Yetman (2010) present a two-country model with leverage constraints and interconnected portfolios. Leverage constraints reduce benefits from international diversification. Medonza and Quadrini (2010) find that financial liberalization (capital mobility) can create contagion, as shocks in one country affect asset prices in both countries. The main focus of this paper is different however, as it looks at deposit insurance and more specifically at the integration of deposit insurance across countries.

There are also empirical contributions on the costs and benefits of deposit insurance. Demirgüç-Kunt and Detragiache (2002) carry out a cross-country comparison of deposit insurance and analyze the effect of deposit insurance on bank stability, measured as the probability of bank distress. Demirgüç-Kunt and Huizinga (2004) analyze whether deposit insurance affects the rate and growth of deposits. They find that deposit insurance reduces the required rate on deposits. In my model, deposit insurance reduces the probability of bank run and the required rate on deposits, consistently with the empirical literature.

3 Model

I develop a two country (Home and Foreign) DSGE model with a financial sector and bank runs. All home variables will be indexed by $H$ and foreign variables by $F$. In each country there are households, firms, banks, a capital producer and a government. Households consume and supply labor to domestic firms. They can save using deposit in their domestic banks. In each country there is a continuum of firms that are subject to idiosyncratic risk. I assume firms produce a homogeneous and tradable good (as in Dedola et al. (2013)), so I abstract from relative prices across countries. Each firm can only borrow from a bank situated on the same
island, so banks are affected by the same idiosyncratic risk as the firms. Banks in either country are subject to costly bank runs when the value of their assets is low. The two countries are financially integrated in the sense that home banks can lend to foreign banks. As in Nuguer (2016), the interbank market exacerbates the transmission of shocks across countries.

In this setting, I introduce deposit insurance and analyze the effect of different insurance regimes. A national deposit insurance scheme is when the government in each county runs a scheme that covers banks in their own country, with different levels of financing and coverage. A harmonized deposit insurance still implies that deposit insurance is run separately in both countries, but now the coverage and size of the deposit insurance fund are similar. A joint deposit insurance is when there is a single deposit insurance fund covering banks in both countries; financing and insurance coverage is then also similar in both countries.

3.1 Households

Households in Home and Foreign are similar. They choose consumption \( C_t \) and labor supply \( L_t \) to maximize lifetime utility. They can save using deposit \( D_t \) in their domestic banks. Households cannot hold capital directly or put their deposits in the banks of the other country. The maximization problem for the households in Home is:

\[
\max_{C_t, D_t, L_t} \ln(C_t^H) - \eta^H \frac{(L_t^H)^{1+\varphi^H}}{1 + \varphi^H}
\]

\[\text{s.t.} \quad C_t^H + D_t^H = w_t^H L_t^H + R_t^H D_{t-1}^H + \Pi_t^H,
\]

where \( \eta^H \) is the disutility of labor, \( \varphi^H \) is the inverse of the Frisch elasticity of labor supply, \( w_t^H \) is wage and \( \Pi_t^H \) are transfers from banks and the capital producer. The equations for foreign households are exactly symmetric. Note that the rate of return on deposits is not risk-free. In this model, banks can default, so the rate on deposits is not predetermined. For this reason, I index the rate of return on deposits \( R_t^H \) by \( t \) and not \( t - 1 \). The determination of \( R_t^H \) is explained in section 3.3.
3.2 Firms

Home firms are segmented on a continuum of islands indexed by $j$. They are hit by an idiosyncratic capital quality shock $\omega^j$. The modeling of idiosyncratic risk is similar to Nuño and Thomas (2017). Firms are perfectly competitive, they produce the final good $Y^j,H_t$ using capital $K^j,H_t$ and labor $L^j,H_t$, with a Cobb-Douglas production function. Firms choose labor to maximize their operating profits:

$$\max_{L^j,H_t} z^H_t (\omega^j,H_t K^j,H_t)^{1-\gamma^H} (L^j,H_t)^{\gamma^H} - w^H_t L^j,H_t,$$

where $z^H_t$ is the level technology in Home. Firms must use loans from banks to purchase capital from the capital producer. A firm can only borrow from a bank that is situated on the same island, so we have:

$$K^j,H_t = A^j,H_{t-1},$$

where $A^j,H_{t-1}$ are loans to firm $j$ in Home. After production takes place, firms sell depreciated capital back to the capital producer. Since firms are perfectly competitive, they make zero profits: their operating profits and proceeds from sale of depreciated capital are used to repay bank loans. Hence, the rate of return on bank loans ($R^{AH}_t$) is perfectly state contingent and given by:

$$R^{AH}_t = \frac{R^{kh}_t + (1 - \delta^H)Q^H_t}{Q^H_{t-1}},$$

where $R^{kh}_t$ is the marginal productivity of capital in Home.

I assume the idiosyncratic capital quality shock $\omega$ is lognormally distributed:

$$\log(\omega) \overset{iid}{\sim} N\left(-\frac{\sigma^2}{2}, \sigma\right),$$

Foreign firms are modelled identically to home firms.

3.3 Capital producers

Home capital producer transforms $I^H_t$ units of the final good into capital and sells it to the firms at price $Q^H_t$. We assume there are adjustment costs of the form:

$$S\left(\frac{I^H_t}{I^H_{t-1}}\right) = \frac{\chi^H}{2} \left(\frac{I^H_t}{I^H_{t-1}} - 1\right)^2,$$
where $\chi^H > 0$. The capital producer chooses investment to maximize its profits:

$$\max_{I_t^H} E_0 \sum_{t=0}^{\infty} N_{t+1}^H \left( Q_t^H (1 - S(I_t^H/I_{t-1}^H)) I_t^H - I_t^H \right),$$

(8)

Profits for the capital producer only occur outside of the steady state, and are transferred back to households as a lump-sum. The law of motion of capital is:

$$K_{t+1}^H = \left( 1 - S(I_t^H/I_{t-1}^H) \right) I_t^H + (1 - \delta^H) K_t^H.$$  

(9)

Home and Foreign have each their own capital producer, with identical functions.

### 3.4 Banks

Banks in each country are segmented on a continuum of islands. They can only lend to a firm situated on the same island, hence they are subject to the firm idiosyncratic risk. Home banks raise deposits from domestic households ($D_t^H$), they give loans to domestic firms ($Q_t^H A_t^H$) on the same island and to foreign banks ($Q_t^B B_t^H$), and accumulate their own net worth ($N_t^H$). Foreign banks are similar to home banks, except $B_t$ is a liability for them, whereas it is an asset for the home banks. The balance sheets of any given bank in Home and Foreign are displayed in tables 1 and 2 respectively. $B_t$ is assumed to be a fixed coupon bond issued by the foreign bank at a price $Q_t^B$ and with a non-predetermined rate of return $R_t^B$ given by:

$$R_t^B = \frac{\text{Coupon} + Q_t^B}{Q_{t-1}^B}$$

(10)

### 3.5 Banks moral hazard

Banks are subject to moral hazard a la [Gertler and Kiyotaki 2010]. They have an incentive to divert a fraction $\theta^H$ of the assets of the banks for their own con-
sumption. Thus, they are subject to an incentive compatibility constraint:

\[ V_t(N^j_t) \geq \theta^H(Q^H_t A^{j,H}_t + Q^B_t B^{j,H}_t) \]  

(11)

The incentive compatibility constraint makes sure that the value of being a banker is greater than the value of the fraction of assets the banker can divert. In equilibrium, this condition will be satisfied with equality so the bankers will not divert.

Foreign banks are also subject to moral hazard. They can divert a fraction \( \theta^F \) of bank assets, net of borrowing from home banks. Home banks are better than foreign depositors at monitoring the foreign banks and can make sure the foreign banks do not divert the assets against their claim. The incentive compatibility constraint is therefore:

\[ V_t(N^{j,F}_t) \geq \theta^F(Q^F_t A^{j,F}_t - Q^B_t B^{j,F}_t) \]  

(12)

Following Gertler and Kiyotaki (2010) I assume every period a fraction \((1-\epsilon^H)\) of banks close down for exogenous reasons and transfer their net worth back to households. This assumption ensures that banks do not accumulate net worth and stop relying on external funding. Following Nuguer (2016), I also assume that home banks have a higher survival probability than foreign banks: \( \epsilon^H > \epsilon^F \). Home banks then discount the future less than foreign banks and this will give rise to lending from home to foreign banks.

### 3.6 Bank runs

A bank run happens when depositors force a bank to liquidate all its assets and take possession of the liquidated assets to recover their claims. If there is no bank run, depositors get the pre-determined rate \( R^{DH}_t \). If a bank run happens, running home depositors can only recover a fraction \( \lambda^H_1 \) of domestic loans and a fraction \( \lambda^H_2 \) of the international bond. Depositors will run on a bank if they believe that the value of liquidated assets will not be enough to cover their deposits. In Home, a bank will be run on if:

\[ \lambda^H_1 R^{AH}_t \omega^{j,H} Q^H_{t-1} A^{j,H}_{t-1} + \lambda^H_2 R^B_t Q^B_{t-1} B^{j,H}_{t-1} < R^{DH}_{t-1} D^{j,H}_{t-1} \]  

(13)

We define \( \bar{\omega}^{j,H} \) (the run threshold) as:

\[ \bar{\omega}^{j,H} = \frac{R^{DH}_{t-1}}{\lambda^H_1 R^{AH}_t} \frac{D^{j,H}_{t-1}}{Q^H_{t-1} A^{j,H}_{t-1}} - \lambda^H_2 \frac{R^B_t}{\lambda^H_1 R^{AH}_t} \frac{B^{j,H}_{t-1}}{Q^H_{t-1} A^{j,H}_{t-1}} \]  

(14)
Banks on islands where the realization of $\omega^j_H$ is above $\bar{\omega}^j_H$ will not be run on, whereas banks on islands with realization of $\omega^j_H$ below $\bar{\omega}^j_H$ will be run on. The idea is that if $\omega > \bar{\omega}$ depositors know their deposits will be paid in full so there is no reason for them to run. However if $\omega < \bar{\omega}$ and a depositor believes that all the other depositors will run, then he should also run in order to get his share of liquidated assets. So a bank run is a sort of self-fulfilling panic. This modeling of a bank run is similar to [Gertler and Kiyotaki (2015)]. A lower value of $\lambda_1$ will makes bank runs more costly, but will also make bank runs more likely to occur, as it reduces the liquidation value of bank assets. Moreover foreign assets make banks more vulnerable to runs than domestic assets, since they carry a lower liquidation value.

In case of a bank run in Foreign, I assume that home banks are paid back before foreign depositors. Hence, a foreign bank will be run on if foreign depositors believe that the value of liquidated assets, after having paid back the home banks, is not enough to cover their claim. As in Home, I assume foreign depositors can only recuperate a fraction $\lambda^F_t$ of bank assets if they run.

$$\lambda^F_t \left( R^A_t \omega^j Q^F_{t-1} A^j_{t-1} - R^B_t Q^R_{t-1} B^j_{t-1} \right) < R^D_t D^j_{t-1}$$  \hspace{1cm} (15)$$

The run threshold in Foreign is:

$$\bar{\omega}^j_F = \frac{R^D_{t-1} D^j_{t-1}}{\lambda^F_t R^A_t Q^F_{t-1} A^j_{t-1}} + \frac{R^B_{t-1} Q^B_{t-1} B^j_{t-1}}{R^A_t Q^F_{t-1} A^j_{t-1}}$$  \hspace{1cm} (16)$$

### 3.7 The maximization problem of the banks

Home banks choose loans to firms, loans to foreign banks and deposits to maximize their value function. The maximization problem of a continuing bank in Home is:

$$\max_{A^j_t, D^j_t, B^j_t} V_t(N^j_t) = E_t \Lambda^H_{t,t+1} \int_{\bar{\omega}^j_t} \left( \epsilon^H V_{t+1}(N^j_{t+1}) + (1 - \epsilon^H)N^j_{t+1} \right)$$

$$-\lambda^{BSH,j}_i \left( Q^H_t A^j_t + Q^B_t B^j_t - N^j_t - D^j_t \right) - \lambda^{ICCH,j}_i \left( \theta^H (Q^H_t A^j_t + Q^B_t B^j_t) - V_t(N^j_t) \right)$$  \hspace{1cm} (17)$
home households. Net worth evolves according to:

\[ N_{t+1}^{j,H} = R_{t+1}^{AH} \omega_{t+1}^{j,H} Q_t^{H} A_{t}^{j,H} + R_{t+1}^{B} Q_{t}^{B} B_{t}^{j,H} - R_{t}^{DH} D_{t}^{j,H} \]  

(18)

The first order conditions of the banks are given in the appendix. Foreign banks solve a similar maximization problem.

3.8 Solution and Aggregation

A solution to the model is an equilibrium where banks, households, firms and capital producers are optimizing and all markets clear. I guess and verify the existence of a solution where bank balance sheet ratios, default thresholds and lagrangian multipliers are equalized across all islands within a country. Banks on different islands of a country can be different in terms of size, but they all have the same leverage and deposit ratios. Bank balance sheet ratios and Lagrangians however are not equalized across countries.

To make sure the number of banks remains constant, I assume exiting banks are replaced by new banks. The new banks receive a transfer from household, a fraction \( \tau \) of the value of bank assets. The aggregate net worth evolution of banks in Home and Foreign is given by:

\[ N_{t}^{H} = (\epsilon^{H} + \tau^{H}) \left( R_{t-1}^{AH} Q_{t-1}^{H} A_{t-1}^{H} (1 - G(\tilde{\omega}_{t}^{H})) + R_{t-1}^{B} Q_{t-1}^{B} B_{t-1}^{H} (1 - F(\tilde{\omega}_{t}^{H}))) \right) \]

\[ -\epsilon^{H} R_{t-1}^{DH} D_{t-1}^{H} (1 - F(\tilde{\omega}_{t}^{H})) \]  

(19)

\[ N_{t}^{F} = (\epsilon^{F} + \tau^{F}) \left( R_{t-1}^{AF} Q_{t-1}^{F} A_{t-1}^{F} (1 - G(\tilde{\omega}_{t}^{F})) \right) \]

\[ -\epsilon^{F} \left( R_{t-1}^{DF} D_{t-1}^{F} (1 - F(\tilde{\omega}_{t}^{F})) + R_{t-1}^{B} Q_{t-1}^{B} B_{t-1}^{F} (1 - F(\tilde{\omega}_{t}^{F}))) \right) \]  

(20)

\( F(\tilde{\omega}) \) is the probability of a run, and is given by:

\[ F(\tilde{\omega}) = \int_{\tilde{\omega}} f(\omega) d(\omega) = \Phi \left( \frac{\log(\tilde{\omega}) + 0.5(\sigma^{H})^2}{\sigma^{H}} \right) \]  

(21)

And \( G(\tilde{\omega}) \) is given by:

\[ G(\tilde{\omega}_{t+1}^{j,H}) = \int_{\tilde{\omega}} \omega f(\omega) d(\omega) = \Phi \left( \frac{\log(\tilde{\omega}) + 0.5(\sigma^{H})^2}{\sigma^{H}} - \sigma^{H} \right) \]  

(22)

where \( \Phi(\cdot) \) is the standard normal cumulative density function.
The aggregate resource constraints of the economy in Home and Foreign are given by:

resource constraint:

\[
Y_t^H = C_t^H + I_t^H + NX_t^H + (1 - \lambda_1^H)R^AH_t Q_{t-1}^H A_t^H G(\bar{\omega}_t^H) + (1 - \lambda_2^H)R^B_t Q_{t-1}^B B_{t-1}^H F(\bar{\omega}_t^H)
\]

(23)

\[
Y_t^F = C_t^F + I_t^F + NX_t^F + (1 - \lambda_1^F)\left(R^AF_t Q_{t-1}^F A_t^F G(\bar{\omega}_t^F) - R^B_t Q_{t-1}^B B_{t-1}^F F(\bar{\omega}_t^F)\right)
\]

(24)

\[
NX_t^H \text{ and } NX_t^F \text{ are the net exports in Home and Foreign and are given by:}
\]

\[
NX_t^H = -NX_t^F = Q_t^B B_t^H - R_t^B Q_{t-1}^B B_{t-1}^H
\]

(25)

The equilibrium condition for the international bond:

\[
B_t^H = B_t^F
\]

(26)

Finally the risky rates of return on deposits in Home and Foreign are given by:

\[
R_t^H = \left(1 - F(\bar{\omega}_t^H)\right) R_t^{DH} B_t^H + \lambda_1^H R_t^AH_t Q_{t-1}^H A_t^H G(\bar{\omega}_t^H) + \lambda_2^H R_t^B Q_{t-1}^B B_{t-1}^H F(\bar{\omega}_t^H)
\]

(27)

where the first term on the right hand side is what depositors get from the banks that are not run, and the second and third terms on the right hand side are what depositors get from liquidated banks. Similarly for Foreign:

\[
R_t^F = \left(1 - F(\bar{\omega}_t^F)\right) R_t^{DF} B_t^F + \lambda_1^F \left(R_t^AF_t Q_{t-1}^F A_t^F G(\bar{\omega}_t^F) - R_t^B Q_{t-1}^B B_{t-1}^F F(\bar{\omega}_t^F)\right)
\]

(28)

3.9 Deposit Insurance

3.10 Deposit Insurance at the National Level

The deposit insurance scheme is run by the government in each country. The government collects deposit insurance fees from non-defaulting banks every quarter.
At time $t$, every home bank must pay a fee that is proportional to its deposits at the beginning of the period: $\iota_t^{H-1}D_t^{H-1}$. The fee is pre-determined. Depositors of liquidated banks then receive a transfer from the government that is proportional to their claim $x_t^{H}D_t^{H-1}R_t^{D}$. I call $x_t$ the deposit insurance coverage. The bigger $x_t$, the more depositors receive in case of a run. A similar scheme is run in Foreign.

Deposit insurance has an impact on the run threshold. Everything else being equal, the bigger $x_t^H$, the smaller the run threshold. Hence deposit insurance can reduce the probability of a run.

$$\bar{\omega}_t^H = (1 - x_t^H)\frac{R_t^{D}}{\lambda_t^H R_t^{AH}} \frac{D_t^{H-1}}{Q_{t-1}^H A_t^{H-1}} - \lambda^2_t \frac{R_t^B}{\lambda_t^H R_t^{AH}} \frac{B_t^{H-1}}{Q_{t-1}^H A_t^{H-1}}$$  \hspace{1cm} \text{(29)}$$

However there is also a cost which is apparent in the net worth evolution of banks:

$$N_t^H = (\epsilon^H + \tau^H) \left( R_t^{AH} Q_t^{H-1} A_t^{H-1} (1 - G(\bar{\omega}_t^H)) + R_t^B Q_t^{B} B_{t-1} (1 - F(\bar{\omega}_t^H)) \right) - \epsilon^H (R_{t-1}^{D} + \iota_{t-1}^H) D_{t-1} (1 - F(\bar{\omega}_t^H))$$  \hspace{1cm} \text{(30)}$$

When we introduce deposit insurance, depositors understand that they will receive an additional transfer in case of a run. This will, everything else being equal, require a lower rate on bank deposits:

$$R_t^H = \left( 1 - F(\bar{\omega}_t) + x_t^H F(\bar{\omega}_t) \right) R_{t-1}^{D} + \lambda_t^H R_t^{AH} \frac{Q_t^{H-1} A_t^{H-1}}{D_t^{H-1}} G(\bar{\omega}_t) + \lambda^2_t R_t^B Q_t^B B_t^{H-1} F(\bar{\omega}_t)$$  \hspace{1cm} \text{(31)}$$

The insurance fund evolves as follows:

$$InsuFund_t^H = InsuFund_{t-1}^H + \iota_{t-1}^H D_{t-1} (1 - F(\bar{\omega}_t^H)) - x_t^H R_{t-1}^{D} D_{t-1} F(\bar{\omega}_t^H)$$  \hspace{1cm} \text{(32)}$$

The value of the fund at time $t$ is what was in the fund in the previous period (the fund carries no interest rate), adding payments from continuing banks and subtracting payout to depositors of failed institutions. I assume when the deposit fund is below target, for example following a negative shock to the economy, the government may increase the deposit insurance fees on all banks. By the same token, when the insurance fund is below target, the payment capacity is reduced and hence deposit insurance coverage falls.

$$\iota_t^H = \bar{\iota}^H + \chi_t \left( \frac{InsuFund_t^H}{E_t} - E_t(InsuFund_{t-1}^H) \right)$$  \hspace{1cm} \text{(33)}$$
Following the European Commission deposit insurance revision of 2014, the deposit insurance target is a fraction $\mu_t^H$ of all outstanding deposits at any time:

$$\overline{\text{InsuFund}_t^H} = \mu D_t^H$$  \hfill (35)\]

Deposit insurance in Foreign is introduced in a similar fashion.

3.11 Joint deposit insurance

Joint deposit insurance means Home and Foreign contribute to the same fund. The evolution of the joint insurance fund is given by:

$$\text{InsuFund}_t = \text{InsuFund}_{t-1} + \iota_{t-1} (D_{t-1}^H (1 - F(\bar{\omega}^H_t)) + D_{t-1}^F (1 - F(\bar{\omega}^F_t)))$$

- $$x_t (R_{t-1} D_{t-1}^H F(\bar{\omega}^H_t) + R_{t-1} D_{t-1}^F F(\bar{\omega}^F_t))$$

So the joint insurance fund increases with payments from both countries and is reduced when payments need to be made to depositors of failed banks in either country. Similarly, the coverage of deposit insurance and the fees paid by banks in the two countries are equalized. Their evolution now depends on the level of the joint fund relative to the target level:

$$x_t = \bar{x} - \chi_x (\overline{\text{InsuFund}} - \text{InsuFund}_t)$$  \hfill (37)\]

$$\iota_t = \bar{\iota} + \chi_\iota (\overline{\text{InsuFund}} - E_t (\text{InsuFund}_{t+1}))$$  \hfill (38)\]

The joint fund target is a fraction of outstanding deposits in both countries:

$$\overline{\text{InsuFund}_t^H} = \mu (D_t^H + D_t^F)$$  \hfill (39)\]

4 Calibration

The calibration of the model follows the literature and is given in table 3. Parameters that are not indexed by $H$ or $F$ are the same for both countries. The first part of the table displays the macro variables. Their calibration follows Nuño and
The second part of the table displays the banking parameters. The survival rate of banks in Foreign ($\epsilon^F$) and the share of asset transfer into new banks ($\tau$) follow Gertler and Kiyotaki (2010). The parameters $\epsilon^H$ and $\theta$ are calibrated to match a steady-state ratio of foreign loans to total assets (i.e. $B^H/(Q^H A^H)$) of about 10% in Home, and a steady-state deposit to total assets (i.e. $D^F/(Q^F A^F)$) ratio of about 70% in Foreign. The idiosyncratic shock volatility $\sigma$ is set to 0.05, which yields bank default rates of about 2% in both countries in steady-state. The parameters $\lambda_1$ and $\lambda_2$ are specific to my model; they determine how costly bank runs are. I set $\lambda_1$ to 0.9, so in case of a bank run, 10% of the domestic assets of the failed institutions are lost. I also assume that foreign assets are harder to liquidate than domestic assets, so I set $\lambda_2 = 0.5$. The last part of the table shows the deposit insurance specific parameters. I set the deposit insurance fund target to be 0.8% of all outstanding deposits, in line with the directive on deposit insurance (directive 2014/49/EU). The coverage in Home is 0.05. It means in case of a bank run, depositors get a government transfer of 5% of their claims. This number may seem low, but this transfer is on top of the assets of the liquidated bank, so depositors do recuperate a sizable fraction of their claims. In the euro area, deposits are not fully covered: only deposits up to 100’000 EUR are covered. To calibrate the coverage, I look at the steady-state fee that bank must pay to allow a coverage of 5%. In steady state the deposit insurance fund must be stable, so total payments to depositors must equal total fees from banks. A coverage of 5% corresponds to a fee of 0.1% of deposits. Data on deposit insurance fees in the Eurozone is not available. I compare this number with the fees in the United States post-crisis. The range of quarterly fees in 2011 to 2016 in the U.S. is from 0.006% for the safest banks to 0.113% for riskier banks, so our baseline calibration is in line with fees on risky banks. Our baseline calibration assumes the deposit insurance in Foreign is weaker than in Home: the coverage and the fund are 80% of those in Home.

According to the Consolidated Banking statistics of the European Central Bank, the interbank lending ratio of German banks were about 11% for the period 2014-2016. I take this number to approximate the ratio of loan to foreign banks over all assets in Home. Over the same period, the deposit ratio in Italy, Spain and Greece were 64%, 70% and 81% respectively.
### Table 3: Calibration

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$</td>
<td>0.99</td>
<td>discount rate</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>0.36</td>
<td>share of capital in production</td>
</tr>
<tr>
<td>$\delta$</td>
<td>0.025</td>
<td>depreciation rate</td>
</tr>
<tr>
<td>$\chi$</td>
<td>0.5</td>
<td>adjustment cost on investment</td>
</tr>
<tr>
<td>$\eta$</td>
<td>1</td>
<td>disutility of labor</td>
</tr>
<tr>
<td>$\varphi$</td>
<td>1</td>
<td>inverse elasticity of labor supply</td>
</tr>
<tr>
<td>$\rho$</td>
<td>0.94</td>
<td>persistency of technology shock</td>
</tr>
</tbody>
</table>

#### Standard RBC parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\epsilon^H$</td>
<td>0.978</td>
<td>bankers survival probability (Home)</td>
</tr>
<tr>
<td>$\epsilon^F$</td>
<td>0.972</td>
<td>bankers survival probability (Foreign)</td>
</tr>
<tr>
<td>$\theta$</td>
<td>0.3</td>
<td>fraction of assets bankers can divert</td>
</tr>
<tr>
<td>$\tau$</td>
<td>0.0018</td>
<td>share of asset transfer into new banks</td>
</tr>
<tr>
<td>$\sigma$</td>
<td>0.05</td>
<td>volatility of idiosyncratic capital quality shock</td>
</tr>
<tr>
<td>$\lambda_1$</td>
<td>0.9</td>
<td>liquidation value domestic assets</td>
</tr>
<tr>
<td>$\lambda_2^H$</td>
<td>0.5</td>
<td>liquidation value international bond</td>
</tr>
</tbody>
</table>

#### Banking parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$x^H$</td>
<td>0.05</td>
<td>Deposit insurance coverage</td>
</tr>
<tr>
<td>$\mu^H$</td>
<td>0.008</td>
<td>Deposit insurance fund target</td>
</tr>
<tr>
<td>$x^F$</td>
<td>0.04</td>
<td>Deposit insurance coverage</td>
</tr>
<tr>
<td>$\mu^F$</td>
<td>0.0064</td>
<td>Deposit insurance fund target</td>
</tr>
<tr>
<td>$\chi_x$</td>
<td>0.01</td>
<td>adjustment parameter of deposit insurance coverage</td>
</tr>
<tr>
<td>$\chi_i$</td>
<td>0.01</td>
<td>adjustment parameter of deposit insurance fee</td>
</tr>
</tbody>
</table>

#### Deposit insurance parameters

5 Results

5.1 Steady-state analysis

First, let us consider how banks choose their asset and liability structure. Foreign banks can choose whether to raise deposits or borrow from home bank. Deposits are cheaper but give rise to possible bank runs. Moreover, loans from home banks relieve the incentive compatibility constraint of foreign banks, since assets pledged to home banks cannot be run on. In equilibrium, foreign banks will choose their
liability structure optimally, combining deposits and borrowing from home banks. Home banks choose whether to lend to home firms or to foreign banks. Loans to foreign banks make home banks more vulnerable to bank runs, since foreign assets are valued less by depositors. Moreover, loans to local firms pay a state-contingent rate of return. Since banks have limited liability, they prefer more volatile assets, as they give a higher probability to large positive outcomes. For those two reasons, home banks find lending to local firms more attractive. In equilibrium, the no arbitrage condition for home banks implies that the interest rate on loans to foreign banks is higher than that to local firms, so as to make the home banks indifferent between the two assets.

I compare the steady state of the model under different deposit insurance regimes. The results are in Table[4]. The first column contains steady-state values under our baseline calibration: deposit insurance is at the national level, with Home having a stronger deposit insurance than Foreign. The second column displays steady-state values when deposit insurance is harmonized, i.e. Foreign strengthens its deposit insurance to match the one in Home, but deposit insurance remains separate. The last column displays steady-state values under the assumption of a fully joint deposit insurance scheme in the two countries.

Going from the benchmark to the harmonized deposit insurance, we find that the run probability in Foreign is lower. This is not surprising since we increased the coverage level in Foreign from 0.04 to 0.05. It is however interesting to note that the run probability decreases also in Home, although the coverage in Home did not change. The increase in deposit insurance coverage in Foreign induces foreign banks to raise more deposits and reduce borrowing from home banks. Home banks then reduce their lending to foreign banks and lend instead more to home firms. Since foreign assets are especially hard to liquidate during a bank run, substituting from foreign to domestic loans reduces the likelihood of runs. The reduction in run probabilities in both countries implies that there are less default costs. Hence, net output is higher in both countries. Banks are less likely to be run on, their net worth is higher and so they are able to give out more loans; hence capital goes up in both countries. Harmonizing deposit insurance then leads to an increase in consumption in both countries. Hence, there are welfare costs to an asymmetric deposit insurance. Home has a higher insurance coverage, but suffers from the lower level of insurance in Foreign. Harmonizing is then beneficial.
for both countries. A detailed welfare analysis will be given in section 5.3.

What happens if instead of just harmonizing, the two countries decide to implement a fully joint deposit insurance scheme? Table 4 shows that there is little difference between the harmonized and fully joint steady states. The difference comes from the fact that $\iota$ is equalized across countries in the fully joint, whereas it is different in the harmonized. Since the run probability is higher in Foreign, we find that in the fully joint case, Foreign pays a slightly higher rate and Home a slightly lower rate compared to the harmonized. Hence, the joint deposit insurance is more favorable to Foreign whereas the harmonized is more favorable to Home. However, either one of those deposit insurance regimes is strongly preferred by both countries compared to the national deposit insurance.

Table 4: Steady-state analysis

<table>
<thead>
<tr>
<th></th>
<th>National</th>
<th>Harmonized</th>
<th>Joint</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C^H$</td>
<td>2.495</td>
<td>2.524</td>
<td>2.523</td>
</tr>
<tr>
<td>$C^F$</td>
<td>2.411</td>
<td>2.462</td>
<td>2.467</td>
</tr>
<tr>
<td>$L^H$</td>
<td>0.926</td>
<td>0.926</td>
<td>0.926</td>
</tr>
<tr>
<td>$L^F$</td>
<td>0.940</td>
<td>0.936</td>
<td>0.936</td>
</tr>
<tr>
<td>$K^H$</td>
<td>32.691</td>
<td>33.768</td>
<td>33.760</td>
</tr>
<tr>
<td>$K^F$</td>
<td>31.454</td>
<td>32.867</td>
<td>33.001</td>
</tr>
<tr>
<td>$Y_{net}^H$</td>
<td>3.248</td>
<td>3.322</td>
<td>3.326</td>
</tr>
<tr>
<td>$Y_{net}^F$</td>
<td>3.261</td>
<td>3.329</td>
<td>3.333</td>
</tr>
<tr>
<td>$D^H$</td>
<td>29.991</td>
<td>30.272</td>
<td>30.194</td>
</tr>
<tr>
<td>$D^F$</td>
<td>23.148</td>
<td>24.978</td>
<td>25.168</td>
</tr>
<tr>
<td>$B$</td>
<td>3.888</td>
<td>3.167</td>
<td>3.082</td>
</tr>
<tr>
<td>$N^H$</td>
<td>6.588</td>
<td>6.663</td>
<td>6.648</td>
</tr>
<tr>
<td>$N^F$</td>
<td>4.417</td>
<td>4.722</td>
<td>4.751</td>
</tr>
<tr>
<td>$F(\bar{\omega}^H)$</td>
<td>1.861%</td>
<td>1.231%</td>
<td>1.175%</td>
</tr>
<tr>
<td>$F(\bar{\omega}^F)$</td>
<td>2.639%</td>
<td>1.580%</td>
<td>1.573%</td>
</tr>
</tbody>
</table>
Figure 1: 1% negative TFP shock in Foreign
5.2 Dynamic analysis

In the first experiment, I consider a 1% negative TFP shock in Foreign and analyze its effects in Foreign and how it transmits to Home. I then analyze how different insurance regimes affect the response to the shock. Impulse response functions are in figure 1. All impulse response functions are displayed as percent deviations from steady state. A negative TFP shock will affects the foreign economy directly, causing output to fall. The price of capital falls due to the lower productivity of capital. The decline in asset price depresses bank net worth, which makes them more vulnerable to bank runs and forces them to curtail loans. Hence, capital and investment sink. Run probabilities increase sharply, leading to greater default costs as well as more withdrawals from the deposit insurance fund. The fund falls below its target so coverage diminishes and banks are required to pay higher fees to replenish the fund. All those effects combined contribute to amplify the effect of the initial shock in Foreign.

Financial integration and bank arbitrage between the different assets implies a comovement between the price of capital and the price of the bond in the two countries. Hence, the decline of $Q^F$ will be accompanied by a decline in $Q^B$ and in $Q^H$. Sinking asset prices will deteriorate the net worth of home banks. The latter will suffer more bank runs and will be less able to provide credit to home firms. Higher default costs and a credit crunch are followed recession also in Home. Hence, the TFP shock originating in Foreign will drive a deep recession in both countries.

What happens if deposit insurance is joint rather than national? The joint insurance scheme implies there is a higher coverage in Foreign. After the shock, the run probability increases by less in Foreign, due to higher insurance coverage. Hence, the recession in Foreign is milder. Foreign capital price falls by less, so the bond and capital prices in Home also fall by less, mitigating the contagion to Home. Home banks are less negatively affected, their run probability increases by less and hence the recession is also milder in Home. The joint insurance fund is more stable, hence the variations in insurance fee and coverage are smaller, which also contributes to smooth output.

The effects are similar if the TFP shock happens in Home instead (see figure 2). In this case, it is the home economy that is hit directly by the shock. Declining
Figure 2: 1% negative TFP shock in Home
asset prices and increase in run probabilities in Home will amplify the shock. Foreign will be affected by the shock because of the comovement in asset prices. Declining net worth in Foreign will cause an increase in default costs and a credit crunch, leading to a recession. A joint deposit insurance scheme is more effective than the national deposit insurance. The increase in run probabilities in both countries is more contained, hence the recession is less severe.

In a nutshell, since the two countries are financially integrated, a fully national deposit insurance is suboptimal if one country has a weaker insurance than the other. Home suffers from the feeble deposit insurance in Foreign. A joint deposit insurance improves the stability of both economies in response to shocks.

5.3 Welfare

I take a second order approximation of the model to calculate welfare. I calibrate the variance of the TFP shocks in both countries to match the standard deviations of GDP in Germany for Home and Italy and Spain for Foreign. Table 5 shows welfare gains in consumption equivalent terms relative to the baseline (i.e. national deposit insurance). The first part of the table looks at welfare gain in the steady state, so taking into account only the difference in steady states and not the effect of shocks. The second part of the table looks at the second order approximation of the welfare function and shows welfare conditional on the initial state of the model being the steady-state. The last part of the table considers the long-term unconditional mean of welfare. Looking at either steady-state, conditional or unconditional welfare gains, it appears clearly that harmonized and joint deposit insurance both greatly improve welfare relative to the national deposit insurance case. The steady-state welfare gains are about 1% for Home and about 2.5% for Foreign. The steady-state welfare gains are mainly due to the higher steady-state consumption in the harmonized and joint models relative to the national. The conditional and unconditional welfare gains are around 3% for Home.

\footnote{I use quarterly real GDP data from the European Central Bank, from 1995Q1 to 2017Q1. Data is logged and hp-filtered to calculate the standard deviations of output. I find a standard deviation of 1.5% for Germany and 1.3% for Italy and Spain. I hp-filter the model series to make them comparable to the data. The standard deviation of TFP shocks are 0.769% in Home and 0.675% in Foreign, which give standard deviations of output of 1.51% in Home and 1.3% in Foreign under the baseline calibration.}
and 4% for Foreign. The conditional and unconditional welfare measures take into account the steady-state improvement in consumption, but also the smaller variability of consumption in response to shocks. Either harmonizing or joining the deposit insurance leads to a smoother response to shocks. Hence, conditional and unconditional welfare gains are even larger than steady-state welfare gains.

Comparing the welfare gains of Harmonized and Joint deposit insurance we find that both are beneficial relative to the baseline, but the two countries do not agree on the ranking of the two alternatives. Home gets larger welfare gains under the harmonized deposit insurance whereas Foreign prefers the fully joint. The fully joint deposit insurance is more favorable to Foreign because it leads to lower bank insurance fees. However Home prefers the harmonized insurance to avoid cross-subsidizing deposit insurance in Foreign, where bank runs are more likely.

<table>
<thead>
<tr>
<th>Steady state</th>
<th>Harmonized</th>
<th>Joint</th>
</tr>
</thead>
<tbody>
<tr>
<td>Home</td>
<td>1.126%</td>
<td>1.075%</td>
</tr>
<tr>
<td>Foreign</td>
<td>2.437%</td>
<td>2.674%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Unconditional</th>
<th>Harmonized</th>
<th>Joint</th>
</tr>
</thead>
<tbody>
<tr>
<td>Home</td>
<td>2.728%</td>
<td>2.693%</td>
</tr>
<tr>
<td>Foreign</td>
<td>3.851%</td>
<td>4.129%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Conditional</th>
<th>Harmonized</th>
<th>Joint</th>
</tr>
</thead>
<tbody>
<tr>
<td>Home</td>
<td>3.251%</td>
<td>3.223%</td>
</tr>
<tr>
<td>Foreign</td>
<td>3.989%</td>
<td>4.251%</td>
</tr>
</tbody>
</table>

5.4 Transition from National to Joint Deposit insurance

This last section considers the transition period from a steady state with national deposit insurance to a steady state with fully joint deposit insurance, assuming there are no shocks during this period. The transition paths of selected variables are given in figure 3. At time zero, the economy is in the old steady state. At time 1, there deposit insurance regime shifts to fully joint, so the economy starts moving towards the new steady state. The introduction of joint deposit insurance leads to a fall of run probabilities in both countries on impact. Less resources are lost on default, so net output increases already in the transition period. In the new steady state, we know from section 5.1 that both economies have a higher
level of capital. Capital is accumulated gradually, so investment is higher in both countries during the transition. More resources are dedicated to investment so consumption is lower during the transition. The increase in capital implies a higher marginal productivity of labor, so labor is also higher during the transition. Lower consumption and higher labor mean the two countries will suffer welfare losses during the transition phase. We also find that Foreign borrows gradually less from Home, as banks switch to raising more deposits. Hence, the current account improves in Foreign and deteriorates in Home. Home experiences an increase in consumption in the first period due to the decline in lending to Foreign.
6 Conclusion

This paper analyzes the effect of deposit insurance in a two country model with a financial sector and international bank lending. Our model features depositors that can run on a bank when the value of bank assets is low. The probability of a bank run depends on macroeconomic conditions and is endogenous. Bank runs are costly because they give rise to default costs. In an open economy setup, shocks in one county are transmitted to the other country through their effect on asset prices. The strength of deposit insurance in any country will then have an effect on both countries and on the transmission of shocks.

I consider three alternative deposit insurance regimes. The first is the fully national deposit insurance, where deposit insurance is run by each country separately, and coverage and funding are different across countries. The second is the harmonized deposit insurance, where deposit insurance is still run separately but the coverage and size of the fund are identical. The fully joint deposit insurance has a unique deposit insurance fund, run jointly by both countries.

My analysis shows that either harmonizing or joining deposit insurance can improve output and consumption in steady state by reducing the probability of bank runs and default costs in both countries. Thus, both policies lead to large steady-state welfare gains. I also find that a joint deposit insurance is less volatile in response to shocks. Hence, after a technology shock in one of the countries, the joint deposit insurance fund is better able to stabilize the probability of run and thus reduce the macroeconomic volatility. However, a detailed welfare analysis shows that the two countries disagree on the ranking of harmonized versus joint deposit insurance. Home ranks Harmonized above Joint, whereas Foreign ranks Joint above Harmonized. The reason is that the joint deposit insurance implies some subsidization from Home to Foreign, which is detrimental to Home. Nevertheless, both countries unequivocally prefer either harmonized or joint to the national deposit insurance.
References


A Full model equations

A.1 Separate deposit insurance

A.1.1 Home

Household first order conditions:

\[ \frac{1}{C_t^H} = \beta^H E_t \left( \frac{1}{C_{t+1}^H} R_{t+1}^H \right) \]  
(40)

\[ \eta^H C_t^H (L_t^H) = u_t^H \]  
(41)

Firm first order conditions:

\[ w_t^H = \gamma^H Y_t^H \]  
(42)

\[ R_t^{kH} = (1 - \gamma^H) \frac{Y_t^H}{K_t^H} \]  
(43)

Production :

\[ Y_t^H = Z_t^H (I_t^H)^{\gamma^H} (K_t^H)^{1-\gamma^H} \]  
(44)

Capital producer first order condition:

\[ 1 = Q_t^H \left( 1 - \chi^H \left( \frac{I_t^H}{I_{t-1}^H} - 1 \right) \right)^2 - \chi^H \left( \frac{I_t^H}{I_{t-1}^H} - 1 \right) \left( \frac{I_t^H}{I_{t-1}^H} - 1 \right)^2 \]

\[ + E_{t+1}^H \left( Q_{t+1}^H \chi^H \left( \frac{I_{t+1}^H}{I_t^H} - 1 \right) \left( \frac{I_t^H}{I_{t-1}^H} - 1 \right)^2 \right) \]  
(45)

Defining \( \phi_t^H \):

\[ \phi_t^H = \frac{Q_t^H A_t^H + Q_t^B D_t^H}{N_t^H} \]  
(46)

Defining run probability:

\[ \bar{\omega}_t^H = (1 - x_t^H) \frac{R_{t-1}^{DH}}{\lambda_t^H R_t^{AH} Q_{t-1}^H A_{t-1}^H} - \lambda_t^H \frac{R_t^{BH}}{\lambda_t^H R_t^{AH} Q_{t-1}^H A_{t-1}^H} \]  
(47)

Aggregate bank net worth evolution:

\[ N_t^H = (\epsilon_t^H + \tau_t^H) \left( R_t^{AH} Q_{t-1}^H A_{t-1}^H (1 - G(\bar{\omega}_t^H)) + R_t^{BH} Q_{t-1}^B D_{t-1}^H (1 - F(\bar{\omega}_t^H)) \right) 
- \epsilon_t^H \left( R_{t-1}^{DH} + x_{t-1}^H \right) D_{t-1}^H (1 - F(\bar{\omega}_t^H)) \]  
(48)
Bank first order conditions: Foc D:

\[ \lambda_t^{BSH} = \frac{E_t \Lambda_{t,t+1}^H}{\lambda_t^H} (1 - \epsilon^H + \epsilon^H \theta^H \phi_{t+1}^H) \left( (R_t^H + \iota_t^H)(1 - F(\bar{\omega}_{t+1}^H)) \right) \]

\[ + (1 - x_t^H) R_t^H f(\bar{\omega}_{t+1}^H) \left( \frac{\omega_{t+1}^H}{\lambda_t^H} + \frac{R_{t+1}^{BH}}{\lambda_t^H A_{t+1}^H} \frac{B_t^H}{Q_t^H A_t^H} - \frac{R_t^{DH} + \iota_t^H}{\lambda_t^H A_{t+1}^H} \frac{D_t^H}{Q_t^H A_t^H} \right) \]  

\[ (49) \]

FOC B:

\[ \lambda_t^{BSH} + \theta^H \lambda_t^{ICCH} = \frac{E_t \Lambda_{t,t+1}^H}{\lambda_t^H} (1 - \epsilon^H + \epsilon^H \theta^H \phi_{t+1}^H) R_{t+1}^{BH} \left( 1 - F(\bar{\omega}_{t+1}^H) \right) \]

\[ + \lambda_2^H f(\bar{\omega}_{t+1}^H) \left( \frac{\omega_{t+1}^H}{\lambda_2^H} + \frac{R_{t+1}^{BH}}{\lambda_2^H A_{t+1}^H} \frac{B_t^H}{Q_t^H A_t^H} - \frac{R_t^{DH} + \iota_t^H}{\lambda_2^H A_{t+1}^H} \frac{D_t^H}{Q_t^H A_t^H} \right) \]  

\[ (50) \]

FOC A:

\[ \lambda_t^{BSH} (1 + \frac{B_t^H}{Q_t^H A_t^H} - \frac{D_t^H}{Q_t^H A_t^H}) + \theta^H \lambda_t^{ICCH} (1 + \frac{B_t^H}{Q_t^H A_t^H}) = \frac{E_t \Lambda_{t,t+1}^H}{\lambda_t^H} (1 - \epsilon^H + \epsilon^H \theta^H \phi_{t+1}^H) \]

\[ \left( (1 - G(\bar{\omega}_{t+1}^H)) R_{t+1}^{AH} + \left( R_{t+1}^{BH} \frac{B_t^H}{Q_t^H A_t^H} - (R_t^{DH} + \iota_t^H) \frac{D_t^H}{Q_t^H A_t^H} \right) (1 - F(\bar{\omega}_{t+1}^H)) \right) \]  

\[ (51) \]

Bank envelope condition:

\[ (1 - \lambda_t^{ICCH}) \theta^H \phi_t^H = \lambda_t^{BSH} \]  

\[ (52) \]

Bank balance sheet constraint:

\[ N_t^H + D_t^H = Q_t^H A_t^H + Q_t^B B_t^H \]  

\[ (53) \]

Aggregate resource constraint:

\[ Y_t^H = C_t^H + I_t^H + (1 - \lambda_t^H) R_{t-1}^{AH} Q_{t-1}^H A_{t-1}^H G(\bar{\omega}_{t-1}^H) + (1 - \lambda_2^H) R_{t-1}^{BH} Q_{t-1}^B B_{t-1}^H F(\bar{\omega}_{t-1}^H) + Q_t^B B_t^H - R_{t-1}^{BH} Q_{t-1}^B B_{t-1}^H + (InsuFund_{t-1}^H - InsuFund_{t-1}^H) \]  

\[ (54) \]

Risky rate on deposits:

\[ R_t^H = (1 - F(\bar{\omega}_{t} + x_t^H F(\bar{\omega}_{t}))) R_{t-1}^{DH} + \lambda_1^H R_{t-1}^{AH} \frac{Q_{t-1}^H A_{t-1}^H}{D_{t-1}^H} G(\bar{\omega}_{t-1}) + \lambda_2^H R_t^{BH} \frac{Q_{t-1}^B B_{t-1}^H}{D_{t-1}^H} F(\bar{\omega}_{t}) \]  

\[ (55) \]
Rate of return on loans:

\[ R_t^H = \frac{R_t^{kH} + (1 - \delta^H)Q_t^H}{Q_t^{H-1}} \]  \hspace{1cm} (56)

Loans and capital:

\[ K_t^H = A_{t-1}^H \]  \hspace{1cm} (57)

\[ K_{t+1}^H = K_t^H (1 - \delta^H) + I_t^H \left( 1 - \frac{\chi^H}{2} \left( \frac{I_t^H}{I_{t-1}^H} - 1 \right)^2 \right) \]  \hspace{1cm} (58)

Home deposit insurance scheme:

\[ x_t^H = \bar{x}^H - \chi^H (\text{InsuFund}^H - \text{InsuFund}_{t-1}^H) \]  \hspace{1cm} (59)

\[ t_t^H = \bar{t}^H + \chi_t \left( \text{InsuFund}^H - E_t(\text{InsuFund}_{t+1}^H) \right) \]  \hspace{1cm} (60)

\[ \text{InsuFund}_{t}^H = \text{InsuFund}_{t-1}^H + t_{t-1}^H D_{t-1}^H (1 - F(\bar{\omega}_t^H)) - x_t^H R_{t-1}^D D_{t-1}^H F(\bar{\omega}_t^H); \]  \hspace{1cm} (61)

A.1.2 Foreign

Household first order conditions:

\[ \frac{1}{C_t^F} = \beta^F E_t \left( \frac{1}{C_{t+1}^F} R_{t+1}^F \right) \]  \hspace{1cm} (62)

\[ \eta C_t^F (L_t^F)^{\varphi_F} = w_t^F \]  \hspace{1cm} (63)

Firm first order conditions:

\[ w_t^F = \gamma^F \frac{Y_t^F}{L_t^F} \]  \hspace{1cm} (64)

\[ R_t^{kF} = (1 - \gamma^F) \frac{Y_t^F}{K_t^F} \]  \hspace{1cm} (65)

Production:

\[ Y_t^F = Z_t^F (L_t^F)^{\gamma_F} (K_t^F)^{1-\gamma_F} \]  \hspace{1cm} (66)
Capital producer first order condition:

$$1 = Q_t^F \left( 1 - \chi^F \left( \frac{I_t^F}{I_{t-1}^F} - 1 \right)^2 - \chi^F \left( \frac{I_t^F}{I_{t-1}^F} - 1 \right) \frac{I_t^F}{I_{t-1}^F} \right)$$  \hspace{1cm} (67)

$$+ E_t \Lambda_{t+1}^F \left( Q_{t+1}^F \chi \left( \frac{I_{t+1}^F}{I_t^F} - 1 \right) \left( \frac{I_{t+1}^F}{I_t^F} \right)^2 \right)$$

Defining $\phi_t^F$:

$$\phi_t^F = \frac{Q_t^F A_t^F - Q_t^B B_t^F}{N_t^F}$$  \hspace{1cm} (68)

Defining run probability:

$$\bar{\omega}_t^F = (1 - x_t^F) \frac{R_{t-1}^{DF}}{1 - R_{t-1}^{AF}} \frac{D_{t-1}^F}{Q_{t-1}^F A_{t-1}^F} + \frac{R_t^B Q_t^B}{R_t^{AF} Q_t^F A_t^F}$$  \hspace{1cm} (69)

Aggregate bank net worth evolution:

$$N_t^F = (\epsilon_t^F + \tau_t^F) \left( R_{t-1}^{AF} Q_{t-1}^F A_{t-1}^F (1 - G(\bar{\omega}_t^F)) \right)$$

$$- \epsilon_t^F \left( (R_{t-1}^{DF} + \iota_{t-1}^F) D_{t-1}(1 - F(\bar{\omega}_t^F)) + R_t^{BF} Q_t^B B_t(1 - F(\bar{\omega}_t^F)) \right)$$  \hspace{1cm} (70)

Bank first order conditions: FOC D:

$$\lambda_t^{BSF} = \frac{E_t A_t^{F,F}}{1 - \epsilon_t^F + \epsilon_t^F \theta_t^F \phi_{t+1}^F} \left( R_t^F + \iota_t^F \right) (1 - F(\bar{\omega}_{t+1}^F))$$

$$+ (1 - x_t^F) R_t^F f(\bar{\omega}_{t+1}^F) \left( \frac{\omega_{t+1}^F}{\lambda_t^F} - \frac{R_t^{BF}}{\lambda_t^F R_t^{AF} Q_t^F A_t^F} \left( B_t^F - \frac{R_t^{DF} + \iota_t^F}{R_t^{AF} Q_t^F A_t^F} D_t^F \right) \right)$$  \hspace{1cm} (71)

FOC B:

$$\lambda_t^{BSF} + \theta_t^{ICCF} \lambda_t^{ICCF} = \frac{E_t A_t^{F,F}}{1 - \epsilon_t^F + \epsilon_t^F \theta_t^F \phi_{t+1}^F} R_t^{BF} \left( 1 - F(\bar{\omega}_{t+1}^F) \right)$$

$$+ f(\bar{\omega}_{t+1}^F) \left( \frac{\omega_{t+1}^F}{\lambda_t^F} + \frac{R_t^{BF}}{R_t^{AF} Q_t^F A_t^F} \left( B_t^F - \frac{R_t^{DF} + \iota_t^F}{R_t^{AF} Q_t^F A_t^F} D_t^F \right) \right)$$  \hspace{1cm} (72)

FOC A:

$$\lambda_t^{BSF} \left( 1 - \frac{B_t^F}{Q_t^F A_t^F} - \frac{D_t^F}{Q_t^F A_t^F} \right) + \theta_t^{ICCF} \lambda_t^{ICCF} \left( 1 - \frac{B_t^F}{Q_t^F A_t^F} \right) = \frac{E_t A_t^{F,F}}{1 - \epsilon_t^F + \epsilon_t^F \theta_t^F \phi_{t+1}^F}$$

$$\left( (1 - G(\bar{\omega}_{t+1}^F)) R_{t+1}^{AF} \right) \left( R_{t+1}^{BF} Q_{t+1}^F A_{t+1}^F + (R_t^{DF} + \iota_t^F) \frac{D_t^F}{Q_t^F A_t^F} \right) (1 - F(\bar{\omega}_{t+1}^F))$$  \hspace{1cm} (73)
Bank envelope condition:

\[(1 - \lambda_t^{CCF})\theta_t^F \delta_t^F = \lambda_t^{BSF}\]

(74)

Bank balance sheet constraint:

\[N_t^F + D_t^F + Q_t^B B_t^F = Q_t^F A_t^F\]

(75)

Aggregate resource constraint:

\[Y_t^F = C_t^F + I_t^F + (1 - \lambda^F)R_t^{AF} Q_{t-1}^F A_{t-1}^F G(\bar{\omega}_t^F) - (Q_t^B B_t^F - R_t^{BF} Q_{t-1}^B B_{t-1}^F) + (InsuFund_t^F - InsuFund_{t-1}^F)\]

(76)

Risky rate on deposits:

\[R_t^F = (1 - F(\bar{\omega}_t) + x_t^F F(\bar{\omega}_t)) R_{t-1}^{DF} + \lambda_t^F \left( R_t^{AF} \frac{Q_{t-1}^F A_{t-1}^F}{D_{t-1}^F} G(\bar{\omega}_t) - R_t^{BF} \frac{Q_{t-1}^B B_{t-1}^F}{D_{t-1}^F} F(\bar{\omega}_t) \right)\]

(77)

Rate of return on loans:

\[R_t^{AF} = \frac{R_t^{kF} + (1 - \delta^F)Q_t^F}{Q_t^F}\]

(78)

Loans and capital:

\[K_t^F = A_{t-1}^F\]

(79)

\[K_{t+1}^F = K_t^F (1 - \delta^F) + I_t^F \left( 1 - \frac{\chi^F}{2} \left( \frac{I_t^F}{I_{t-1}^F} - 1 \right)^2 \right)\]

(80)

Foreign Deposit insurance scheme:

\[x_t^F = \bar{x}^F - \chi_x^F (InsuFund_t^F - InsuFund_{t-1}^F)\]

(81)

\[i_t^F = \bar{i}^F + \chi_i \left( InsuFund_t^F - E_t(InsuFund_{t+1}^F) \right)\]

(82)

\[InsuFund_t^F = InsuFund_{t-1}^F + i_t^F D_{t-1} F(\bar{\omega}_t^F) - x_t^F R_{t-1}^{DF} D_{t-1}^F F(\bar{\omega}_t^F)\]

(83)
A.1.3 Interbank loans

\[ R_{t}^{BF} = \frac{\text{Coupon} + Q_{t}^{B}}{Q_{t-1}^{B}} \]  
\[ R_{t}^{BH} = R_{t}^{BF} \]  
\[ B_{t}^{H} = B_{t}^{F} \]  

A.2 Joint deposit insurance

Replacing in all equations \( x_{t}^{F} \) and \( x_{t}^{H} \) by the common coverage \( x_{t} \) and \( \iota_{t}^{H} \), \( \iota_{t}^{F} \) by the common fee \( \iota_{t} \), Aggregate resource constraint Home becomes:

\[ Y_{t}^{H} = C_{t}^{H} + I_{t}^{H} + (1 - \lambda_{1}^{H})R_{t}^{AH}Q_{t-1}^{H}A_{t-1}^{H}G(\omega_{t}^{H}) + (1 - \lambda_{2}^{H})R_{t}^{BH}Q_{t-1}^{B}B_{t-1}^{H}F(\bar{\omega}_{t}^{H}) + Q_{t}^{B}B_{t}^{H} - R_{t}^{BH}Q_{t-1}^{B}B_{t-1}^{H} + \iota_{t-1}D_{t-1}^{H}(1 - F(\bar{\omega}_{t}^{H})) - \iota_{t}R_{t-1}^{DH}D_{t-1}^{H}F(\bar{\omega}_{t}^{H}) \]  
\[ (87) \]

Aggregate resource constraint Foreign becomes:

\[ Y_{t}^{F} = C_{t}^{F} + I_{t}^{F} + (1 - \lambda_{1}^{F})R_{t}^{AF}Q_{t-1}^{F}A_{t-1}^{F}G(\omega_{t}^{F}) - (Q_{t}^{B}B_{t}^{F} - R_{t}^{BF}Q_{t-1}^{B}B_{t-1}^{F}) + \iota_{t-1}D_{t-1}^{F}(1 - F(\bar{\omega}_{t}^{F})) - \iota_{t}R_{t-1}^{DF}D_{t-1}^{F}F(\bar{\omega}_{t}^{F}) \]  
\[ (88) \]

Joint deposit insurance scheme:

\[ x_{t} = \bar{x} - \chi x(\text{InsuFund} - \text{InsuFund}_{t}) \]  
\[ (89) \]

\[ \iota_{t} = \bar{\iota} + \chi \iota (\text{InsuFund} - E_{t}(\text{InsuFund}_{t+1})) \]  
\[ (90) \]

\[ \text{InsuFund}_{t} = \text{InsuFund}_{t-1} + \iota_{t-1} \left( D_{t-1}^{H}(1 - F(\bar{\omega}_{t}^{H})) + D_{t-1}^{F}(1 - F(\bar{\omega}_{t}^{F})) \right) - x_{t} \left( R_{t-1}^{DH}D_{t-1}^{H}F(\bar{\omega}_{t}^{H}) + R_{t-1}^{DF}D_{t-1}^{F}F(\bar{\omega}_{t}^{F}) \right) ; \]  
\[ (91) \]