Cross-Country Spillovers In Interbank Liquidity Crises*

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ABSTRACT

Financially integrated economies observe a cross-country credit boom prior to financial recessions and a bust afterwards. This paper presents a two-country real business cycle model with banking sector where privately known intermediation efficiency of banks make them heterogeneous and gives rise to an interbank market. Overaccumulation of assets or low productivity in one country may lead to credit freeze in both financially integrated countries due to the existence of moral hazard and asymmetric information in the interbank market. A "sail together" financial integration may go into a "sink together" interbank credit freeze.

JEL Classification: E44, F34, F41, G01, G15, G21

Keywords: Financial integration, interbank market, asset accumulation, productivity,

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moral hazard, asymmetric information, credit freeze.

I Introduction

Recent macrofinance literature has emphasized on the propagation and amplification of random adverse financial shocks which primarily causes the banking crises (Gertler and Kiyotaki, 2010, 2015). However, recent studies on banking crises has highlighted a close linkage between such crises and credit conditions (Gorton, 2010, 2012). Recent empirical research also corroborate the existence of typical patterns across diverse episodes. There are closed economy models of banking crises (Gertler and Kiyotaki, 2015; Boissay et al., 2016). However, in a financially integrated world, banking crises may propagate and affect other countries. Banking crises are rare events, they follow credit-intensive booms, and involve with multiple nations occasionally. These stylized facts therefore call for an alternative approach of banking crises.

When countries are financially integrated, the interbank market equilibrium may be different from that of a closed economy. Moreover, the interbank crises may result from the states of other countries and therefore the threshold level of the states may also vary for crises. A financially integrated world may lead to spillover effects of banking crises from one country to another. These ideas lead to the research questions: how does the interbank market operate in a financially integrated two-country model? When do countries face inter-banking crises in an integrated world? and is there any spillover effect of inter-banking crises from one country to another? In this paper, we seek for the answers of these questions under a two-country model.

In this paper, when two countries are integrated through interbank lending, banking crises result from the procyclicality of bank balance sheets of either/both of the countries and may have spillover effects of interbank market freeze on each other. Countries get financially integrated to "sail together" and survive during recessions. However, due to overaccumulaion by one country both the countries may fall into an interbank freeze to "sink together". During expansions, credit supply increases pushing both the corporate

and interbank lending rates down. With lower rates the agency problem in the interbank market gets aggravated leading to contractions in interbank funding. Financial integration may lead to a disastrous interbank market freeze if total credit boom is larger than the productive use of loans.

In our model, we follow the real business cycle setup with heterogeneous banks as in Boissay et al. (2016). However, we have a two-country world where the countries are symmetric. Banks are heterogeneous due to the privately observed intermediation efficiency. They can obtain funds from the depositor/shareholders and/or the interbank market and lend to homogeneous good producing firms. Due to the usual agency problem in the interbank market, banks can borrow and divert funds to lower return assets and such diversion cannot either traced or recovered by the lending banks. Less efficient banks have more incentive to divert, and this diversion depends on the rate of returns in the economy. To restrict such diversion, interbank market has a borrowing capacity resulting from the incentive compatibility constraint. However, lower return in the corporate loans market increases the incentive for diversion and therefore market responds through lowering the borrowing capacity and eventually the market goes into a freeze. In a financially integrated world freeze in one country leads to freeze in another country for lower rates of returns.

The mechanism that leads to a banking crises in a two-country world is as follows. A sequence of favorable, productivity shocks lead to an expansion of credit. The more efficient banks borrow from the less efficient ones to expand their corporate loan operations. The size of the overall banking sector increases and the economy booms. However, when the aggregate productivity growth goes down to converge to its average course, the demand for corporate loans and the corresponding rate goes down. As a result, the interbank lending rate goes down resulting into more incentive for less efficient banks to borrow and divert funds. Therefore, counterparty risk goes up since the identity of these diverting banks are unknown; interbank lending declines and the market goes into

a freeze. When two countries are integrated through interbank lending, a market freeze in one country leads to a freeze in another country as well. Either two countries have an operating interbank market or both goes into a freeze. Excessive credit creation by one country triggers a two-country wide credit freeze. The countries may also go into a freeze from very low productivity in either or both of the countries.

We calibrate the interbank market equilibrium of the model and assess its quantitative properties. Potentially, the model can generate banking crises in one country due to an endogenous factor- overaccumulation of assets or an exogenous factor- low productivity or a combination of both the endogenous and exogenous factors in a period. Moreover, the banking crises in one country shows a spillover effect on another country, i.e., a country that could have a well operating interbank market without any integration, falls into interbank market freeze due to either of the factors of another country after any financial integration. Thus, as in data, banking crises in one country in our model are closely linked to asset accumulation and productivity of not only its own but also another country to which the country is financially integrated. However, we find that this story largely depends on how the countries are integrated, e.g., when households are allowed to deposit in domestic country only, countries are integrated through only the interbank market, and firms can only borrow capital from the domestic banks.

The paper proceeds as follows. Section II depicts some related literature of macroeconomic models with financial frictions, and international spillover effect, contagion. Section III documents the facts about financial recessions of 14 OECD countries for the period 1870-2008 as in Boissay et al. (2016). Section IV describes the basic model with representative household, representative firm, and heterogeneous banks. Section V characterizes the interbank market equilibrium for both closed and financially integrated two countries those are integrated in different dimensions. Section VI, presents the quantitative analysis and the results of the interbank market equilibrium to alternative state spaces. Section VII concludes the paper.

II Related Literature

This paper is related to the macroeconomic literature with financial frictions. For instance, Bernanke et al. (1999), Gertler and Karadi (2011), Jermann and Quadrini (2012), and Christiano et al. (2014) show how financial market frictions can amplify the financial shocks and generate long-lasting recessions. However, the models are linearized in this class of research and this paper departs from this approach to characterize the important and critical nonlinearities in the mechanism of the interbank market. The important difference is to show the boom-bust cycle as an outcome of endogenous factors rather than of a big financial shock only.

In this respect, this paper is related to the literature featuring powerful amplification mechanism[1] resulting from financial frictions, e.g., He and Krishnamurthy (2012), and Brunnermeier and Sannikov (2014). This paper is also related to the literature on sudden stops in emerging market economies. For example, as in Mendoza and Smith (2006) and Mendoza (2010), we find that a standard (mild) productivity shock can trigger a crisis if the agent is highly leveraged. These are also open economy models similar to our model. However, this paper departs in that it does not have exogenous interest rate; rather endogenous model driven interest rates which play a central role in the mechanism of the interbank market equilibrium.

This paper is also related to the financial contagion literature for international market. For example, Calvo (1998) and Chang and Velasco (2001), among others, study the interaction of the banking system and currency markets in a crisis. However, we do not introduce any currency market; rather the crisis spreads out from one country to another through the banking channel. Allen and Gale (2000), and Perri and Quadrini (2018) study the financial contagion as an outcome of liquidity preference shock. Perri and Quadrini

[1]Financial crises are inherently nonlinear events, often featuring sudden plummet in asset prices and sharp collapse in output, while with a slow recovery rate. The most recent approach to capture this nonlinearity is to allow for an occasionally binding constraint.

(2018) show that in a two-country model with financial frictions, a global liquidity shortage induced by pessimistic self-fulfilling expectations can quantitatively generate longer and deeper recessions following credit booms. The main differences between theirs and our work are that they focus on balance sheet effect from the private sector, i.e., the role of balance sheets in constraining borrowers from spending when financial markets are imperfect, while our work highlights the role of the wholesale banking sector at the heart of the recent financial crisis in which credit dried up and market froze.[2]

A recent work[3] of Gertler et al. (2019) incorporates banking panics into a standard New Keynesian model and captures both qualitatively and quantitatively the effects of financial collapse on investment, output, and employment. They show that a credit boom can increase financial instability of the system, as in Boissay et al. (2016). The sudden and discrete nature of the financial collapse characterized by the paper is induced without observing large exogenous productivity shocks, either. Instead, banks that hold imperfectly liquid long term assets and issue short term debts facing liquidity mismatch are vulnerable to panic failure of household to roll over deposits. A plausible magnitude of negative capital quality shock reduces the value of banker's capital, which either brings banks immediately into insolvency, or leads to a self-fulling rollover crisis in which the liquidation of assets at firesale prices forces banks into default, similar to the Cole and Kehoe (2000) model of sovereign default but contrast with the "early withdrawal" mechanism in the Diamond and Dybvig (1983) model[4]. One of their paper's contributions to the macro-finance literature is that they show that banking panics (or bank runs) are quantitatively

[2]See Gertler and Kiyotaki (2010), Gertler and Karadi (2011), and Curdia and Woodford (2010)for papers that incorporate banking and Iacoviello (2005), Eggertsson and Krugman (2012), and Guerrieri and Lorenzoni (2017) for papers that included household debt.

[3]See also, Gertler and Kiyotaki (2015) and Gertler et al. (2016).

[4]The traditional bank run models, starting from Diamond and Dybvig (1983), focus on the retail banking sector in which a "sequential service constraint" takes in effect to generate runs, i.e., only households who get to banks early will have their money back, a first-come, first-serve scenario. However, recent bank run mostly occurs in the wholesale banking (or interbank market) sector, such as the failure of Continental Illinois in 1984 and the collapse of Lehman Brothers in 2008.

more important than non-linearities coming from occasionally binding constraints, as in Brunnermeier and Sannikov (2014) and He and Krishnamurthy (2012). They also managed to endogenize the probability of bank runs by relating it to macroeconomic fundamentals. However, there are three main weaknesses associated with Gertler et al. (2019). First, it is not clear what the negative capital quality shocks stand for in the model if we are trying to understand the interactions between the financial market and the real economy. Second, the paper tends to replicate what happened during the 2007-08 financial crisis but fails to match the exact timing of when the crisis occurred. This issue may be addressed by incorporating some adjustment cost. Third, their model generates a counterfactual faster recovery rate from the recession than in the data. The lack of persistence may be resolved by assigning an equally important role to the real side of the economy in which household deleverages as well in the crisis.

III Financial Recession Facts

Based on data from Jordà et al. (2011, 2013) and Schularick and Taylor (2012) of 14 OECD countries from 1870 to 2008, there are two facts (first two) regarding the financial recessions. The data for the third fact is taken from Bank for International Settlements (BIS).

Fact 1: Financial recessions are rare events

Financial recessions are rare events in comparison to other recessions. From data collected of 196 recessions of 14 OECD countries, average probability of a financial recession is 2.36 percent whereas other recessions have an average probability of 8.93 percent.

Fact 2: Financial recessions follow credit booms

Financial recessions do not hit at a random; rather break out during credit boom. Credit is 3.25 percent above the trend in the peak year prior to a financial recession in comparison to only 0.61 percent above the trend in case of other recessions.

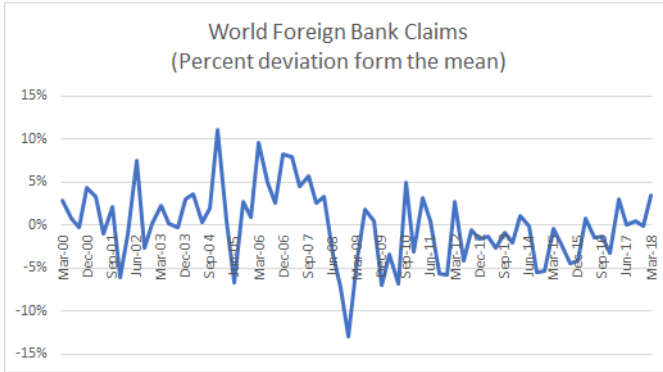

Figure 1: International Bank Claims Growth

Fact 3: International financial recessions follow international credit booms

International financial recessions follow an increase of international credit by more than 8 percent from the average in the peak year prior to the recession and during the financial recession the international credit decreases by almost 13 percent from the average. Figure 1 shows an international credit boom before the financial crisis of 2008.

IV The Baseline Model

This section explains a symmetric two-country ($j = 1, 2$) Real Business Cycle (RBC) model with banking sector. Each country is populated with one risk averse representative household, one risk-neutral representative competitive firm, and risk-neutral, heterogeneous, and competitive banks with a mass one. For ease of notation, we will exclude any country subscripts for symmetric country characterization; country notations will be introduced when required.

1 The Representative Household

There is an infinitely lived, risk averse, representative household in each of the countries. Household in each country has preferences over consumption, c, with an utility function

$$\mathbb{E}_t \sum_{\tau=0}^{\infty} \beta^{\tau} u(c_{t+\tau}) \tag{1}$$

where, the usual regularity conditions are satisfied (i.e., $u'(c) > 0$, $u''(c) < 0$, $u'(0) = \infty$, $u'(\infty) = 0$), the psychological discount factor of the household is denoted $\beta \in (0, 1)$ which is not country-specific, and $\mathbb{E}_t(\cdot)$ denotes the expectation operator. The household starts each period t with an individual asset a. Aggregate assets are denoted A. We can think a as either bank equity or bank deposit and the composition of a is indeterminate due to the lack of friction between the household and the banks. We refer a as the bank deposit and assume that the gross return on deposits is denoted r. Following the macro-finance literature (e.g., Gertler and Kiyotaki, 2010; Gertler and Karadi, 2011), we assume that household cannot finance the firms directly due to the frictions between them. We also assume that the supply of labor is inelastically one unit by the household who earns unit wage w for labor, obtains firm profit π, and receives a lump-sum transfer χ corresponding to the financial intermediation cost of the banks (more explanations are in the banking sector section). A representative household therefore maximizes her utility (1) by deciding on her consumption/saving subject to the budget constraint

$$c + a' = ra + w + \pi + \chi \tag{2}$$

2 The Representative Firm

This is a two-country model where the firm lives only for a period and produces a homogeneous good that can be either consumed or invested. To produce the good the firm needs to hire capital k and labor h. The production function $zF(k, h)$ follows a constant returns to scale technology and satisfies the standard Inada conditions. The countries may

differ due to their country-specific total factor productivity (TFP) shocks, z. However, TFP in both countries are assumed to follow the same exogenous AR(1) process:

$$\log z' = \rho_z \log z + \varepsilon' \tag{3}$$

where the persistence parameter $|\rho_z| < 1$ and the innovation ε is normally distributed with mean zero and standard deviation σ_z. At the beginning of period t, ε is realized, before the firm decides on the requirement of capital k and labor h. At the beginning of the period t, firm is born without any resources and depends on banks to borrow capital k at a gross corporate loan rate R. Capital k depreciates at rate $\delta \in (0, 1)$. At the end of the period, the firm repays the corporate loan. For production, the firm also rents labor from the household and in return pays w per unit of labor. The firm chooses capital, k and labor, h for production to maximize profit,

$$\pi = zF(k, h) + (1 - \delta)k - Rk - wh \tag{4}$$

3 The Banking Sector

The banking sector plays a very significant role in this model due to two salient features. First, there is heterogeneity in the intermediation skill among banks, i.e., some banks have more intermediation skill than others. This heterogeneity among banks creates an interbank market where the least efficient banks lend to the most efficient ones. Second, following the corporate finance literature (e.g., Tirole, 2006), there is moral hazard problem in the banking sector along with asymmetric information, which essentially impede the interbank market functioning. Overall, banks perform both the retail banking and wholesale banking. On the retail side, they collect deposits from the household and lend to the firms, and on the wholesale side, they issue interbank claims to reallocate assets among themselves where low skilled banks lend to the high skilled ones.

3.1 Banks

There is a continuum of risk-neutral, competitive banks in both countries. They are born at the end of period $t-1$ and only live for one period, i.e., banks die at the end of period t. Each bank, after birth, collects deposit a from the household. They then become heterogeneous by drawing a random, bank-specific, intermediation skill p. Henceforth, we denote bank p as bank with intermediation skill p. The skill p is distributed over the interval $[0, 1]$ with cumulative distribution $\mu(p)$, satisfying $\mu(0) = 0$, $\mu(1) = 1$, and $\mu'(p) > 0$. If the bank p decides to lend to the firm, then at the end of the period there is an intermediation cost $(1-p)R$ per unit of corporate loan, so that bank p earns an effective gross return of pR from corporate loan.

To avoid any deadweight losses in the economy, household receives a lump-sum rebate χ, which is essentially equal to the intermediation cost. These intermediation costs may arise from the prospection, screening, and monitoring while originating or servicing the loan. The banks can also invest into an outside project with a constant gross return γ. For fixing the idea, we refer this outside option as the storage technology which is at least as good as just letting the good depreciate, i.e., $\gamma \geq 1 - \delta$.

Due to the heterogeneity of banks in terms of intermediation skill p, in each country there is an intraperiodic interbank market, where low p banks lend to the high p ones at gross rate ρ. In equilibrium, this interbank loan rate must be lower than the corporate loan rate R; otherwise all banks would find it optimal to lend in the interbank market at higher rate ρ than lending to the firms at lower corporate rate R. Similarly, the storage return γ must be lower than the interbank lending rate ρ; otherwise all banks would find it optimal to store and not participate in the interbank lending market. Banks p take the interbank lending rate ρ and the corporate lending rate R as given and decides whether, and how much to borrow or lend.

Let Φ be the borrowing per deposit by a borrowing bank p, where $\Phi \geq 0$ also denotes

the publicly observable and endogenous market funding ratio. If a bank p decides to borrow Φ (per unit of deposit) from other banks at cost ρ then gets a gross unit return on deposits equal to $pR(1+\Phi) - \rho\Phi$, and lends $1+\Phi$ (per unit of deposit) to the firm for gross return pR. If a bank decides to lend to other banks, instead, then the gross return on deposit is just ρ.

Gross return on deposits for bank p is then

$$r(p) \equiv \max\{pR(1+\Phi) - \rho\Phi, \ \ \rho\} \tag{5}$$

Bank p chooses to be a borrower when

$$pR(1+\Phi) - \rho\Phi \geq \rho \Leftrightarrow p \geq \bar{p} \equiv \frac{\rho}{R} \tag{6}$$

Inequality (6) imposes a participation constraint on bank p to be a borrower, not a lender in the interbank market. Banks with $p < \bar{p}$ are less efficient in intermediation and hence lend to the more efficient banks $p \geq \bar{p}$, and the marginal bank $\bar{p}$ is indifferent between the two options. In a frictionless world, $\bar{p} = 1$ since all banks with $p < 1$ would lend to the most efficient one with $p = 1$ in that case. The economies would have reached the first-best allocations then. There are two frictions prevalent on the interbank market which prevent the economies from reaching their first-best allocation: moral hazard and asymmetric information.

Before explaining the details and solutions of the moral hazard problem and asymmetric information in the interbank market we need to see the overall market flow in figure 2. Households do not know the skill level of banks p, while this skill level is unknown to other banks as well. Therefore asymmetric information rises. Banks with $p \geq \bar{p}$ borrows Φ per deposit from the interbank market, lends $(1+\Phi)$ per deposit to the firms, get $(1+\Phi)R$ from the firms in return, and finally returns $\rho\Phi$ to the lender. However, banks $p < \bar{p}$ may pretend to be high-skill bank and borrow from the interbank market and invest in an alternative storage technology at a return γ. This gives rise to the moral hazard in the interbank market.

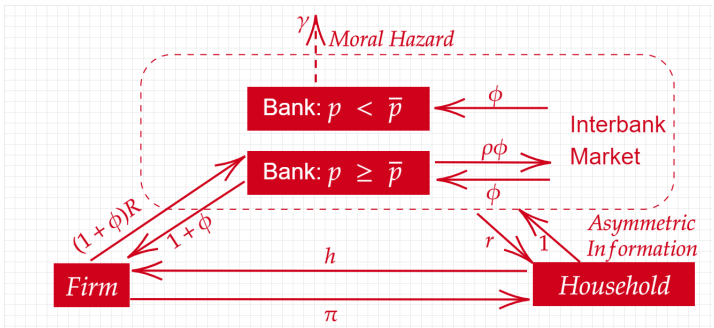

Figure 2: Market Flows

3.2 Moral Hazard

We assume that the creditors cannot trace the proceeds of the storage technology and therefore cannot seize those. As a consequence, borrowing banks may choose to renege on their interbank debt contracts and walk away from the lenders. So, interbank loan contracts are not enforceable. A bank p that walks away with $(1 + \Phi)a$ and invests in the storage technology, gets $\gamma(1 + \theta\Phi)a$ as payoff, where $\theta \in [0, 1]$ is the cost for walking away from the interbank market after borrowing (the higher θ, the more this cost). Such opportunistic behavior is referred as "diversion" (e.g., Hart, 1995; Burkart and Ellingsen, 2004).

Corporate finance literature (e.g., Tirole, 2006) refers the diversion as a standard moral hazard problem: (i) the higher Φ also increases the gain from diversion, and the diversion opportunity cost increases with (ii) bank efficiency p and (iii) the spread between the corporate lending rate R and the return on the storage technology γ. The last feature, which implies that as the corporate lending rate goes down, banks have an incentive to walk away from the interbank market, is consistent with recent empirical evidence of taking high risks by the banks during low interest rates. (see, e.g., Maddaloni and Peydró, 2011; Jiménez et al., 2014).

3.3 Asymmetric Information

The intermediation skill of the banks are private information; ex ante lenders cannot observe them and also cannot verify them ex post. Therefore, lenders ignore any private incentives of the borrowers to divert funds. This makes the interbank loan contracts the same for all banks, i.e., none of the market funding ratio (Φ), and the interbank lending rate (ρ) depends on p. However, the lenders want to deter the borrowers from diverting. This is done by limiting the quantity of funds to the borrowers so that the least efficient banks with $p < \bar{p}$ have no incentive to pretend as high efficiency bank and divert:

$$\gamma(1 + \theta\Phi) \leq \rho \tag{7}$$

This is the incentive compatibility constraint which, eventually, sets a limit for Φ, i.e., the market funding ratio above which no bank would like to lend. Hence, it can also be regarded as the lenders' funding tolerance. At the optimum, this incentive compatibility constraint binds and the borrowing banks utilizes the full borrowing capacity:

$$\Phi \equiv \frac{\rho - \gamma}{\gamma\theta}$$

The borrowing capacity (Φ) increases with the interbank lending rate (ρ). With a higher ρ, banks lend more, and only more efficient (high p) banks keep demanding a loan. Lenders have an incentive to tolerate a higher market funding ratio Φ since more efficient banks have lower incentive to divert. Therefore, there is a positive selection effect on the borrowers caused by an increase in the interbank rate. Symmetrically, there is a detrimental effect on incentives caused by a decrease in the interbank rate. In limit, when the interbank rate is equal to the return on storage ($\rho = \gamma$), the demand is null ($\Phi = 0$) since no borrowers can commit herself to repay.

V Equilibrium Analyses

The interbank market equilibrium largely depends on whether the country is a closed economy or integrated with other countries. We will first characterize the equilibrium of the banking sector in one country without any integration (see Boissay et al., 2016 for full explanations). Then, we will introduce different dimensions of integration between two countries and characterize the corresponding interbank market equilibrium.

1 Markets Without Integration

A. Interbank Market Clearing

In interbank markets equilibria of two countries without any integration, the interbank rate ρ clears the markets. We seek for an equilibrium where the return on storage is lower than the interbank rate ($\gamma < \rho$) so that the trade takes place ($\Phi > 0$). In a world of two countries without any integration, a mass $\mu(\bar{p})$ of banks lend and the complement mass $1 - \mu(\bar{p})$ of banks borrow Φ per unit of deposit. The market clearing condition thus becomes

$$\underbrace{A\mu\left(\frac{\rho}{R}\right)}_{\text{Supply}} = \underbrace{A\overbrace{\left[1-\mu\left(\frac{\rho}{R}\right)\right]}^{\text{Extensive Margin}}\overbrace{\frac{\rho-\gamma}{\theta\gamma}}^{\text{Intensive Margin}}}_{\text{Demand}} \tag{8}$$

$$\Leftrightarrow R = \Psi(\rho) \equiv \frac{\rho}{\mu^{-1}\left(\frac{\rho-\gamma}{\rho-\gamma(1-\theta)}\right)}$$

The interbank market clearing condition shows that as the interbank rate, ρ increases so does the aggregate supply, while there are two opposite forces in the aggregate demand. On the one hand, an increase in the interbank rate causes lower aggregate demand because fewer borrowers demand funds at higher rate; this is an extensive margin effect. On the other hand, a higher interbank rate increases the borrowing capacity and thus aggregate demand of funds; this is the intensive margin effect. At the aggregate level,

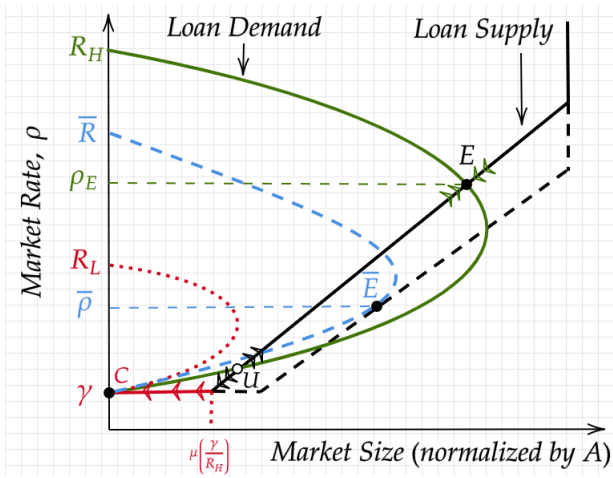

Figure 3: Interbank Market Clearing

when there are more borrowers, i.e., when ρ is small enough the later effect more than offsets the earlier effect. It follows that when the interbank rate ρ is small, the aggregate demand curve bends backward and increases with ρ. The function $\Psi(\rho)$ is strictly convex and there exists a threshold $\bar{R} \equiv \Psi(\bar{\rho})$ for the corporate loan rate R above which there are two equilibria with trade and below which there is no equilibrium with trade. In the later case, there exists a cutoff $\bar{p} = \gamma/R$ such that banks with $p < \bar{p}$ store, banks with $p > \bar{p}$ lend to the firm, and bank $\bar{p}$ is indifferent. We will refer to such no-trade equilibrium as a banking crisis. However, such equilibrium is Pareto-dominated by the trade equilibrium and therefore we rule out this equilibrium assuming that banks always coordinate in trade equilibrium. Figure 3 shows the overall situation.

B. Aggregate Corporate Loan Market Clearing

The aggregate supply of corporate loans depends on the existence of the interbank market operations. On the one hand, when interbank trades take place, the supply of corporate loans is A, i.e., all bank assets are channeled to the firms. On the other hand, when the interbank market is frozen, banks with $p < \gamma/R$ use the storage technology and the aggregate supply of corporate loans is $[1 - \mu(\gamma/R)]A$. The demand of aggregate corporate loan is determined through solving for capital, k from firm's profit maximization

problem. Thus, the aggregate corporate loan clearing condition is

$$f_k^{-1}\left(\frac{R+\delta-1}{z}\right) = \begin{cases} A & \text{for equilibrium with trade} \\ A\left[1-\mu\left(\frac{\gamma}{R}\right)\right] & \text{otherwise} \end{cases} \tag{9}$$

where $f_k(k) \equiv \partial F(k,1)/\partial k$.

C. Interbank Loan Market Freeze

The interbank loan market freezes if and only if

$$A > \overline{A} \equiv f_k^{-1}((\overline{R}+\delta-1)/z) \Leftrightarrow z < \overline{z} \equiv (\overline{R}+\delta-1)/f_k(A);$$

otherwise, the interbank loan market operates. $\overline{A}$ is the "absorption capacity" of the banks. This is the maximum quantity of assets that the banks can allocate efficiently. Above this threshold there is no trade in the interbank market because of the counterparty fears. This is equivalent to the TFP threshold $\overline{z}$, below which the interbank market freezes. Market freezes thus result either from the overaccumulation of assets by the household or from an adverse productivity shock that reduces banks' absorption capacity, or from a combination of both endogenous and exogenous factors. Figure 4 exhibits this situation.

2 Two firms Closed Economy Model

Let us continue to think in terms of a closed economy. There are two firms $i = 1, 2$ with identical technology and equal mass (0.5 each). Their productivity follows the same AR(1) process, but the shocks to productivity are independent draws. As far as the banking sector's deposit, loan, and interbank rates are concerned, they will continue to follow the relationships derived in previous sections. The wages, i.e., Marginal Productivity of Labor (MPL) across the two firms must be identical. The labor market equilibrium (with

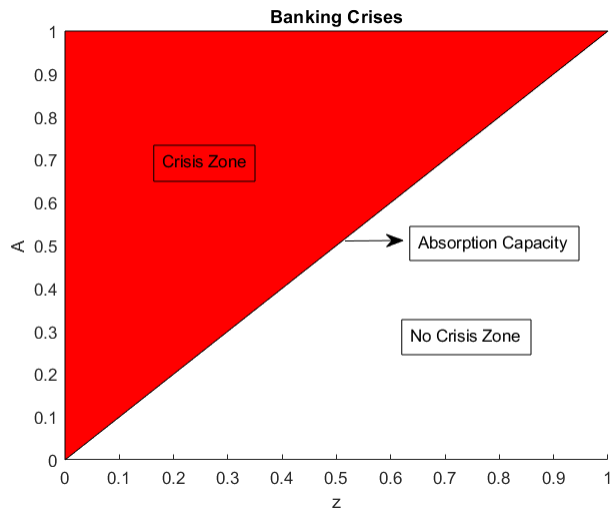

Figure 4: Banking Crises Zone

household supplying labor inelastically at 1) is as follows:

$$\begin{aligned} z_1 f_h(k_1, h_1) &= z_2 f_h(k_2, h_2) \\ 0.5(h_1 + h_2) &= 1 \end{aligned}$$

For Cobb-Douglas technology with α as the capital share, capital/labor ratio across the two firms will follow

$$\frac{k_1}{h_1} = \left(\frac{z_2}{z_1}\right)^{\frac{1}{\alpha}} \frac{k_2}{h_2} \tag{10}$$

Since both types rent capital at the same market rate, their Marginal Productivity of Capitals must be equal.

$$\frac{k_1}{h_1} = \left(\frac{z_1}{z_2}\right)^{\frac{1}{1-\alpha}} \frac{k_2}{h_2} \tag{11}$$

However, (10) and (11) can not hold simultaneously. Thus only the high productivity firm will produce. It will rent all the capital and hire all the labor available in the economy. The equilibrium is trivially the same as in Boissay et al. (2016), except that $\max\{z_1, z_2\}$ will be the economy's productivity.

3 A Two-country World with Perfect Integration

In a closed economy model the monitoring costs $(1-p)\,R$ are rebated back to the households to abstract from wealth effects of monitoring costs. In a two-country world, where a country's savings may end up for deposit and loans in another country, we will assume that these transfers go to the source of the savings. Suppose all capital markets and labor markets are integrated in a symmetric two-country world. The environment is then equivalent to a closed economy with two firms. Only one country will produce by renting the entire world's capital and hiring the total labor supply of the two countries. This case is obviously not interesting.

4 A Two-country World without Labor Mobility

In this section we assume that households can work only at the domestic firm. Under this restriction, firms in both countries will operate and produce. Under integration, deposits made by household, deposits taken by banks, and loans made by banks may differ. Let A_j continue to be the aggregate deposits made by households of country j, let D_j denote the deposits taken by a (ex-ante identical) bank of country j, and k_j denote the loan (that equals the capital stock) taken by the representative firm in country j.

We will alternatively consider environments in which cross-border deposits are (1) permitted or (2) prohibited. In each of these, we will in turn consider cases in which (i) cross-border interbank as well as corporate loans are permitted, (ii) only corporate loans are permitted and (iii) only interbank lending is permitted.

4.1 With Cross-border Deposit Mobility

In this subsection, we assume that the depositors and the banks in either country are free to make and take cross-border deposits.

a (i): With Open Interbank and Corporate Loan Markets

In this case, banks can lend to both banks and corporates of either country. From the perspective of depositors, all banks are then multinational and ex-ante identical. The total deposits of the two countries $A_1 + A_2$ will be equally deposited at all the banks, now with a mass of 2. Therefore the deposits taken by each bank will be

$$D_j = D = \frac{A_1 + A_2}{2} \tag{12}$$

Under interbank trade the interest rate ρ will be common across the two countries. Furthermore, the firms' borrowing rate R will also be common. Then, with inelastic labor supply fixed at unity, the two countries' capital ratios will follow from (11) as

$$k_1 = \left(\frac{z_1}{z_2}\right)^{\frac{1}{1-\alpha}} k_2 \tag{13}$$

The market clearing condition for the corporate loan market can be expressed as

$$\sum_j k_j = \sum_{j=1,2} f_{k_j}^{-1}\left(\frac{R+\delta-1}{z_j}\right) = \begin{cases} \sum_j A_j & \text{for trade equilibrium} \\ \left[1-\mu\left(\frac{\gamma}{R}\right)\right]\sum_j A_j & \text{otherwise} \end{cases} \tag{14}$$

where the first case holds if and only if $R > \overline{R} > \Psi(\bar{\rho})$.

When interbank trade exists, the total supply of interbank loans will equal the total demand:

$$2D\mu\left(\frac{\rho}{R}\right) = 2D\left[1-\mu\left(\frac{\rho}{R}\right)\right]\frac{\rho-\gamma}{\theta\gamma} \tag{15}$$

a (ii): With Open Corporate Loan Market Only

Let us continue to assume that household can deposit in either country's banks. While banks cannot make cross-border interbank loans, the firms can still borrow from banks across the border. Banks can still lend to other domestic banks and therefore the interbank loan market equilbrium must satisfy

$$D\mu\left(\frac{\rho_j}{R}\right) = D\left[1-\mu\left(\frac{\rho_j}{R}\right)\right]\frac{\rho_j-\gamma}{\theta\gamma}.$$

where we have incorporated the fact that with open corporate loan market, R is common across the two countries. The above in turn implies that ρ will also be common and so will be the per unit deposit rate. Once again, from the perspective of the depositors, banks in the two countries are fullly multinational. As in the previous case with complete banking sector integration, the deposits are

$$D_j = D = \frac{A_1 + A_2}{2}$$

The two countries' capital ratios will follow from (11) as

$$k_1 = \left(\frac{z_1}{z_2}\right)^{\frac{1}{1-\alpha}} k_2$$

The market clearing condition for the corporate loan market can be expressed as

$$\sum_j k_j = \sum_{j=1,2} f_{k_j}^{-1}\left(\frac{R+\delta-1}{z_j}\right) = \begin{cases} \sum_j A_j & \text{for trade equilibrium} \\ \left[1-\mu\left(\frac{\gamma}{R}\right)\right]\sum_j A_j & \text{otherwise} \end{cases}$$

where the first case holds if and only if $R > \overline{R} > \Psi(\bar{\rho})$.

a (iii): With Open Interbank Market Only

Let us continue to assume that household can deposit in either country's banks. While banks can make interbank loans internationally, the firms can only borrow from their own country's banks. The banks are no-longer multinationals – their opportunity sets now diverge. Hence, the deposits they attract are no-longer going to be identical. They will be determined by the equilibrium as described below.

First note that two arbitrage conditions must hold. First, deposit rates offered by banks must be equal across the two countries. Second, under interbank trade, no storage will occur in either country.

Lemma 1 *In an interbank trade equilibrium the corporate loan rates in both countries are equalized.*

Proof. Let $\Phi_j \geq 0$ be the publicly known interbank borrowing (per unit of deposit) in country j. Irrespective of Φ_j, the cutoff rule for the marginal lender/borrower bank is:

$$\bar{p}_j = \frac{\rho}{R_j}.$$

Since household can deposit in either country, all banks (in both countries) must offer the same deposit rate:

$$r = R_j \int_{\frac{\rho}{R_j}} p \frac{d\mu(p)}{1 - \mu(p)}$$

Hence, $R_j = R$ for both country j. This in turn requires that

$$k_1 = \left(\frac{z_1}{z_2}\right)^{\frac{1}{1-\alpha}} k_2$$

Since no storage occurs under interbank trade

$$k_1 + k_2 = A_1 + A_2$$

Finally, since the incentive compatibility constraint holds with equality, i.e., $\gamma(1 + \theta\Phi) = \rho$, in both countries the borrowing capacity, $\Phi = \frac{\rho-\gamma}{\gamma\theta}$ must be the same. Within each country the mass of banks lending in the interbank market, $\mu(\frac{\rho}{R})$, is the same. Also the borrowing per unit of deposits for the banks making corporate loans Φ is the same. This implies that

$$k_j = D_j$$

Banks in each country attract an amount of deposit that clears the domestic interbank lending as well as corporate loans. Hence, once the deposits are made, there is no need for cross-border interbank or corporate loans.

The banking sector equilibrium within each country follows the closed economy, which leads to the following proposition

Proposition 1 *Interbank trade exists in both countries if and only if*

$$\sum_{j=1,2} f_{k_j}^{-1}\left(\frac{\overline{R} + \delta - 1}{z_j}\right) \geq \sum_{j=1,2} A_j$$

The converse of this result is that a banking sector freeze must occur simultaneously across the two countries. However, the deposit rates will still be the same across the two countries. This is only possible if

$$r = R_j \left[\frac{\gamma}{R_j} \mu \left(\frac{\gamma}{R_j} \right) + \int_{\frac{\gamma}{R_j}} p \frac{d\mu(p)}{1 - \mu(p)} \right] \text{ for both country } j.$$

Once again $R_j = R$ for $j = 1, 2$ must hold and the capital used by firms must follow (13).

Corollary 1 *Under a banking sector freeze, the equilibrium capital allocations and corporate loan rate $\{k_1, k_2, R\}$ are given by*

$$\begin{aligned} \sum_j k_j &= \sum_{j=1,2} f_{k_j}^{-1} \left(\frac{R + \delta - 1}{z_j} \right) = \left[1 - \mu \left(\frac{\gamma}{R} \right) \right] \sum_j A_j; \\ k_1 &= \left(\frac{z_1}{z_2} \right)^{\frac{1}{1-\alpha}} k_2. \end{aligned}$$

Finally, in an interbank trade equilibrium, the equilibrium rate $\rho(R)$ continues to be determined by (15) with $2D$ on its both sides now trivially replaced by $\sum D_j$:

$$\left(\sum_{j=1,2} D_j \right) \mu \left(\frac{\rho}{R} \right) = \left(\sum_{j=1,2} D_j \right) \left[1 - \mu \left(\frac{\rho}{R} \right) \right] \frac{\rho - \gamma}{\theta \gamma} \tag{16}$$

4.2 Without Cross-border Deposit Mobility

Banks in each country now take only domestic deposits:

$$D_j = A_j. \tag{17}$$

However, their asset side has no cross-border restrictions. We now sequentially consider the three alternatives.

b (i): With Open Interbank and Corporate Loan Markets

The banking sector equilibrium in this case is fairly similar to that under case a(i) except for the size of the banks' balance sheets. Banks now have access to only domestic pool of deposits. The amount of loans therefore have to balance accordingly. With

common corporate loan rates in the two countries:

$$k_1 = \left(\frac{z_1}{z_2}\right)^{\frac{1}{1-\alpha}} k_2$$

must hold. However, unlike in case a(i) $k_j \neq D_j = A_j$ now. That is, firms in country j may be borrowing from the other country and vice versa. When interbank trade exists, a common $\rho = \Psi^{-1}(R)$ emerges from (16)

$$\left(\sum_{j=1,2} A_j\right) \mu\left(\frac{\rho}{R}\right) = \left(\sum_{j=1,2} A_j\right) \left[1 - \mu\left(\frac{\rho}{R}\right)\right] \frac{\rho - \gamma}{\theta\gamma}$$

Finally, the world-economy will jointly experience a credit crunch iff

$$\sum_{j=1,2} f_{k_j}^{-1}\left(\frac{\overline{R} + \delta - 1}{z_j}\right) < \sum_j A_j,$$

where $\overline{R} = \Psi(\bar{\rho})$. The corporate loan market clearing can be expressed as

$$\sum_j k_j = \sum_{j=1,2} f_{k_j}^{-1}\left(\frac{R + \delta - 1}{z_j}\right) = \begin{cases} \sum_j A_j & \text{for trade equilibrium} \\ \left[1 - \mu\left(\frac{\gamma}{R}\right)\right] \sum_j A_j & \text{otherwise} \end{cases}$$

where the first case holds if $R > \Psi(\bar{\rho})$.

b (ii): With Open Corporate Loan Market Only

Here, banks can make cross-border loans to firms and therefore R must be equal in the two countries. Banks can make within country interbank loans. Let ρ_j denote within country interbank rates. The interbank loan market equilibrium can now be expressed as

$$A_j \mu\left(\frac{\rho_j}{R}\right) = A_j \left[1 - \mu\left(\frac{\rho_j}{R}\right)\right] \frac{\rho_j - \gamma}{\theta\gamma}.$$

Obviously, $\Psi : \rho \to R$ is common for both countries.

Proposition 2 *With open corporate loan markets, within country interbank lending rates are equal.*

With common corporate loan rates in the two countries:

$$k_1 = \left(\frac{z_1}{z_2}\right)^{\frac{1}{1-\alpha}} k_2$$

must hold. However, as in b(i) $k_j \neq A_j$. As in b(i), the world-economy will jointly experience a credit crunch iff

$$\sum_{j=1,2} f_{k_j}^{-1}\left(\frac{\overline{R}+\delta-1}{z_j}\right) < \sum_j A_j,$$

where $\overline{R} = \Psi(\bar{\rho})$. The corporate loan market clearing can be expressed as

$$\sum_j k_j = \sum_{j=1,2} f_{k_j}^{-1}\left(\frac{R+\delta-1}{z_j}\right) = \begin{cases} \sum_j A_j & \text{for trade equilibrium} \\ \left[1-\mu\left(\frac{\gamma}{R}\right)\right]\sum_j A_j & \text{otherwise} \end{cases}$$

where the first case holds if $R > \Psi(\bar{\rho})$. In the second case, the amount stored in each country equals $\mu\left(\frac{\gamma}{R}\right) A_j$.

b (iii): With Open Interbank Market Only

Under interbank trade, once again, ρ will be common in both countries. However, corporate loan rates may no longer be equal. The interbank loan market equilibrium can now be expressed as

$$\underbrace{A_1\mu(\bar{p}_1)}_{\text{Domestic Supply}} + \underbrace{A_2\mu(\bar{p}_2)}_{\text{Foreign Supply}} = \underbrace{A_1[1-\mu(\bar{p}_1)]\Phi_1}_{\text{Domestic Demand}} + \underbrace{A_2[1-\mu(\bar{p}_2)]\Phi_2}_{\text{Foreign Demand}}$$

Using $\Phi_1 = \Phi_2 = \Phi = \frac{\rho-\gamma}{\gamma\theta}$, and $\bar{p}_j = \frac{\rho}{R_j}$, the market clearing condition becomes,

$$A_1\mu\left(\frac{\rho}{R_1}\right) + A_2\mu\left(\frac{\rho}{R_2}\right) = \left[A_1\left(1-\mu\left(\frac{\rho}{R_1}\right)\right) + A_2\left(1-\mu\left(\frac{\rho}{R_2}\right)\right)\right]\frac{\rho-\gamma}{\theta\gamma} \tag{18}$$

$$\Leftrightarrow \frac{A_1}{A_2} = -\frac{\mu_2(1+\Phi)-\Phi}{\mu_1(1+\Phi)-\Phi}$$

where, $\mu_j = \mu\left(\frac{\rho}{R_j}\right)$ for $j \in \{1,2\}$.

It is not possible to characterize the properties of R_1 and R_2 as a function of ρ. We need to characterize ρ as a function of R_1 and R_2. It further complicates the multiplicity problem by perhaps increasing its dimensionality. One may have to address this numerically. Suppose a solution exists such that $R_1, R_2 > \rho > \gamma$. In equilibrium

$$k_j = f_{k_j}^{-1}\left(\frac{R_j + \delta - 1}{z_j}\right), \text{ for } j = 1, 2, \tag{19}$$

and the market clearing for corporate loans requires supply of corporate loans, l_j be

$$l_j = A_j\left[1 - \mu\left(\frac{\rho}{R_j}\right)\right]\left(1 + \frac{\rho - \gamma}{\theta\gamma}\right), \text{ for } j = 1, 2. \tag{20}$$

Under a closed economy the aggregate supply of corporate loans in normal times would be the total deposit collected by the banks. However, equation (20) is a novel finding of the model where the aggregate corporate lending does not only depend on the savings of the households, i.e., A but on other factors- such as- corporate lending rate-R, interbank lending rate- ρ, and storage components- γ and θ as well.

There are now five unknowns in the model: $\{R_1, R_2, k_1, k_2, \rho\}$. If an equilibrium exists, they should sensibly solve the five equations: (18), (19), and (20).

If there is no solution to the above problem, then we are back in the crisis world. Both countries will be in autarky with their capital employment and the loan rates given by the two equations:

$$l_j = \left[1 - \mu\left(\frac{\gamma}{R_j}\right)\right] A_j = f_{k_j}^{-1}\left(\frac{R_j + \delta - 1}{z_j}\right), \text{ for } j = 1, 2$$

while the amount stored in each country equals $\mu\left(\frac{\gamma}{R_j}\right) A_j$.

Banking sector's return on deposit: The return on deposits depends on three factors: corporate loan revenue, interbank lending revenue, and the borrowing cost. These factors are as follows for country $j = 1, 2$:

Corporate loan revenue: $\int_{\bar{p}_j}^{1} p\left[R_j\left(1 + \Phi\right)\right] d\mu(p)$
Interbank loan revenue: $\int_{0}^{\bar{p}_j} p\rho d\mu(p)$

Interbank borrowing cost: $\int_{\bar{p}_j}^{1} p\rho\Phi d\mu(p)$

The banking sector's return on deposit would be:

$$r_j \equiv \int_0^1 r_j(p) d\mu(p)$$

$$= \begin{cases} R_j \left[\int_{\bar{p}_j}^{1} p(1+\Phi) d\mu(p)\right] + \int_0^{\bar{p}_j} p\rho d\mu(p) - \int_{\bar{p}_j}^{1} p\rho\Phi d\mu(p) & \text{for equilibrium with trade} \\ R_j \left[\int_{\gamma/R_j}^{1} p d\mu(p)\right] + \gamma\mu\left(\frac{\gamma}{R_j}\right) & \text{otherwise} \end{cases}$$

Rearranging this, we have

$$r_j = \begin{cases} \int_0^{\bar{p}_j} p\rho d\mu(p) + \int_{\bar{p}_j}^{1} p\left[R_j + \Phi(R_j - \rho)\right] d\mu(p) & \text{for equilibrium with trade} \\ R_j \left[\int_{\gamma/R_j}^{1} p d\mu(p)\right] + \gamma\mu\left(\frac{\gamma}{R_j}\right) & \text{otherwise} \end{cases} \tag{21}$$

where under the equilibrium trade, the first term represents the interbank lending revenue of a $\mu(\bar{p}_j)$ mass of banks those are lenders and the second term denotes the corporate loan revenue plus profit from market funded capital for a $1 - \mu(\bar{p}_j)$ mass of banks those are borrowers. In contrast, when there is no equilibrium exists with trade, there is no banking intermediation, and a mass $\mu(\gamma/R_j)$ of banks find it optimal to use the storage technology.

5 General Equilibrium

Before we proceed to the quantitative analysis, a general equilibrium of the world economy in which two countries connected only with open interbank market is defined as follows. The state variables for a particular individual's optimization problem in country j are (i) the individual asset holdings a_j, (ii) the aggregate asset holdings $\{A_1, A_2\}$, and (iii) the realization of the technology shocks $\{z_1, z_2\}$. Let $s = \{A_1, A_2, z_1, z_2\}$. In the sequel, we denote by $\Gamma_j(s)$ the perceived law of motion of aggregate assets in the country j and by $R_j(s), r_j(s)$, and $\rho(s)$ and $w_j(s)$ the pricing functions for corporate loans, deposits,

interbank loans and labor, respectively; we also denote by $\pi_j(s)$ and $\chi_j(s)$ the profit and rebate functions. All these functions are function of aggregate assets $\{A_1, A_2\}$ and productivity $\{z_1, z_2\}$, which are both taken as given by the household and capture the presence of externalities. The household j's recursive optimization problem written as

$$V(a, s) = \max_{a',c,n} u(c - \nu(n)) + \beta \mathbb{E}_t V(a', s') \tag{22}$$

subject to

$$a' + c = r(s)a + w(s)n + \pi(s) + \chi(s)$$
$$A' = \Gamma(s)$$

where, in the calibrated version of the model, $u(x) = x^{1-\sigma}/(1-\sigma)$ and $\nu(n) = n^{1+\nu}/(1+\nu)$. The solution to this problem is a set of decision rules $a(a_j, s), n(a_j, s)$, and $c(a_j, s)$.

The firm's problem in country j is simply given by

$$\max_{k,h} zF(k, h) + (1-\delta)k - w(s)h - R(s)k,$$

which leads to the decision rules $k(s)$ and $h(s)$. Finally, the solution of banks' problem in country j leads to the aggregate loans $l(s)$ and $\phi(s) = (\rho(s) - \gamma)/\gamma\theta$, where only aggregate assets enter the solution due to the linearity of the problem. In the recursive rational expectation equilibrium, actual and perceived law of motions coincide in each country j, respectively.

5.1 *Definition (Recursive competitive general equilibrium)*

A recursive competitive equilibrium of the world economy, given the aggregate state $s = \{A_1, A_2, z_1, z_2\}$, is a sequence of prices defined by the pricing functions $R(s), r(s), \rho(s)$, and $w(s)$, two perceived law of motions for aggregate assets $\Gamma_1(s)$ and $\Gamma_2(s)$, and a set of decision rules for each country $j = 1, 2$ of $\{c(a_j, s), a'(a_j, s), k(a_j, s), h(a_j, s), \phi(a_j, s), l(a_j, s)\}$ with the value function $V(a_j, s)$ such that,

1. $\{c(a_j, s), a'(a_j, s), n(a_j, s)\}$ *and* $V(a_j, s)$ *solve the household j's recursive optimization problem taking* $R_j(s), r_j(s), w_j(s), \pi_j(s), \chi_j(s)$ *and* $\Gamma_j(s)$ *as given.*

2. $k_j(s)$ *and* $h_j(s)$ *solve the firm j's optimization problem taking* $R_j(s), w_j(s)$ *as given.*

3. $\phi_j(s)$ *solves the banks' optimization problem taking* $R_j(s), r_j(s)$, *and* $\rho(s)$ *as given. Aggregate loans in each country j are, respectively*

$$l_j(s) = \begin{cases} A_j \left[1 - \mu\left(\frac{\rho}{R_j(s)}\right)\right]\left(1 + \frac{\rho-\gamma}{\theta\gamma}\right), & \text{if } A \leq \bar{A}(z_1, z_2) \\ \left[1 - \mu\left(\frac{\gamma}{R_j(s)}\right)\right] A_j, & \text{otherwise} \end{cases}$$

4. *The perceived law of motion for aggregate assets is consistent with the actual law of motions:* $a'_j(a, s) = \Gamma_j(s)$.

5. *Wages satisfy* $w_j(s) = z_j F_h(k_j(s), h_j(s))$, *and the corporate loan rate satisfies* $R_j = z_j F_k(k_j(s), h_j(s)) + 1 - \delta$, *the deposit rate satisfies*

$$r_j(s) = \begin{cases} \int_0^{\bar{p}_j(s)} p\rho d\mu(p) + \int_{\bar{p}_j(s)}^1 p\left[R_j(s) + \Phi(R_j(s) - \rho)\right] d\mu(p) & \text{if } A \leq \bar{A}(z_1, z_2) \\ R_j(s)\left[\int_{\gamma/R_j(s)}^1 p d\mu(p)\right] + \gamma\mu\left(\frac{\gamma}{R_j(s)}\right) & \text{otherwise} \end{cases}$$

where $\bar{p}_j(s) = \rho(s)/R_j(s)$

6. *The aggregate intermediation cost rebated to the household is given by* $\chi_j(s) = (R_j(s) - r_j(s))A_j - (R_j(s) - \gamma)(A_j - k_j(s))$, *and the firm j's profits are equal to zero,* $\pi_j(s) = 0$.

7. *Goods, labor, capital, and interbank market clear:*

$$c_j(A_j, s) + a'_j(A_j, s) = z_j F(k_j(s), h_j(s)) + (\gamma + \delta - 1)(A_j - k_j(s)) + (1 - \delta)A_j$$

$$h_j(s) = n_j(A_j, s)$$

$$k_j(s) = l_j(s)$$

$$A_1\mu\left(\frac{\rho(s)}{R_1(s)}\right) + A_2\mu\left(\frac{\rho(s)}{R_2(s)}\right) = \left[A_1\left(1 - \mu\left(\frac{\rho(s)}{R_1(s)}\right)\right) + A_2\left(1 - \mu\left(\frac{\rho(s)}{R_2(s)}\right)\right)\right]\frac{\rho(s) - \gamma}{\theta\gamma}$$

8. *The banking sector's absorption capacity is given by*

$$\bar{A}(z_1, z_2) = \left(\frac{1-\alpha}{\vartheta}\right)^{\frac{1}{\nu}} \left(\frac{\alpha}{\bar{R}+\delta-1}\right)^{\frac{\nu+\alpha}{\nu(1-\alpha)}} \sum_{j=1,2} z_j^{\frac{1+\nu}{\nu(1-\alpha)}}$$

VI Quantitative Analysis

In this section, we investigate the quantitative properties of the interbank market equilibrium of the model in two parts. First, we set the functional forms and the parameters to calibrate the interbank market equilibrium. Second, we investigate the results on the equilibrium for different possible states. Following Boissay et al. (2016), we investigate the quantitative properties of the general equilibrium model using the calibrated values of the parameters from Table 1.

1 Calibration

The technology of the representative firm production is represented by a constant returns to scale production function of the form $z_j F(k_j, h_j) \equiv z_j k_j^{\alpha} h_j^{1-\alpha}$ with $\alpha \in (0, 1)$ for $j = 1, 2$. The capital elasticity α is set to 0.3 in the production function, and we assume that the capital depreciation rate is 10 percent per annum ($\delta = 0.1$). We also assume the persistence of the productivity shock $\rho_z = 0.89$ and standard deviation of productivity shock $\sigma_z = 0.013$ or 1.3 percent following Boissay et al. (2016). For the Foreign country, we use the AR(1) estimates that are consistent with those of the peripheral European countries so that $\sigma_{zf} = 3$ percent. We solve the model numerically using the collocation method, with decision rules iterations as in Boissay et al. (2016), allowing for discontinuities in the asset accumulation at the points at which the economy switches regime.

The banking sector parameters include the distribution of banks $\mu(\cdot)$, the diversion technology parameter, θ, and the return on storage γ. We assume that $\mu(p) = p^{\lambda}$ with

Table 1: Calibration Parameters

Parameters	Variable	Value
Discount factor (Deflated for growth)	β	0.971
Inverse of Frisch elasticity	ν	0.500
Labor disutility	ϑ	0.945
Risk aversion	σ	2.000
Capital elasticity	α	0.300
Capital depreciation rate	δ	0.100
Std. of productivity shock in Home Country	σ_{zh}	0.013
Std. of productivity shock in Foreign Country	σ_{zf}	0.030
Persistence of productivity shock	ρ_z	0.890
Bank distribution; $\mu(p) = p^\lambda$	λ	26.00
Diversion cost	θ	0.085
Storage technology	γ	0.952

$\lambda \in \mathbb{R}^+$. The other banking parameters are calibrated jointly so that a financial recession occurs rarely (on average every 42 years as in fact 1) and satisfying other targets as in Boissay et al. (2016). Table 1 has the calibration parameters for the interbank market equilibrium.

2 Results

To solve for the five unknowns $(R_1, R_2, k_1, k_2, \rho)$, we need to work with five equations: (18), (19), and (20). The first equation is interbank equilibrium:

$$A_1\mu\left(\frac{\rho}{R_1}\right) + A_2\mu\left(\frac{\rho}{R_2}\right) = \left[A_1\left(1-\mu\left(\frac{\rho}{R_1}\right)\right) + A_2\left(1-\mu\left(\frac{\rho}{R_2}\right)\right)\right]\frac{\rho-\gamma}{\theta\gamma}$$

Replacing $\mu(p) = p^\lambda$, we get

$$A_1\left(\frac{\rho}{R_1}\right)^\lambda + A_2\left(\frac{\rho}{R_2}\right)^\lambda = \left[A_1\left(1-\left(\frac{\rho}{R_1}\right)^\lambda\right) + A_2\left(1-\left(\frac{\rho}{R_2}\right)^\lambda\right)\right]\frac{\rho-\gamma}{\theta\gamma} \tag{23}$$

The second and third equations are capital allocations:

$$k_j = f_{k_j}^{-1}\left(\frac{R_j+\delta-1}{z_j}\right), \text{ for } j = 1, 2$$

Replacing the production function $F(k,1) = k^{\alpha}$ we get

$$k_j = \left(\frac{R_j + \delta - 1}{\alpha z_j}\right)^{1/(\alpha-1)}, \text{ for } j = 1, 2 \tag{24}$$

The fourth and fifth equations are supply of corporate loans:

$$k_j = A_j \left[1 - \mu\left(\frac{\rho}{R_j}\right)\right]\left(1 + \frac{\rho - \gamma}{\theta\gamma}\right), \text{ for } j = 1, 2$$

Replacing values of k_j from (24) and $\mu(p) = (p)^{\lambda}$ we get

$$\left(\frac{R_j + \delta - 1}{\alpha z_j}\right)^{1/(\alpha-1)} = A_j \left[1 - \left(\frac{\rho}{R_j}\right)^{\lambda}\right]\left(1 + \frac{\rho - \gamma}{\theta\gamma}\right), \text{ for } j = 1, 2. \tag{25}$$

Now, we have three unknowns: R_1, R_2, and ρ, in three nonlinear equations (23) and (25).

In case of interbank market freeze, interbank rate ρ is equal to the storage return γ and the corporate loan rates R_j comes from

$$\left[\frac{R_j + \delta - 1}{\alpha z_j}\right]^{1/(\alpha-1)} = \left[1 - \left(\frac{\gamma}{R_j}\right)^{\lambda}\right] A_j, \quad \text{for } j = 1, 2 \tag{26}$$

Since under financial integration (open interbank only with no deposit mobility) the state space includes A_1, A_2, z_1, and z_2, we can fix asset holdings and productivity of country 1 to see what happens to the solution at one point at a time. By fixing these at an average value we get similar results like Boissay et al. (2016), i.e., given asset accumulation A, if the productivity z goes down below a threshold then the country gets into banking crisis. The country also gets into crisis if for a given productivity level z, a country saves beyond a threshold level. These results are visible from figure 5.

In figure 5, the red crosses are the crisis zones, i.e., either productivity is very low given the asset level or/and asset accumulation is very high given a below average productivity level. Here, we assume that the asset level and productivity level of country 1 are at an average level.

Figure 6 exhibits the interbank market equilibrium given fixed asset holding and productivity for country 1, and fixed asset holding but varying productivity level of country

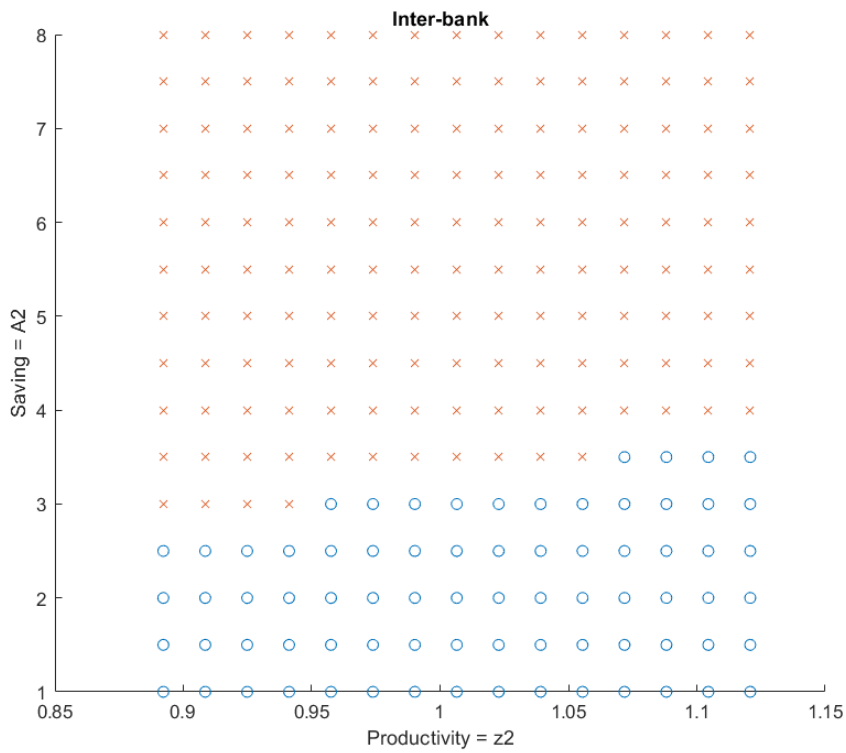

Figure 5: Crisis and No Crisis Zone

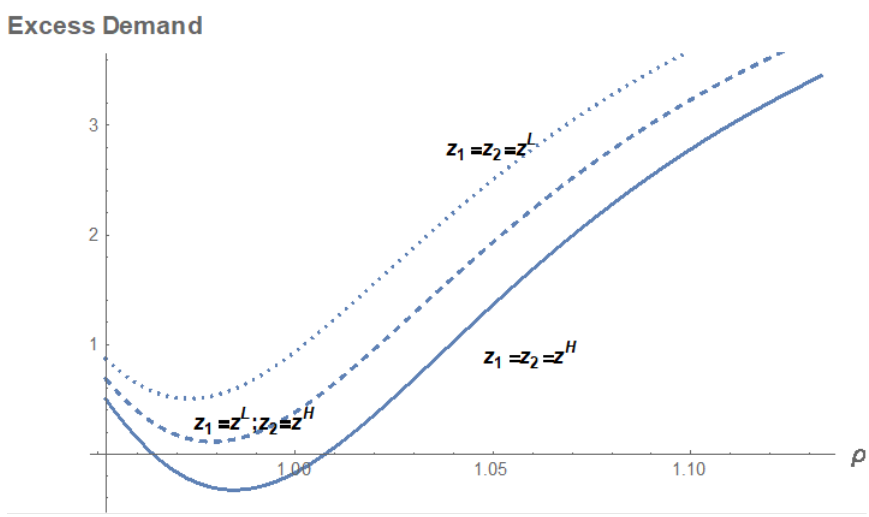

Figure 6: Interbank Market Equilibrium with varying productivity

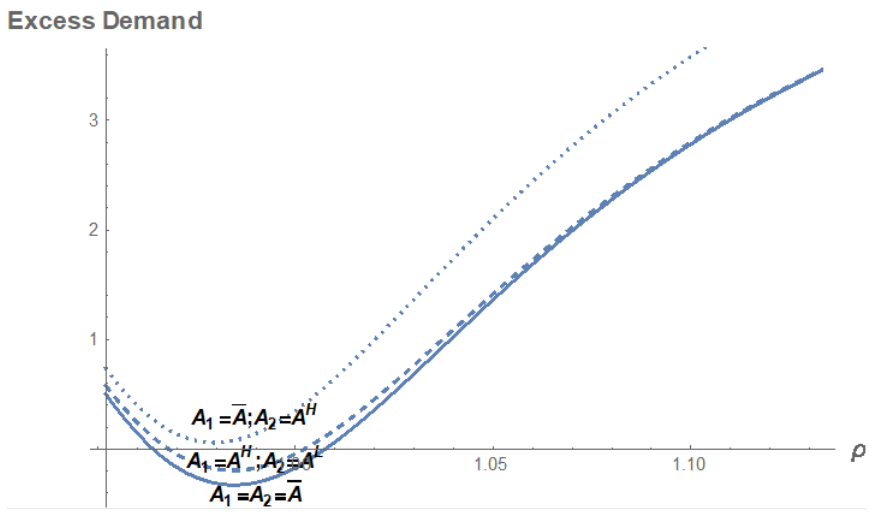

Figure 7: Interbank Market Equilibrium with varying saving

2. We have fixed the asset holding of both countries at an average level but varied the productivity level to identify in which cases we have an interbank market operation and in which cases there are market freezes. The dotted line is for low productivity in both countries where we observe no interbank market operation. This result is intuitive because low productivity in both countries implies low requirement of capital while saving is relatively high. A higher supply with lower demand for corporate loans causes a reduction in the corporate loan rate such that no interbank lending occurs. The solid line is for high productivity in both countries where there is interbank market operation. However, we have multiple equilibria for such high productivity in both countries. The dashed line is for low productivity in country 1 but high in country 2 and we observe market freeze in this case. This is the most interesting and a key finding of this paper. With sustainable saving and high productivity, country 2 could have an interbank trade equilibrium without any integration with country 1. However, since it has decided to "sail together", now it must also "sink together" under no interbank trade equilibrium in the integrated world.

Figure 7 shows the interbank market equilibrium with fixed average productivity for both countries but varying saving level. The solid line is for average saving level of both

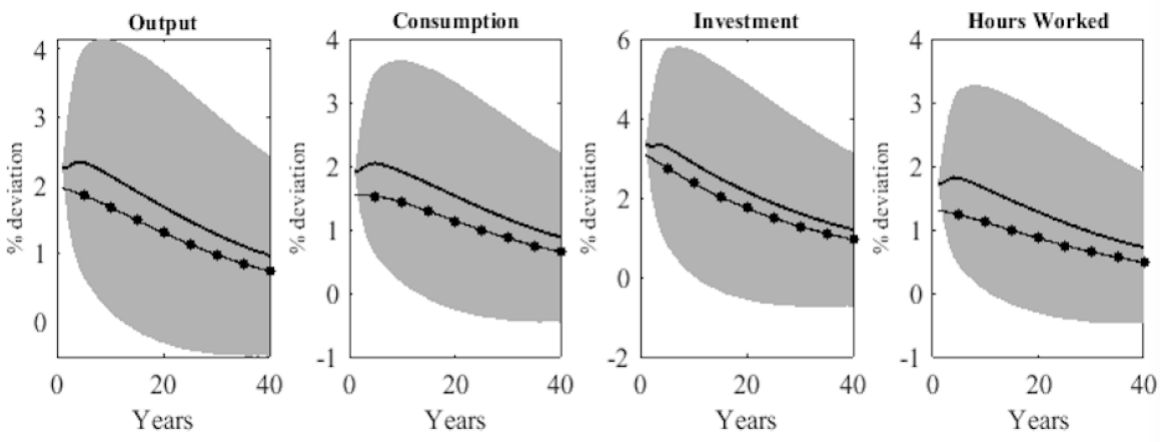

Figure 8: Impulse response to a one standard deviation technology shock

countries where there is multiple equilibria with interbank trade. The dashed line has high saving for country 1 but low saving for country 2. We have multiple trade equilibria in this case as well. However, the difference is in this time country 1 can survive even with high level of saving because it decided to "sail together" with country 2 and their extreme end saving levels average outed. This is the positive outcome of integration which was the motive for integration. However, in the dotted line country 1 has an average asset holding while country 2 has high level of saving and there is no trade equilibrium. Country 1 could have an interbank trade equilibrium without any integration with country 2 but because they integrated they have to experience a "sink together" situation and an interbank market freeze. This is the negative outcome of the integration.

We assume the economy is at the steady state with the long-run average of z to analyze the home country response. Figure 8 compares the dynamics in the model (thick plain line) with those in a frictionless model (round markers). It is evident from the figure that output, consumption, investment, and hours worked are comparatively larger than those in Boissay et al. (2016). Therefore, a two-country model responds more than the closed-economy model or the frictionless RBC model due to a larger interbank market integrating banking sectors of two countries together.

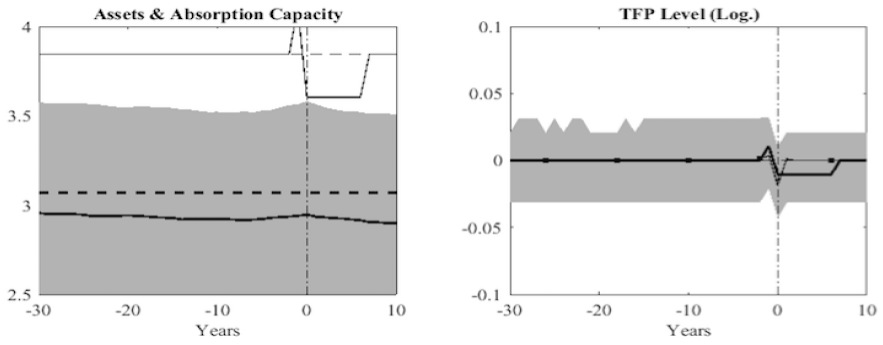

Figure 9: Typical path to financial recessions in the Home country

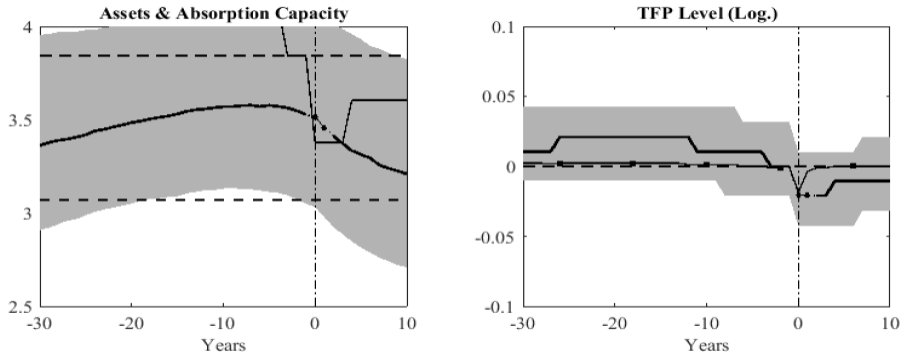

Figure 10: Typical path to financial recessions in the Foreign country

Figure 9 and 10 shows the typical path to financial recessions of the Home country and Foreign country, respectively. These are depicted from the simulation of the model over 50,000 periods with the years of recessions and crises identified. By convention, period 0 corresponds to the period when the financial recession (or the crises) bursts. Note that in the simulation, only the Foreign country is hit by the shock so that its banks' absorption capacity (thick plain line) as well as the endogenous dynamics of banks' assets (thin plain line) cross out with each other around the crises, while those in Home country are relatively stable.

Since two countries share the interbank market, the Home country experiences financial recessions due to the contagion effect. Figure 11 shows the dynamics of the output

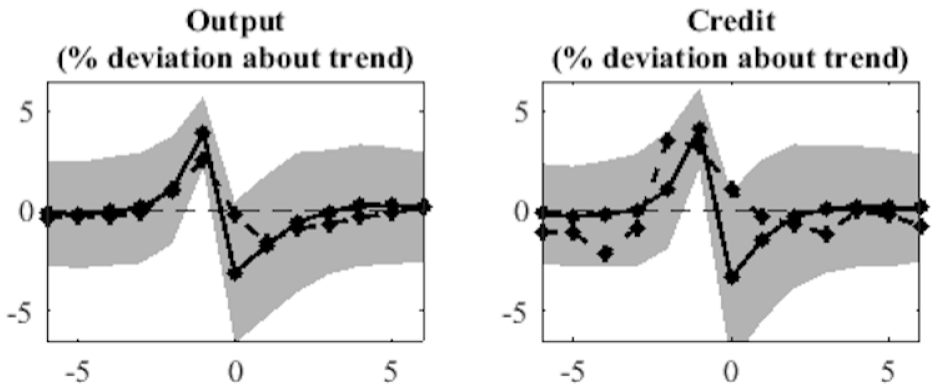

Figure 11: Dynamics of output and credit gaps around recessions in Home country

and credit gaps around recessions in the Home country.

Compared to that in the closed economy, we see that the relative size and duration of financial recessions from simulations both increase in the world economy. Thus, they confirm that the model generates deeper and longer financial recessions than other recessions, which are associated with a boom-bust cycle in the credit. However, our two-country model generates financial recessions with a frequency of 1.29 percent, nearly 50 percent lower than that in a closed economy (See Boissay et al., 2016, page 519). In other words, the very nature of a shared interbank market makes the economy less susceptible to negative productivity shocks, but the resulted crisis are more pronounced if they occur. The intuition is that, an internationally integrated interbank market endowed with a relatively larger "absorbing capacity" acts as a shield against negative shocks and fluctuations, which makes crisis less frequent. Rationally anticipating this, borrowers have more incentive to leverage and the gain from diversion increases as well. The interbank moral hazard issue potentially becomes more severe and implies larger macroeconomic contractions once induced by a crisis.

VII Concluding Remarks

In this paper, we offered a two-country model where the countries are symmetric. Banks become heterogeneous by their private intermediation efficiency. This heterogeneity gives rise to an interbank market. However, due to the moral hazard problem along with private intermediation skills, less efficient banks may have an incentive to borrow in the interbank market and divert funds at a lower return asset. A borrowing capacity constraint restricts these less efficient banks from diverting the funds. However, a lower corporate lending rate and interbank rate increases the incentive of these banks to divert funds and the interbank market responds by lowering the borrowing capacity. At some point, the interbank market goes to a freeze if the rates of return are sufficiently low.

A sequence of favorable productivity shocks lead to an expansion of credit. However, when the productivity growth goes down from an increasing trend, corporate lending rate goes down along with the demand. Counterparty risk goes up and the market stops lending to each other. When two countries are integrated through interbank lending, a market freeze in one country leads to a freeze in another country as well. Either two countries have an operating interbank market or both goes into a freeze. Excessive credit creation by one country triggers a two-country wide credit freeze. The countries may also go into a freeze from very low productivity in either of the countries.

In this paper, we made some strong assumptions for tractability reason and presented a stylized model. Indeed, we left out some features of the banking sector that would deserve attention for future extensions. For example, we assume that households cannot lend the firms directly and firms cannot issue any equity or debt securities. Moreover, we assume that firms do not default on loans. Another possibility would be time or/and country varying return on storage technology. All these extensions are left for future research.

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