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THE BROADENING OF ACTIVITIES IN THE FINANCIAL SYSTEM: IMPLICATIONS FOR FINANCIAL STABILITY AND REGULATION

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The Broadening of Activities in the Financial System: Implications for Financial Stability and Regulation*

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Abstract

Conglomeration and consolidation in the financial system broaden the activities financial institutions are undertaking and cause them to become more homogenous. Although resulting diversification gains make each institution appear less risky, we argue that financial stability may not improve as total risk in the financial system remains the same. Stability may even fall as institutions' incentives for providing liquidity and limiting their risk taking worsen. Optimal regulation may thus not provide a relief for diversification.

However, we also identify important benefits of a broadening of activities. By reducing the differences among institutions, it lowers the need for inter-institutional risk sharing. This mitigates the impact of any imperfections such risk sharing may be subject to. The reduced importance of such risk sharing, moreover, lowers externalities across institutions. As a result, institutions' incentives are improved and there is less need for regulating them.

Keywords: conglomeration, financial consolidation, homogenization, stability
JEL Classification: G21, G28

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1 Introduction

The ongoing transformation of the financial sector has made financial institutions more similar. For one, mergers and acquisitions have led to consolidation. This has changed institutions that were previously focused on a specific region or industry into global institutions that face like risks. Deregulation has allowed institutions to extend beyond their traditional boundaries and combine banking, investment and insurance activities in one organization. These conglomerates carry out a wide range of activities, rather than being specialized into a single line of business. Moreover, financial innovation in the form of securitization has made it possible to transfer a variety of risks in the financial system. As a result, financial institutions could reduce their risk concentrations, lowering the idiosyncracies in their portfolios. Evidence from the banking industry suggests that these effects may have indeed been large: the correlation of the share prices of large U.S. banks has risen from 28% to 54% between 1995 and 2000 alone (Group of Ten, 2001).

An increasing homogeneity of financial institutions should be welcomed in that it may reflect underlying diversification of risks.[1] The implications of this development, however, are likely to go beyond pure diversification effects as also the interactions among financial institutions are changed. For example, while in the past an insurance company could rely on banks to provide liquidity when the insurance sector faced difficulties, following conglomeration banks may become unable to lend as they are now also exposed to insurance risk. Risk sharing among institutions may hence be affected. Moreover, there are likely to be effects that arise because institutions respond to a homogenization by adjusting their portfolios. This may be because they anticipate the consequences of increased similarities, or because the resulting diversification makes them feel safer.

From the viewpoint of financial regulation, the trend towards homogenization raises the question of whether this is a process that should be encouraged or not. Given the importance of capital requirements in controlling risks in particular at banks, there is also the issue of how this instrument is to be used in a financial system characterized by ongoing homogenization. Should regulators treat institutions more leniently when they become diversified, and are, therefore, likely to be more similar to each other? The current regulatory stance towards diversification is mixed. While the new Basel accord allows for a diversification relief for some risks (operational risks) it does not for others (credit risks). This has been criticized by some observers on the grounds that portfolio theory suggests that diversification stabilizes institutions and should thus be fully honored. In particular

[1] While conglomeration leads to functional diversification, consolidation through mergers and acquisitions fosters in particular geographical diversification. Most obviously, securitization facilitates diversification by allowing financial institutions to transfer risks.

financial institutions are advocating a diversification relief for all risks (e.g., FleetBoston Financial, 2003).

This paper aims at understanding some of the questions that emerge from the homogenization of financial institutions, and the challenges it poses for financial regulation. We present a model where financial crises are triggered by aggregate shortages of liquidity.[2] In such a shortage, not all projects financed by institutions (banks) can be continued. Moreover, also the existing liquidity cannot be allocated efficiently anymore due to an imperfection in the interbank market. Risk sharing among institutions is thus incomplete. As a result, some projects cannot be continued at their originating institutions, even though aggregate liquidity would in principal allow for this. Such projects may then be bought up by institutions with a liquidity surplus. However, this causes an efficiency loss because originating institutions are best users of their projects (for example, due to the knowledge they have acquired in the course of financing the project). Financial institutions therefore underinvest in liquidity since due to the efficiency loss they cannot recoup the full value of projects bought in a crisis.

We view the process of homogenization as arising from institutions expanding into activities undertaken by other institutions in the financial system. For example, this may refer to a bank increasing its share of insurance business. Or, to an European bank acquiring an American bank.[3] Consistent with portfolio theory, the resulting diversification effect lowers the risks at each individual institution. However, from a system-wide point of view, homogenization only leads to a reallocation of risks. In particular, it does not affect the consolidated balance sheet of the financial system. Therefore, crises do not become less likely.

Even though homogenization thus has no direct stabilizing effect, it nevertheless brings about benefits. Since it reduces the differences among institutions, the liquidity holdings of institutions become more similar. Thus, there is less need to redistribute liquidity in a crisis, and institutions suffer less from imperfections in the interbank market. As a result, there are fewer inefficient discontinuations of projects.

However, the reduced occurrence of project discontinuations also has a downside. It increases institutions' risk-taking incentives and reduces their supply of liquidity to the market. In an unregulated economy, or in an economy where capital requirements are

[2] In contrast to the traditional literature, we do not emphasize bank runs as the source of fragility. This is consistent with the fact that bank runs have become a rare event in developed countries. In particular, none of the Group of Ten countries has experienced a systemic bank run since World War II.

[3] Homogeneity in this paper refers to institutions' activities becoming more similar. Alternatively, there may also be homogeneity in 'behavior', arising due to institutions adopting common risk management techniques or due to uniform regulation (e.g., Persaud, 2000).

not binding, institutions thus respond by increasing the riskiness of their portfolios. As there is no stabilizing effect of homogenization, the probability of a crisis thus rises. The overall welfare implications of homogenization are ambiguous, as the externalities from the reduced supply of liquidity may outweigh the benefits from fewer inefficient project discontinuations.

Because of the underinvestment in liquidity, there is a role for regulation in improving welfare. In fact, appropriate capital requirements, by acting as a charge on risk taking, can correct institutions' incentives.[4] As homogenization does not improve stability, such capital requirements should not be eased when an institution becomes more diversified.[5] When capital requirements can be implemented without causing frictions, this can completely eliminate the undesirable reoptimizing at institutions following a broadening of their activities. Thus, there is a rationale for regulators' reluctance to allow for a full diversification discount, even though it may seem implausible considering portfolio theory.

However, regulators should reduce capital charges when the overall degree of homogenization in the financial system increases. The reason is as follows. In a more homogenous financial system, it is less likely that an institution will be able to borrow from others in a crisis, as these will be in difficulties as well. If institutions were myopic, they may fail to realize this, and conclude that they have become safer due to homogenization, since the latter reduces the riskiness of each institution's balance sheet. By contrast, rational institutions should anticipate that the scope for insurance through the interbank market has diminished. Therefore, they rely less on the interbank lending, which has the effect of reducing the liquidity externality that operates through the interbank market. As a result, institutions' incentives improve and there is less need for the regulator to correct them.[6]

This argument is probably best understood when put to its extreme. Suppose the financial system is fully homogenized. Institutions are then completely identical. They should thus anticipate that there is no possibility for interbank risk sharing and the interactions among them thus disappear. As a result, there are no externalities anymore and institutions will choose a socially efficient amount of liquidity.

The paper proceeds as follows. The remainder of this section reviews the related lit-

[4]There is no need to use capital requirements to encourage insitutions to diversify since institutions already privately benefit from diversification.

[5]One may think that this result arises because there is no contagion here, and thus there are no positive externalities from reduced risk at an individual institution. However, it has been shown that contagion may in fact be worsened through diversification as the resulting increase in similarities makes spillovers among institutions more severe (Wagner, 2006).

[6]This improvement in banks' incentives may bring about various benefits when capital requirements cannot fully correct institutions' incentives, for example because the regulator cannot perfectly observe institution's risks.

erature. The next section describes the model. In Section 3 we analyze the impact of a broadening of activities for when capital requirements are not binding. Section 4 studies the consequences of homogenization for financial regulation and the following section discusses the results. The final section concludes.

1.1 Related Literature

There has been considerable interest in recent years in the wider implications of financial institutions expanding their activities and reallocating risks in the financial system. Many contributions have focused on risk shifting among institutions of different types. For example, Allen and Gale (2005) show that a transfer of risks from the banking into the insurance sector can add to systemic risk when regulation is ill-designed. In Allen and Carletti (2006) risk transfer among sectors creates contagion by subjecting the banking system to the systemic risk of the insurance sector. In Wagner and Marsh (forthcoming), risk transfer has stability effects when it takes place among institutions that differ with respect to their fragilities.

Other papers have focused on the desirability of conglomeration, emphasizing that it creates opportunities for risk-shifting within the conglomerate. For example, in Freixas, Loranth and Morrison (2006) conglomeration poses a trade-off. On one hand, it generates diversification gains. However, on the other hand, the protection that the banking arm of the conglomerate enjoys due to deposit insurance creates an incentive to shift risk out of the insurance into the banking part. Some authors have, moreover, argued that an expansion of activities at a financial institution often goes along with an increase in its size. This may change the institution's risk-taking incentives through an implicit 'too-big-too-fail' insurance (e.g., Hughes, Mester and Moon (2001)).

It has also been shown that a simply pooling of risks across institutions can be undesirable (Shaffer, 1989 and Wagner, 2006). The reason is that a shock that was previously experienced only in one part of the financial system, may then affect more institutions and can, if sufficiently large, also lead to their failure. When systemic crises are more costly than individual crises, diversification of risks in the financial system may be undesirable. This insight differs from the present paper in that diversification *per se* is beneficial here; it is only the resulting reoptimization at banks that can cause unwelcome effects.

Some papers have also pointed out that an expansion of the activities at financial institutions may facilitate herding. For example, Acharya and Yorulmazer (2004) present a model where herding in investment choices arises because banks want to increase the likelihood of failing jointly in order to induce a regulator to bail them out. In Acharya and Yorulmazer (2005), bank owners invest in correlated assets because they do not internalize the costs of a joint failure due to limited liability. In the present paper, institutions' also benefit from being more correlated. However, this is socially desirable as it reduces the need for ex-post risk sharing (another difference is that the homogenization considered here does not change the consolidated balance sheet of the financial system, as opposed to herding).

An important strand of the literature on financial stability has analyzed the consequences of linkages among financial institutions. In our paper it is the interbank market that provides risk sharing among institutions, which, however, only operates imperfectly due to its inability to allocate liquidity efficiently in a crisis. The literature has emphasized the existence of various risk sharing mechanisms but also pointed to their imperfections. In particular, it has been shown that risk sharing may be costly ex-post by causing spillovers in a crises, such as through asset markets, credit exposures or interbank market contagion (e.g., Allen and Gale, 1998, Freixas, Parigi and Rochet, 2000, Aghion, Bolton, and Dewatripont, 2000). An increased homogeneity of financial institutions should also be beneficial in the presence of such risk sharing channels. This is for the same reason as in our setup: it reduces the need for risk sharing and thus the scope for costly spillovers.

2 The Model

The financial system consists of a continuum of institutions, which we refer to as banks. There is a unit mass of them. Banks are owned by risk neutral households and invest on their behalf in firms. Households do not directly invest in firms because banks can make use of economies of scale, for example because of fixed monitoring costs or because firms' projects are indivisible. For concreteness, we assume that each bank collects one unit of funds from households.

There are three dates. At date 0, a bank can invest in a storage technology (liquidity) and in a risky asset. The storage technology simply transfers one unit of funds from the current period to the next. By contrast, the return on the risky asset materializes over two periods. At the intermediate date 1, each unit of the risky asset (a 'project') gives an uncertain return η_i, where $i \in [0, 1]$ indexes banks.[7] The intermediate return consists of an aggregate component ε and a bank-specific component ε_i, arising because banks are specialized into different activities (e.g., into different regions or different industries). The aggregate shock ε is uniformly distributed on $[-1/2, 1, 2]$ with density $\phi(\varepsilon) = 1$. The bank shock ε_i takes with equal probability the values s and $-s$ with $0 < s < 1/2$ and is assumed to be independently distributed across banks. Whether a bank has received a positive or

[7] As will become clear later, η_i can also be interpreted as a liquidity shock.

negative shock is private information.

The intermediate return η_i can be written as

$$\eta_i = \varepsilon + w\varepsilon_i \tag{1}$$

where w, $0 \leq w \leq 1$, is the relative weight on the idiosyncratic shock. The expected value of η_i is zero since both the aggregate and the bank specific shock have zero mean. Negative values for η_i can be interpreted as unexpected liquidity needs from the project.

In order to be continued, a project requires a liquidity injection of $l > 0$ at date 1.[8] If this injection is not provided, the project becomes worthless, i.e., the return at date 2 is zero. If the injection is provided, and the project is continued at the originating bank, it yields R at date 2 and returns the liquidity injection l. On the other hand, if the project is continued at another bank, the project returns only γR $(0 \leq \gamma < 1)$ plus the liquidity injection. $1-\gamma$ is the value loss that arises because the acquiring bank is only an inferior user of the project (for example, because the originating bank has obtained in the course of financing the project specific knowledge). For the special case of $\gamma = 0$, projects cannot be employed at other banks at all.

At date 1, after the intermediate returns have materialized, banks can smooth their liquidity needs by trading liquidity at an interbank market. A bank's liquidity L_i before borrowing and lending consists of investment in liquidity at date 0 plus the intermediate return on the risky asset

$$L_i = 1 - X_i + \eta_i X_i \tag{2}$$

where $X_i \in [0,1]$ denotes the date 0 investment in the risky asset. Note that bank liquidity is private information because of the unobservability of bank shocks. Banks' demand for liquidity L_i^D is given by the liquidity needed to continue its projects: $L_i^D = X_i l$. It follows that the banks' liquidity needs $L_i^D - L_i$ have an idiosyncratic component.

From (2) we can derive the total (aggregate) amount of liquidity in the banking sector $L := \int_0^1 L_i di = 1 - X + \varepsilon X$, where $X := \int_0^1 X_i di$ is the aggregate investment in the risky asset (the bank specific shocks ε_i cancel out in L by the law of large numbers). The aggregate demand for liquidity is given by $L^D = \int_i L_i^D di = Xl$.

When $L \geq L^D$, there is sufficient aggregate liquidity to finance all projects. Competition ensures then that the interest rate on lending in the interbank market is zero, since this is the return on the storage technology. Thus, banks can insure their liquidity needs at no cost. By contrast, when $L < L^D$, there is insufficient liquidity to finance all projects in the

[8] For example, because a multi-stage project requires capital investment at date 0 and date 1. This feature is borrowed from Holmström and Tirole (1998), where firms have (real) liquidity needs at an intermediate date.

economy. Banks with a liquidity deficit compete then for the scarce liquidity. Given that the value of the project is zero in the absence of a liquidity injection, this would require the interbank interest rate to rise to a level which makes the return from financing assets (net of borrowing costs) equal to zero (if this were not the case, banks which are rationed would offer to pay a slightly higher interest rate, which would strictly increase their profits).

We presume that such financing of assets at a zero net return cannot take place. Appendix A formalizes this as being due to an asset substitution problem: because of high interest rates, financing projects through borrowing causes a large debt burden for a bank. The bank thus benefits little from the date 2 return on the risky project, and may hence rather invest its liquid funds in an inferior project. As this reduces the bank's ability to pay off its debt at date 2, banks with liquidity surplus will not find it optimal to lend (this is essentially the debt overhang problem of Myers (1977), recently applied to banks by Flannery(1994)).[9] [10]

We refer to a situation of $L < L^D$ as a liquidity crisis. Such a crisis occurs when $L = 1 - X + \varepsilon X < L^D = Xl$ or, from rearranging, if the aggregate shock ε is lower than

$$\widehat{\varepsilon} := 1 + l - 1/X \tag{3}$$

Given that ε is uniformly distributed on $[-1/2, 1/2]$, the probability of a liquidity crisis $\pi := \Pr(\varepsilon < \widehat{\varepsilon})$ can be expressed as

$$\pi = \widehat{\varepsilon} + 1/2 = 3/2 + l - 1/X \tag{4}$$

The date 2 returns are as follows. When there is no liquidity crisis at date 1 (i.e., $\varepsilon \geq \widehat{\varepsilon}$), banks with a liquidity deficit (if they exist) can borrow their required amounts from the interbank market. Thus, all projects are financed at date 1 and continued at their originating banks. Since any excess liquidity $L_i - L_i^D$ (which may be positive or negative) is transferred at zero interest, a bank's return at date 2, $W_i^0(\eta_i)$, is simply the return on its risky asset plus liquidity holdings at date 1:

$$W_i^0(\eta_i) = RX_i + L_i(\eta_i) \tag{5}$$

[9] We do not want to emphasize this particular form of interbank failure. Our results also hold for other imperfections in the interbank market (in fact, for our results to hold we only need that there is *some* inefficiency in the allocation of liquidity at date 1). Such imperfections may, for example, arise from the inability of market participants to observe the financial health of banks (Berger et. al., 2000), the interbank market becoming cautious in times of crisis (Flannery, 1996) or because of coordination problems (e.g., Freixas, Parigi, Rochet, 2000).

[10] Note that granting each other credit lines at low interest rates at date 0 cannot improve upon the interbank market allocation because liquidity is unobservable: banks would try to draw the credit line in a crisis regardless of whether they actually have liquidity needs as this provides them with cheap liquidity.

When there is a liquidity crisis at date 1 (i.e., $\varepsilon < \widehat{\varepsilon}$), we presume that each bank holds an amount of liquidity such that when it has received a negative shock (i.e., when it is an 'unlucky bank'), it does not itself have sufficient liquidity to finance all its assets, whereas if it has received a positive shock ('lucky bank'), it does ('partial insurance'). An unlucky bank will then use all its liquidity to finance as many of its own projects as possible. The remaining projects then become worthless for the bank, either because the bank cannot inject liquidity or because it sells projects to other banks. The latter is because, since there is an aggregate shortage of liquidity and the value of a project without liquidity injection is zero, the price of assets sold is driven to zero. The date 2 return, $W_i^{1,-}(\eta_i)$, of such a bank consists then of the return on the maximum amount of assets which can be financed with its own liquidity (L_i/l), plus liquidity holdings at date 1:

$$W_i^{1,-}(\eta_i) = RL_i(\eta_i)/l + L_i(\eta_i) \tag{6}$$

In contrast, a bank which receives a positive idiosyncratic shock first uses its liquidity to finance its own projects and then uses the remaining liquidity to acquire assets from banks which have experienced a negative shock. Given remaining liquidity $L_i - X_i l$, it can purchase (at a zero price) and finance $(L_i - X_i l)/l = L_i/l - X_i$ assets, giving a return of γR.

The bank's overall return is then

$$W_i^{1,+}(\eta_i) = RX_i + L_i(\eta_i) + \gamma R(L_i(\eta_i)/l - X_i) \tag{7}$$

The bank's total expected return, W_i, is given by

$$W_i = \int_{\widehat{\varepsilon}}^{1/2} \frac{W_i^0(\varepsilon - ws) + W_i^0(\varepsilon + ws)}{2}\phi(\varepsilon)d\varepsilon + \int_{-1/2}^{\widehat{\varepsilon}} \frac{W_i^{1,-}(\varepsilon - ws) + W_i^{1,+}(\varepsilon + ws)}{2}\phi(\varepsilon)d\varepsilon \tag{8}$$

Using equations (5)-(7) this simplifies to

$$W_i = RX_i + (1 - X_i) - \frac{1}{2}\int_{-1/2}^{\widehat{\varepsilon}} R[X_i - L_i(\varepsilon - ws)/l]d\varepsilon + \frac{1}{2}\int_{-1/2}^{\widehat{\varepsilon}} \gamma R[L_i(\varepsilon + ws)/l - X_i]d\varepsilon \tag{9}$$

Denoting with $\overline{\varepsilon} = E[\varepsilon \mid \varepsilon < \widehat{\varepsilon}]$ the expected level of the aggregate shock in a crisis and using $\pi = \widehat{\varepsilon} + 1/2$, we can write this as

$$W_i = RX_i + (1 - X_i) - \frac{\pi}{2}R[X_i - L_i(\overline{\varepsilon}(\pi) - ws)/l] + \frac{\pi}{2}\gamma R[L_i(\overline{\varepsilon}(\pi) + ws)/l - X_i] \tag{10}$$

where

$$\overline{\varepsilon}(\pi) = (\pi - 1)/2 \tag{11}$$

Equation 11 follows from $\overline{\varepsilon}(\pi) = \int_{-1/2}^{\widehat{\varepsilon}} \varepsilon\phi(\varepsilon)d\varepsilon / \int_{-1/2}^{\widehat{\varepsilon}} \phi(\varepsilon)d\varepsilon$.

From (10) we have that W_i consists of the total expected return when there is no liquidity crisis, $RX_i + (1 - X_i)$, minus the expected foregone returns from having to sell or liquidate assets when an unlucky bank in a liquidity crisis, $\frac{\pi}{2}R[X_i - L_i(\bar{\varepsilon} - ws)/l]$, plus the expected gains from buying up assets when a lucky bank in a crisis, $\frac{\pi}{2}\gamma R[L_i(\bar{\varepsilon}+ws)/l - X_i]$.[11]

2.1 Equilibrium and Social Inefficiency

Each bank chooses X_i in order to maximize its expected return W_i in (10), subject to its liquidity holdings given by equation (2) and taking as given the amount of aggregate investment X (and thus π and $\bar{\varepsilon}$). From (10) the bank's FOC is

$$\frac{\partial W_i}{\partial X_i} = R - 1 - \frac{\pi}{2}R[1 - (-1 + \bar{\varepsilon} - ws)/l] + \frac{\pi}{2}\gamma R[(-1 + \bar{\varepsilon} + ws)/l - 1] = 0 \quad (12)$$

Note that because of constant returns, the FOC does not specify a level of X_i but rather a level of aggregate investment X (because $\pi = \pi(X)$ and $\bar{\varepsilon} = \bar{\varepsilon}(\pi)$) for which an individual bank is indifferent between investing in the risky asset and holding liquidity.[12]

By contrast, the socially efficient amount of investment maximizes total bank return in the economy, which consists of the sum of the returns of all banks

$$W = \int_i W_i di = RX + (1 - X) - \frac{\pi}{2}R[X - L(\bar{\varepsilon} - ws)/l] + \frac{\pi}{2}\gamma R[L(\bar{\varepsilon} + ws)/l - X] \quad (13)$$

where $L(\varepsilon \pm ws) = 1 - X + \varepsilon X \pm wsX$. Proposition 1 shows that banks invest too much in the risky asset, i.e., they provide less than the socially efficient amount of liquidity.[13]

Proposition 1 *Banks' provision of liquidity is inefficiently low, i.e., $dW/dX_i < \partial W_i/\partial X_i$. In particular, we have*

$$dW/dX_i - \partial W_i/\partial X_i = -\frac{1}{2}(1 - \gamma)R\frac{wsX}{l}\pi'(X_i) \quad (14)$$

Proof. *See Appendix C.* ■

The inefficiency of banks' liquidity holdings arises from an externality: when a bank holds less liquidity (i.e., invests more in the risky asset), it reduces the net aggregate

[11] Our financial system displays fragility in the sense that a small reduction in liquidity (from $L = L^D$ to $L < L^D$) can lead to a breakdown of interbank lending and the discontinuation of assets at all banks with liquidity deficits, even though the aggregate liquidity shortage is only infinitesimal.

[12] Appendix B provides the conditions under which the X implied by (12) is indeed consistent with our setup: Appendix B.1 shows that the equilibrium X is consistent with partial insurance, Appendix B.2 verifies that a bank has no incentive to deviate to either full or no insurance.

[13] This underinvestment in liquidity is a common feature in models of financial fragility, see for example Bhattacharya and Gale (1987).

liquidity $L - L^D$. This increases the probability of a liquidity crisis by increasing the domain of asset shocks for which a liquidity crisis occurs ($\widehat{\varepsilon}$ increases): $\pi'(X_i) > 0$. This is costly because in a liquidity crisis, liquidity cannot be allocated efficiently.

As the proposition shows, the efficiency loss from the inefficient liquidity allocation is: $\frac{1}{2}(1-\gamma)R\frac{wsX}{l}$, consisting of the mass of unlucky banks in a crisis 1/2, the loss from not being able to continue a project at the originating bank $(1-\gamma)R$ and the amount of projects which unnecessarily are not continued at unlucky banks wsX/l. The latter is because for the new states in which a liquidity crisis occurs we have $\varepsilon = \widehat{\varepsilon}$ and hence $L^D = L$. Thus, unlucky banks have a liquidity deficit of $wsX_i = wsX$ and lucky banks have a liquidity surplus of $wsX_i = wsX$. Hence, due to the interbank market failure, an amount wsX of liquidity is not allocated efficiently and as a result wsX/l projects cannot be continued anymore.

3 The Broadening of Activities

We now investigate the impact of banks being able to engage in activities beyond their specialized line of business. To this end we assume that a bank can make up to a fraction $\overline{q}$ $(0 \leq \overline{q} \leq 1)$ of its total investment X_i at date 0 into another asset. This asset is assumed to be diversified and only differs from the specialized asset in that it pays ε rather than $\eta_i = \varepsilon + \varepsilon_i$ at the intermediate date, as it does not contain a bank specific shock.

$\overline{q}$ thus represents banks' diversification opportunities. Changes in $\overline{q}$ may, for example, be the result of deregulation which allows banks to spread their activities geographically or to enter into new business lines. Improved diversification opportunities may also arise from financial innovation. For example, the recent arrival of credit derivatives has allowed banks to trade loan risks that were previously considered untradeable. (e.g., BIS 2004). Thus, banks can sell specific loan risk (arising from their specialization into regions or industries, for example) and buy aggregate loan risk.

To incorporate such a broadening of activities in our setup, we normalize the relative weight of the intermediate bank shock in the absence of diversification possibilities to 1. The extent to which a bank is diversified (i.e., the share of its total investment that is in the diversified asset) is denoted with q_i $(0 \leq q_i \leq \overline{q})$. The date 1 liquidity of a bank with a diversification degree q_i is then $L_i = 1 - X_i + ((1-q_i)\eta_i + q\varepsilon)X_i$, which can be rearranged to

$$L_i = 1 - X_i + (\varepsilon + (1-q_i)\varepsilon_i)X_i \tag{15}$$

Note that for $w = 1 - q_i$, L_i is identical to (2). Hence, the setup of the previous section corresponds to an aggregate degree of diversification $q = 1 - w$ with $q := \int_0^1 q_i di$ (because of symmetry there will be $q_i = q$ in equilibrium).

What is the degree of diversification of activities banks will choose? From equation (10) we have that an increase in q_i increases a bank's return

$$\frac{\partial W_i}{\partial q_i} = \frac{-\partial W_i}{\partial w} = \frac{1}{2}(1-\gamma)R\frac{sX_i}{l}\pi > 0 \tag{16}$$

This is because, as can be seen from (15), a unit increase in q_i reduces the idiosyncratic component of a bank's liquidity by $(\varepsilon_i - \varepsilon)X_i = sX_i$. When being unlucky in a crisis the bank then loses sX_i/l less assets and when being lucky it can buy sX_i/l less assets. As $\gamma < 1$, the gain from the former is always larger than the loss from the latter. Or, in other words, diversification makes a bank's liquidity closer to average liquidity in the banking sector. Thus, it suffers less from the inability of the interbank market to smooth liquidity in a crisis. As banks thus unambiguously benefit from diversification, they always choose the maximum degree of diversification. Thus, in equilibrium we have $q_i = q = \overline{q}$.

We next address the implications of a broadening of activities for the stability and the efficiency of the banking system. We interpret the broadening as arising from a (small) increase in the diversification opportunities $\overline{q}$ by $d\overline{q} > 0$ (for example, because deregulation). As we have already established that banks benefit from diversification, they will respond by expanding their activities. Since $q_i = \overline{q}$, we have $dq_i = dq = d\overline{q} > 0$.

We consider first the consequences for the stability of banking system, as measured by the probability of a liquidity crisis π. Although stability enters welfare already through its impact on the efficiency of the banking system (W in equation (13) is decreasing in π), it is nevertheless instructive to study stability on its own, as it is typically believed that financial crises also cause externalities beyond the one present in our model. For example, banks may not fully internalize the cost of projects being discontinued, as they ignore any loss to the owner of the project (our framework implicitly assumes that banks fully extracts the surplus from the projects they finance).

The stability implications of the increase in q are as follows. First, there is no direct stabilizing effect of diversification, as one may have perhaps expected. Although diversification clearly reduces the variance of the liquidity needs at each individual bank by reducing its exposure to idiosyncratic shocks, it does not alter the aggregate risk in the financial system. As crises occur only when there are aggregate liquidity shortages, stability is therefore unchanged. This can also be directly appreciated by noting that π in equation 4 only depends on the aggregate amount of investment in the risky asset but not on the idiosyncratic components of banks' liquidity holdings.

However, there is an indirect effect of diversification because it has an impact on banks' incentives to provide liquidity and to invest in the risky asset. As already discussed, diversification reduces the inefficiencies associated with imperfect liquidity allocations by making an institution's liquidity more similar to the average amount of liquidity in the financial system. This lowers a bank's costs of investing in the risky asset by reducing the amount of 'unnecessary' discontinuations: from (12) we have that the marginal benefits from investing in the risky asset are increasing in q_i

$$\frac{\partial(\partial W_i/\partial X_i)}{\partial q_i} = -\frac{\partial(\partial W_i/\partial X_i)}{\partial w} = \frac{1}{2}(1-\gamma)\frac{R}{l}\pi > 0 \tag{17}$$

Thus, allocating funds towards the risky asset becomes relatively more attractive, and providing liquidity becomes less attractive. It follows that a bank will increase its investment in the risky asset following diversification: $dX_i/dq_i > 0$. Thus, aggregate investment X increases and liquidity holdings L decrease. As a result, the likelihood of a liquidity crisis rises.

In the absence of a stabilizing, direct, effect it follows that

Proposition 2 *A broadening of activities in the financial system reduces stability.*

It should be emphasized that this result arises even though banks are fully aware of the absence of a stabilizing effect of diversification. If this were not the case, and banks wrongly conclude from the reduced variability of their liquidity holdings following diversification that they have become safer, they may bias their portfolio even more towards the risky asset.

We next address the implications for the efficiency of the banking system, as measured by its expected return W. From the previous considerations, it is clear that there are two, opposing, effects. On the one hand, the improved diversification resulting from the broadening of activities enhances banking efficiency by reducing banks' reliance on imperfect liquidity smoothing through the interbank market. On the other hand, it also encourages a bank to reduce its liquidity holdings. As banks already underinvest in liquidity, this intensifies negative externalities across banks, with adverse ramifications for efficiency.

The overall efficiency impact should then depend on the relative size of the two effects. However, when only the liquidity externality described so far is present, the first effect always dominates in our setup. This is because the externality operates through reducing the gains from investing in the risky asset at other banks. As in equilibrium the marginal gains from investing in the risky asset are zero (equation 12), this externality is always completely offset through portfolio reallocations at banks. By contrast, if there are externalities that reduce gains at other banks independently of their level of investment in the risky asset, there is no such offsetting behavior and the efficiency implications become ambiguous.

In Appendix D we demonstrate this ambiguity for when there are fixed costs of being in a liquidity crisis, i.e. costs that are unrelated to the amount of assets that have to be liquidated. Within the confines of our framework, such costs may, for example, arise because banks face costs of organizing the transfer of assets. More generally, they may also arise from network externalities, such as a breakdown of the payment system.

It is shown in Appendix D that for when these costs are small, the first effect still dominates. However, for sufficiently large costs, the second effect is dominating. Hence

Proposition 3 *A broadening of activities has ambiguous implications for banking efficiency.*

Proof. *See Appendix D.* ■

Taken together, Proposition 2 and 3 thus suggest that in an unregulated financial system, a broadening of banks' activities is not necessarily beneficial because banks respond by increasing their risk. With some qualifications, this result may also apply to the current financial system. First, non-bank financial institutions typically face no capital requirements that could limit increases in risk. Second, within the banking sector institutions hold substantial amounts of capital in excess of regulatory requirements. For example, U.S. banks hold about 75% more capital than prescribed by the regulator (Flannery (2002)). It has been argued that capital requirements are thus not binding (e.g., Flannery (2002) and Allen and Carletti (2005)). Hence, banks may have leeway to respond to a broadening of their activities by increasing their risk, as in the unregulated economy.

4 Financial Regulation

In this section we study how regulation should respond to a broadening of activities in the financial system. We thereby presume that the regulator has no advantage over the interbank market, that is, he cannot improve upon the liquidity allocation in a crisis. We first demonstrate that a provision of liquidity by the central bank (i.e., a lender of last resort policy) cannot overcome inefficiencies. We then turn to the role of capital requirements in improving upon the efficiency of the financial system.[14]

Ineffectiveness of a Lender of Last Resort (LOLR) Policy Suppose that the central bank commits to providing an amount of liquidity L^{CB} to the market in a crisis. Also assume that the liquidity injection takes place at market interest rates.[15] Since liquidity

[14] The general role for regulation in the present framework is more extensively analyzed in Wagner (2005).

[15] It has been argued (e.g., Bagehot (1873)) that the lender of last resort should only operate at a penalty interest rate. However, in practice lending often occurs without a premium over the market interest rate

needs are real in our setup (i.e., they are used to continue physical assets rather than to settle financial claims), a central bank would need to store L^{CB} at date 0 in order to have L^{CB} available in case a crisis occurs. In a closed model, L^{CB} would somehow needed to be obtained from banks. Obviously, this is then not a sensible intervention as it simply transfers liquidity from banks to the central bank.

Rather, we shall examine the situation where the central bank possesses own liquid funds of L^{CB} that it can provide in a crisis. Since this amounts to injecting additional resources into the economy, it is not possible to study the welfare implications of such a LOLR policy. However, it is informative to analyze the impact on the probability of a liquidity crisis.

Given this liquidity injection, a liquidity crisis will now occur only if $L + L^{CB} < L^D$. Analogous to equation (4) one can derive the expression for the probability of a liquidity crisis π

$$\pi = 3/2 + l - (1 + L^{CB})/X \tag{18}$$

showing that for a given X, a liquidity injection reduces the probability of a crisis.

However, a lower π has the effect of increasing banks' incentives to invest in the risky asset ($\partial W_i/\partial X_i$ is decreasing in π, as shown in Appendix B.1). Thus, there is an offsetting effect on the probability of a liquidity crisis. As the next proposition shows, the initial impact of the liquidity injection will be even completely neutralized:

Proposition 4 *A liquidity injection in a crisis does not affect stability.*

This neutrality result can be understood by noting that the introduction of L^{CB} does not directly enter the bank's FOC condition for X_i (equation 12); it enters only indirectly via π and $\overline{\varepsilon}$. Recalling that $\overline{\varepsilon} = (\pi - 1)/2$, it follows that the FOC is still fulfilled for the probability of default prior to the implementation of the LOLR policy, implying that the equilibrium probability of a liquidity crisis is unchanged. Thus, banks increase their investment in the risky asset and reduce liquidity by an amount that exactly offsets the impact of L^{CB} on the probability of a crisis. Thus, the provision of liquidity by the central bank is ineffective because it is anticipated by banks *ex-ante* and causes an offsetting reduction in their liquidity holdings.[16]

Capital Requirements Capital requirements specify that banks have to hold a certain amount of capital per unit of risk they hold on their balance sheet. We assume that

(Goodhart and Schoenmaker, 1995) and thus lending at high interest rates may not be feasible. In our framework this is explained by the asset substitution problem that is caused by high interest rates.

[16] Similarly, neither should an (anticipated) private provision of liquidity from outside the banking sector (e.g., from hedge funds) mitigate the occurrence of crises.

when banks are constrained by capital requirements (that is they want to hold more risk than their amount of equity allows), they can raise new equity at a constant cost. Capital requirements, if binding, can hence be interpreted as a charge on bank risk. We denote this charge per unit of investment X_i by δ, with $\delta \geq 0$. When $\delta'(q_i) = 0$ the regulator sets the charge independent of the bank's diversification, while if $\delta'(q_i) < 0$ there is a diversification discount.

Optimal regulation has to correct the negative externalities from banks' portfolio choices. As banks underinvest in liquidity and thus overinvest in risk, it follows that optimal capital requirements are always binding. Thus, a bank's return is equal to its return in absence of regulation (equation 10) minus δX_i

$$W_i = RX_i + (1 - X_i) - \frac{\pi}{2} R[X_i - L_i(\bar{\varepsilon}(\pi) - ws)/l] + \frac{\pi}{2}\gamma R[L_i(\bar{\varepsilon}(\pi) + ws)/l - X_i] - \delta X_i \quad (19)$$

Analogous to Proposition 1 we have that the liquidity externality posed by bank i is given by

$$\frac{dW}{dX_i} - \frac{\partial W_i}{\partial X_i} = -\frac{1}{2}(1-\gamma)R\frac{(1-q)sX}{l}\pi'(X_i) + \delta = -\frac{1}{2}(1-\gamma)R\frac{(1-q)s}{l}\frac{1}{X} + \delta \quad (20)$$

where the last equality follows because of $\pi'(X_i) = 1/X^2$ in equilibrium. Hence, if the regulator sets

$$\delta = \frac{1}{2}(1-\gamma)R\frac{(1-q)s}{l}\frac{1}{X}$$

we have $\frac{dW}{dX_i} = \frac{\partial W_i}{\partial X_i}$ and banks choose the socially efficient amount of liquidity.

It follows that

Proposition 5 *Optimal capital requirements should*

i) increase in the cost of discontinuing projects at the originating bank $1-\gamma$*,*

ii) be independent of a bank's degree of diversification q_i*,*

iii) decrease in the degree of homogenization of the financial system q*,*

iv) be zero when there is complete homogenization ($q = 1$)

The first result is obvious from previous discussions: if γ is low, then the cost of interbank failure increases. Therefore, the liquidity externality becomes more severe, and banks should optimally face higher penalties for taking on risk. The independence of bank diversification q_i arises because when a bank broadens its activities, this does not affect aggregate liquidity risk and thus not the probability of a crisis. Hence regulation should take a neutral stand towards bank diversification. This contrasts with the diversification relief that the new Basel accord allows for operational risk[17] and with practitioners' demands

[17] The new Basel accord does not provide for a diversification discount for credit risk. However, regulators assume that banks hold a well diversified credit portfolio and may impose additional capital charges if this is not the case (BIS, 2005).

(e.g., FleetBoston Financial, 2003) to provide a full capital relief also for diversification of credit risk.[18]

The reason for why an increase in the homogenization of the financial system q reduces capital requirements is as follows. When banks are more homogenous, their liquidity holdings become more similar. Thus, there is less need to reallocate liquidity through the interbank market. Hence, interbank market failure becomes less costly and the liquidity externality diminishes. When the financial system is fully homogenized, that is when all institutions carry out the same activities, there is even no need at all anymore for interbank smoothing. Imperfections in the interbank market become irrelevant and hence there are no externalities across banks anymore. The scope for imposing capital requirements vanishes.

The reduced need for regulation for when the financial system becomes more homogenous may have positive welfare ramifications itself when regulators cannot implement the optimal δ, for example, because they have only imperfect knowledge of the parameters determining it (such as the risk level at banks or the cost of not being able to continue projects $1-\gamma$). It may also be beneficial because capital requirements distort banks' incentives (they may do this, for example, by reducing the franchise value of banks, e.g., Blum 1999). The fact that capital requirements do not seem to be directly binding for most banks, indicates that such imperfections may be important in practice.

5 Discussion

Other externalities. While our analysis is based on interbank externalities, it is typically presumed that liquidity crises also cause costs outside the banking sector. For example, in a liquidity crisis banks' projects are liquidated (that is, firms they finance have to discontinue or postpone activities), the cost of which may not be fully internalized by banks (contrary to what we have implicitly assumed). When such costs are present, the case for homogenization is worsened as the reduction in stability following banks' lower supply of liquidity becomes then more costly. Also, homogenization will then not fully remove the need for regulation anymore, as it only overcomes the externalities arising from the interbank market failure.

The broadening of activities and aggregate risk. We have presumed that the activities banks are diversifying into carry the same aggregate risk. If this were not the case, then diversification could have a direct stabilizing effect if it lowers aggregate risk in the economy.

[18] Wagner (2006) argues that optimal capital requirements may even *increase* when a bank becomes more diversified. This is because by diversifying, a bank makes itself more similar to other banks. This in turn increases the likelihood that banks are in stress jointly rather than alone, which is costly for banks (for example, because it is then more difficult to borrow funds as all institutions have liquidity demands).

Suppose, for example, that deregulation allows financial institutions to invest in a new activity, that is uncorrelated with existing activities in the financial system. Then, diversification would lower aggregate risk (still, this would not imply that the overall stability implications of diversification are improved, as it would also increase banks' incentives to invest in the risky asset). Recent trends in the financial system (in particular conglomeration and consolidation), however, mainly relate to financial institutions expanding into activities that are already undertaken in the financial sector (e.g., a bank starts insurance activities or a European bank enters the American loan market). The ongoing broadening of activities is thus unlikely to reduce aggregate risk in the financial system.

Contagion. Diversification may have stability effects beyond the ones analyzed here, when there is contagion among institutions. Contagion can, for example, arise because liquidity problems at a bank and the resulting forced asset liquidation may depress asset prices and cause problems at other banks (e.g., Allen and Gale (1998)). It may be argued that diversification should then have a direct stabilizing effect: as diversification reduces the variance of a bank's liquidity needs, it lowers the probability of an individual institution encountering a crisis[19] and thus the possibility of contagion. However, this reasoning ignores that an institution is more likely to suffer from contagion when it is in a critical situation itself. As diversification makes institutions more similar, it becomes more likely that when one institution is in difficulties, other institutions are in difficulties as well. Contagious spillovers may hence increase following diversification. In fact, Wagner (2006) has shown that, overall, diversification may be less beneficial when there are contagion effects.

Debt financing. In our model there is no debt, and hence crises only occur because there is insufficient liquidity to continue projects. By contrast, Wagner (2006) has analyzed diversification in a framework where low returns on a risky asset cause bank runs. Diversification has then two, and opposing, effects. On the one hand, diversification reduces the probability of an individual bank failure by reducing the variance of asset returns. On the other hand, by making institutions more similar, it raises the probability of joint failure of institutions. The probability of systemic crisis thus rises. When a systemic crisis is more costly than individual crises, the welfare implications of diversification are ambiguous, as in the absence of debt.

Other risk sharing mechanisms. In our model, it is the interbank market that provides risk sharing. In practice, there are more channels through which risk sharing can take place, for example, through secondary markets for assets, banks building up mutual credit

[19] This effect is not present in our framework because individual bank liquidity does not matter as long as there is no aggregate crisis since banks can always borrow from other banks.

exposures or banks exchanging deposits. The literature has emphasized that such risk sharing is also imperfect as it may give rise to costly spillovers in a crisis (e.g., Rochet and Tirole 1999, Allen and Gale 2000, Aghion, Bolton and Dewatripont 2000, Freixas, Parigi and Rochet 2000). For instance, the failure of one bank may have a negative impact on another bank through its negative effect on asset prices. Homogenization should then have a similar beneficial effect as in our model because, by making institutions more similar, it reduces their need for risk sharing. This, in turn, will allow institutions to rely less on these risk sharing channels and reduces costly spillovers.

6 Concluding Remarks

The homogenization of financial institutions has complex implications for the stability and the efficiency of the financial system. This paper has highlighted some of them. First of all, in a world of ongoing homogenization it is misleading to exclusively focus on the risks at the institutional level. This is because resulting diversification makes institutions' portfolios appear less risky, while from an aggregate perspective risks are only shifted around. Regulators should thus not be tempted to equate reduced portfolio risk with improved stability. Contrary to what portfolio theory suggests, providing a full diversification relief may thus not be optimal. Moreover, regulators should be aware that homogenization has an impact on institutions' incentives for risk taking and providing liquidity. When capital requirements are not binding, this may have undesirable consequences for financial stability.

However, homogenization also brings about important benefits. By making institutions more similar to each other, it reduces their need to rely on interinstitutional risk sharing. As such risk sharing may be subject to imperfections, the efficiency of the financial system should improve. The reduced reliance on risk sharing also lowers externalities among institutions. This is because institutions should anticipate that their increased similarity makes it less likely that they can smooth liquidity needs with other institutions. The interactions among institutions are therefore lowered and the scope for financial regulation that arises from interbank externalities diminishes. The latter may particularly be beneficial for when regulation is subject to imperfections itself.

Appendix A (Interbank Market Failure when $L < L^D$)

We provide here a mechanism for a failure of the interbank market in allocating liquidity in a crisis. It arises because there is an incentive for asset substitution when there is debt outstanding (Myers, 1977). The asset substitution problem is particularly severe at banks because 'bank assets do not have contractible, easily described risk properties' and 'banks confront numerous opportunities for asset substitution' (Flannery, 1994). In a crisis, incentives for asset substitution are intensified because the high interest rate increases the debt burden.

To focus the analysis, we model the extreme case of the interbank market fully functioning in normal times, but breaking down completely in crisis times (our main results do not depend on these features; what is required is only that interbank liquidity smoothing does sometimes not work perfectly). We assume that a bank can at date 1 now use its liquid funds to start a new (and inferior) project (the 'new' project), rather than injecting them into the project started at date 0 (the 'old' project). A unit of the new project requires an outlay of 1 and returns liquid funds of R_L date 2. Besides, it provides also private benefits of R_P to the bank. Inferiority of the project implies $R_L + R_P < R$.

Suppose that the interbank market is operative when $L < L^D$. A bank's net gain from financing an additional old project through borrowing at the market interest rate r is $(R + l) - (1 + r)l = R - rl$. Thus, an equilibrium would require $r = R/l$ in order to make a bank indifferent between financing additional projects through borrowing and not injecting liquidity (which would make the projects worthless). The date 2 return of a bank with a liquidity deficit that borrows B_i and invests all its liquid funds $(L_i + B_i)$ in the old projects is thus (see also equation 6)

$$RL_i/l + L_i + (R + l)B_i/l - (1 + r)B_i = R \cdot L_i/l + L_i$$

This return is independent of B_i because the net gains from borrowing are zero. On the other hand, if a bank borrows funds B_i and invests them into new projects, its date 1 return is simply $R_P(L_i + B_i)$. This is because the value of the non-continued old assets is zero and the liquid part of the returns from the new project are used to pay off the debt (see below). Hence there is only the private benefit from investing in the new project. From comparing the pay-offs, one can see that a bank finds it optimal to engage in assets substitution iff

$$R \cdot L_i/l + L_i < R_P(L_i + B_i)$$

Thus, for sufficiently high levels of borrowing B_i, banks would always choose to invest in the inferior asset. However, in practice a bank's total position in the interbank market is likely to be partly observable (for example, there is evidence that interest rates depend on a bank's net position in the interbank market), restricting its ability to borrow unlimited amounts. To incorporate this feature, we assume here simply that banks can borrow up to a total amount $\overline{B}$ without their position being observed by other banks

If $B_i = \overline{B}$ fulfills the above equation, banks would find it optimal to borrow $\overline{B}$ and engage in asset substitution. As a result the bank would default on its debt, as its date 2 liquid funds, $R_L(L_i + \overline{B})$, will be smaller than its outstanding debt, $(1+r)\overline{B} = (1+R/l)\overline{B}$ (this can be shown from rearranging above inequality for L_i and inserting into $R_L(L_i + \overline{B})$). Hence, nobody would be willing to lend to the bank and interbank lending breaks down.

Consider next the case of no aggregate liquidity shortage. The return from borrowing at the interbank market and continuing the old projects is then $RX_i + L_i$ (from equation 5) as all projects can then be continued at zero borrowing costs. By contrast, the return from borrowing B_i and engaging in asset substitution is still $R_P(L_i + B_i)$. Banks do then find it optimal not to engage in asset substitution when

$$R \cdot X_i + L_i < R_P(L_i + B_i)$$

When this condition is fulfilled, lending can take place as there are sufficient liquid assets at date 2 to repay lenders. Note that the gains from borrowing and investing are higher when there is no aggregate liquidity shortage ($R \cdot X_i + L_i > R \cdot L_i/l + L_i$) because interest rates are then lower. Hence, there are $\overline{B}$ for which both of the above conditions are fulfilled. For such $\overline{B}$ we have then that the interbank market operates in normal times but breaks down in a crisis.

Appendix B (Characteristics of the Equilibrium)

Appendix B.1 (Partial Insurance in an Equilibrium)

We show that there are parameters for which an X that fulfills the FOC (12) implies partial insurance: i.e., in a crisis a lucky bank always has excess liquidity, while an unlucky bank has liquidity needs. The latter follows immediately from the fact that an unlucky bank will have less than the average amount of liquidity, which is already insufficient in a crisis. Regarding the former, since liquidity increases with the aggregate shock, the condition that a lucky bank always has enough liquidity to finance its own assets is fulfilled whenever there is sufficient liquidity at the minimum asset shock $\varepsilon = -1/2$. This condition writes

$$L_i(\varepsilon = -1/2) - L_i^D = 1 - X_i + (-1/2 + ws)X_i - X_i l \geq 0$$

Dividing by X_i, using $X_i = X$ (because of symmetry in equilibrium) and substituting X using (4), this condition simplifies to $\pi \leq ws$. We show next that there are parameter values that jointly fulfill this inequality and the FOC.

To make use of the inequality $\pi \leq ws$, we first show that $\partial W_i/\partial X_i$ is decreasing in π. From comparing W_i and $\partial W_i/\partial X_i$ (equation 10 and 12) we find that

$$W_i = \frac{\partial W_i}{\partial X_i} X_i + 1 + (1+\gamma)\frac{\pi}{2} R/l$$

Partially differentiating wrt. π and using $\partial W_i/\partial \pi < 0$ (analogous to Proposition 1 one can show that $\partial W_i/\partial \pi = -(1-\gamma) ws \frac{R}{2l} X_i$) we obtain

$$\frac{\partial W_i}{\partial \pi} = \frac{\partial(\partial W_i/\partial X_i)}{\partial \pi} X_i + (1+\gamma)\frac{1}{2} R/l < 0$$

from which it follows that $\partial W_i/\partial X_i$ is decreasing in π.

Using $\overline{\varepsilon} = (\pi - 1)/2$ to write the FOC (12) as a function of π hence gives $\partial W_i(\pi, ws)/\partial X_i \geq \partial W_i(\pi = ws, ws)/\partial X_i$ as $\pi \leq ws$. Since $\partial W_i(\pi, ws)/\partial X_i = 0$ we obtain that when

$$\begin{aligned}\frac{\partial W_i(ws, ws)}{\partial X_i} &= R - 1 - \frac{ws}{2} R[1 - (-1 + \frac{ws-1}{2} - ws)/l] + \frac{ws}{2}\gamma R[(-1 + \frac{ws-1}{2} + ws)/l - 1] \\ &= R - 1 + \frac{ws}{2} R(1-\gamma) - \frac{ws}{2} R/l[3/2(1+\gamma) + ws(1/2 - 3/2\gamma)] \leq 0\end{aligned}$$

is met, both the FOC and $\pi \leq ws$ are fulfilled. Indeed, this condition can be fulfilled for a variety of parameter values: for example for $\gamma < 1/3$, the expression in the squared brackets is positive; by letting l become small, the last term can then be made an arbitrarily large negative number.

Appendix B.2 (Global Optimum)

We show that an X with partial insurance which fulfills the FOC (12) does indeed constitute a global equilibrium. This requires that it neither pays off for a single bank to deviate to a situation where it always has sufficient liquidity in a liquidity crisis (full insurance) nor to a situation where it never has sufficient liquidity in a crisis (no insurance). In the following, we therefore presume that (12) holds, i.e., X is such that $\partial W_i/\partial X_i = 0$ and show that a bank has no incentive to deviate from partial insurance.

No deviation to full insurance: a fully insured bank never has to liquidate assets in a crisis and can always buy up assets from other banks. Its return is then analogous to (10)

$$W_i^{FI} = RX_i + (1 - X_i) + \frac{\pi}{2}\gamma R[L_i(\overline{\varepsilon} - ws)/l - X_i] + \frac{\pi}{2}\gamma R[L_i(\overline{\varepsilon} + ws)/l - X_i]$$

Taking derivative wrt. X_i and comparing to the FOC condition under partial insurance (equation 12) we obtain

$$\frac{\partial W_i^{FI}}{\partial X_i} = \frac{\partial W_i}{\partial X_i} + \frac{\pi}{2}(1-\gamma) R[1 - (-1 + \overline{\varepsilon} - ws)/l] > 0$$

where the inequality follows from $\partial W_i/\partial X_i = 0$ and $1-(-1+\overline{\varepsilon}-ws)/l > 0$ (since $\overline{\varepsilon} \leq 1/2$). Thus, under full insurance, the bank's return is strictly increasing in its risk taking. A bank therefore has an incentive to increase its investment in the risky asset, which pushes the bank into partial insurance. Thus, full insurance cannot be a worthwhile deviation from partial insurance.

No deviation to no insurance: under no insurance, a bank always has to liquidate assets in a crisis and can never buy up assets from other banks. The expression for its return is thus

$$W_i^{NI} = RX_i + (1 - X_i) - \frac{\pi}{2}R[X_i - L_i(\overline{\varepsilon} - ws)/l] - \frac{\pi}{2}R[X_i - L_i(\overline{\varepsilon} + ws)/l]$$

Taking derivative wrt. X_i and making use of equation (12) we find that

$$\frac{\partial W_i^{NI}}{\partial X_i} = \frac{\partial W_i}{\partial X_i} - \frac{\pi}{2}(1-\gamma)R[1 - (-1 + (\overline{\varepsilon} + ws))/l] < 0$$

because of $1 - (-1 + \overline{\varepsilon} + ws)/l > 0$ (since $\overline{\varepsilon} \leq 1/2$, $s \leq 1/2$ and $w \leq 1$). Hence, the bank has an incentive to reduce its risk, which would push the bank into partial insurance. Thus, no insurance cannot also be a worthwhile deviation.

Appendix C (Proof of Proposition 1)

From (13) we have that the efficient level of investment fulfills $dW/dX_i = \partial W_i/\partial X_i + \partial W/\partial\pi \cdot \pi'(X_i)$. Using W_i from (9) and $\pi = \widehat{\varepsilon} + 1/2$ (equation 4) we can write $W = \int_i W_i di$ as

$$W = RX + (1 - X) - \frac{1}{2}\int_{-1/2}^{\pi-1/2} R[X - L(\varepsilon - ws)/l]d\varepsilon + \frac{1}{2}\int_{-1/2}^{\pi-1/2} \gamma R[L(\varepsilon + ws)/l - X]d\varepsilon$$

Differentiating wrt. π and simplifying gives $\partial W/\partial\pi = -\frac{1}{2}(1-\gamma)R\frac{wsX}{l} < 0$. From $\pi'(X_i) = 1/X^2$ (since $X_i = X$ in equilibrium) we have that $\pi'(X_i) > 0$. It follows that $dW/dX_i < \partial W_i/\partial X_i$, hence banks invest more than the socially optimal amount in the risky asset.

Appendix D (Proof of Proposition 3)

We assume now that a bank incurs costs $C > 0$ when there is a liquidity crisis. Thus, equation (10) for bank returns becomes

$$W_i = RX_i + (1 - X_i) - \frac{\pi}{2}R[X_i - L_i(\overline{\varepsilon}(\pi) - ws)/l] + \frac{\pi}{2}\gamma R[L_i(\overline{\varepsilon}(\pi) + ws)/l - X_i] - \pi C$$

The bank's first order condition (equation 12) is unchanged. Multiplying the FOC with X_i and subtracting from W_i gives

$$W_i = 1 - \frac{\pi}{2}R[-1/l] + \frac{\pi}{2}\gamma R/l - \pi C = 1 + \frac{\pi}{2}(1+\gamma)R/l - \pi C$$

which is equal to banking efficiency W as all banks are identical. Thus, in equilibrium the degree of diversification affects W through the probability of a liquidity crisis π. As we have shown in the main text that π increases after an increase in banks' diversification possibilities, it follows that efficiency increase iff

$$\frac{1+\gamma}{2}R/l > C$$

and otherwise decreases. Thus, for when the costs of a liquidity crisis C are small, efficiency is enhanced. However, when C is sufficiently large, efficiency decreases.

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