Available online at www.sciencedirect.com
ScienceDirect
J. Finan. Intermediation 17 (2008) 330–356
Journal of Financial Intermediation
www.elsevier.com/locate/jfi

The homogenization of the financial system and financial crises

Wolf Wagner *

Department of Economics, TILEC and CentER, Tilburg University, Postbus 90153, 5000 LE Tilburg, The Netherlands

Received 29 March 2006
Available online 17 January 2008

Abstract

Financial institutions, especially large banks, have reached beyond their traditional activities in recent years and have become more homogeneous as a result. Even though this brings about diversification gains, we show that their stability may fall as consequence since institutions' incentives for taking on risk and supplying liquidity deteriorate. Optimal regulation should hence not provide a relief for diversification. However, we also identify an important benefit of this development. When financial institutions become more homogeneous, there is less need for risk sharing among them. This in turn mitigates the impact of any imperfections such risk sharing may be subject to.

Keywords: Conglomeration; Consolidation; Homogenization; Financial crises; Regulation; Welfare

1. Introduction

The transformation of the financial sector has made financial institutions more homogeneous. Mergers and acquisitions, for instance, 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 has made it possible to transfer a variety of risks within the financial system. As a result, financial institutions could reduce their exposures to concentrated risks,

* Fax: +31 13 466 3042.
E-mail address: wagner@uvt.nl.

1042-9573/$ – see front matter
doi:10.1016/j.jfi.2008.01.001

lowering the idiosyncrasies in their portfolios. Especially for large banks these effects have been substantial. This can be witnessed from the correlation in their share prices, which has risen from 28% to 54% between 1995 and 2000 alone (Group of Ten, 2001).[1]

An increased homogeneity of financial institutions should be welcomed in that it may reflect underlying diversification of risks.[2] The implications of this development, however, are likely to go far beyond diversification. 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 exposed to the same risk. Thus, when institutions become more homogeneous, their ability to share risks changes. Moreover, homogenization may cause institutions to reoptimize their portfolios, leading for instance to an adjustment in their liquidity holdings. This may be, for example, because underlying diversification has made them safer, allowing them to hold less liquidity.

The homogenization of the financial system thus raises various important questions for financial regulation. Is this a process which should be encouraged? How should regulatory instruments, such as capital requirements, be used in a financial system which becomes more homogeneous? Should regulators treat institutions more leniently when they diversify their activities, and, therefore, may become more similar to each other?

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 institutions have uncertain liquidity demands from projects. Uncertainty is both aggregate and institution-specific. Financial crises arise when there is an aggregate shortage of liquidity, that is when the combined liquidity needs of all projects financed at financial institutions exceed the total liquidity in the financial system. In such a shortage, obviously not all projects can be continued. Moreover, because liquidity demands are idiosyncratic there are also institutions with a surplus of liquidity that could be lend to other institutions. Since the market for liquidity only works imperfectly in a crisis,[3] this surplus liquidity cannot be efficiently allocated. 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 it. These projects then have be continued at institutions with a liquidity surplus. However, this causes an efficiency loss because originating institutions can make better use of their projects.

We model the homogenization process as institutions investing into each others' types of projects. This may be thought of as a European bank taking over an American bank (and thus investing in "American projects") or a bank starting an insurance arm (thus investing in "insurance projects").[4] Homogenization hence reduces the idiosyncrasies in institutions' liquidity needs and makes them individually less risky. However, from an aggregate point of view, it only reallocates risks in the financial sector and the consolidated balance sheet of the financial system remains

[1] The homogeneity of smaller banks and non-bank financial institutions is likely to have changed at a slower pace since they have been less affected by the transformation of the financial system.

[2] While conglomeration leads to functional diversification, consolidation through mergers and acquisitions fosters in particular geographical diversification. Most obviously, financial innovation facilitates diversification by make more risks tradeable.

[3] In our baseline model this is because interinstitutional lending breaks down whenever there is an aggregate liquidity shortage.

[4] While we consider homogenization of *activities*, there can also be homogenization in *behavior* because institutions adopt similar risk management techniques or become subject to uniform regulation (e.g., Persaud, 2000).

the same. Since crises are caused by aggregate shortages of liquidity, they do not become less likely.

Even though homogenization thus has no direct stabilizing effect,[5] it nevertheless brings about benefits. This is because, by lowering institutions' exposure to idiosyncratic risk, it makes their liquidity needs more similar. This implies that less liquidity has to be redistributed in a crisis. As a result, the amount of projects that have be inefficiently discontinued at originating institutions falls.

However, there is also a downside. In our model a financial institution holds a socially inefficient combination of projects and liquidity: it invests too much in (risky) projects and too little in liquidity. The reason for this is that it does not take into account that more risk and less liquidity at its institution increase the chance of inefficient project discontinuations at other institutions since both make aggregate liquidity shortages more likely. Homogenization worsens the inefficiency in an institution's risk-liquidity choice. Since it reduces the amount of projects that it may have to discontinue in a crises, it increases the institution's gain from investing in projects. Thus, following homogenization institutions start to invest more in risky projects, at the cost of holding liquidity. Liquidity shortages become more likely as a result, and the probability of a crisis rises unambiguously. We show that the costs from more risky and less liquid financial institutions may outweigh the benefits from fewer inefficient project discontinuations. Hence, overall welfare may fall due to homogenization.

Since institutions' risk-liquidity choices are socially inefficient in our model, there is a role for regulation in improving welfare. We show that appropriately designed capital requirements, by discouraging risk taking, can induce the efficient combination of projects and liquidity at institutions. We also show that such capital requirements should not be eased for an institution that becomes more diversified as a result of investing in other projects. The reason is that diversification does not affect an institution's aggregate risk, which is what drives financial crises.

This is an important result since there is an ongoing debate about whether capital standards should be lowered for a diversified institution. The current regulatory stance toward 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). Many observers, and in particular financial institutions themselves, have criticized this on the grounds that diversification should always be recognized since it reduces an institution's risk (e.g., FleetBoston Financial, 2003). Our analysis provides a rationale for regulators' reluctance to allow for a full diversification discount.

However, we show that capital requirements for an institution should be reduced when the financial system as a whole becomes more homogeneous.[6] The reason is as follows. In a more homogeneous financial system it becomes unlikely that an institution will be able to borrow from others when it has liquidity needs, simply because other institutions are probably having liquidity needs at the same time. Rational institutions should anticipate this and rely less on interinstitutional risk sharing.[7] The impact of an institution's risk and liquidity choices on other

[5] This is not to say that there *cannot* be a direct effect (as we argue in the paper, such an effect could go either way). Rather, we abstract from a direct effect in order to isolate the indirect effects of homogenization.

[6] Thus, optimal capital charges fall with total diversification in the financial system but not with an institution's own degree of diversification.

[7] By contrast, if institutions were myopic and would only focus on their own balance sheet, they may fail to realize that the scope for risk sharing has diminished and may conclude that they have become safer since the riskiness of their balance sheet has fallen.

institutions decreases as a consequence. Therefore, an institution internalizes more of the effects of its actions, which in turn lessens the need for regulating it.

This argument is probably best understood when put to its extreme. Suppose that the financial system is fully homogenized, that is all institutions invest in the same projects. The liquidity needs of institutions are hence identical and there is no longer a possibility for sharing liquidity risk through borrowing and lending. The interactions between financial institutions then cease to exist in our model. As a result, externalities among institutions are absent, implying that institutions will choose a socially efficient combination of projects and liquidity.

The paper proceeds as follows. The next section discusses related literature. Section 3 describes the model. In Section 4 we analyze the impact of homogenization in the absence of regulation. Section 5 studies the consequences for financial regulation. In Section 6 we discuss our results. The final section concludes.

2. Related literature

Several papers have recently pointed to undesirable aspects of financial institutions expanding their activities and reallocating risks in the financial system. For example, Allen and Gale (in press) and Allen and Carletti (2006) show that a transfer of risk from the banking sector into the insurance sector can increase systemic risk. This is because it creates linkages among the two sectors, which can cause a crisis to spillover from the insurance to the banking sector. Wagner and Marsh (2006) consider risk transfer between institutions that differ with respect to their fragilities, and show that it may lower financial stability when the more fragile sector is relatively less risk-averse.

Our model differs from these papers in that the reallocation of risks *per se* is desirable (since it provides diversification). The reason why welfare can fall is because institutions reoptimize their portfolios. It is well known that financial institutions may overinvest in risk and underinvest in liquidity (e.g., Bhattacharya and Gale, 1987). Our paper shows that diversification worsens this problem since it increases institutions' gains from investing in (risky) projects and reduces their incentives to hold liquidity.[8]

Our paper also points to a new benefit of diversification. Typically, diversification is considered desirable because, by lowering the probability of institutional failures, it makes financial crises less likely. This effect is absent in our model since financial crises are driven by aggregate uncertainty, which cannot be removed through diversification. Rather, the benefit of diversification comes in the form of lower costs of a crisis because it makes institutions more similar to each other.

The analysis of homogenization connects our paper to the literature on bank herding since both homogenization and herding increase the correlation of banks' portfolios. Several arguments have been brought forward why such herding may arise. Scharfstein and Stein (1990), for example, have shown that managers have an incentive to mimic the behavior of their peers due to reputation concerns. In Acharya and Yorulmazer (2006) investment in correlated activities increases the probability of joint failure of banks. Bank owners have an incentive to undertake

[8] While we consider risk shifting between institutions, Freixas et al. (in press) study risk shifting within a conglomerate. They show that deposit insurance gives the conglomerate an incentive to shift risk from its insurance to its banking arm, which in turn increases the conglomerates' overall risk-taking (compared to standalone institutions). Relatedly, Goldstein and Pauzner (2004) consider diversification among investors and show that it can cause contagion among countries through a wealth effect (that is, an increase in investors' risk aversion following a reduction in their wealth).

such investments (that is, to herd) because the costs of joint failures are borne by depositors. In Acharya and Yorulmazer (2007) banks undertake correlated investments because they prefer failing together since in a systemic crisis the regulator has to bail them out.

In the herding literature correlation is typically costly from a social perspective. For example, in Acharya and Yorulmazer (2007) it increases the likelihood of a systemic crisis in which assets have to be sold at a loss to outsiders. By contrast, correlation (without the reoptimization at banks) is socially desirable in our paper. There are two reasons for this. First, more correlation does not imply more aggregate risk (as it does in Acharya and Yorulmazer). This is because higher correlation comes from diversification, which raises correlation by reducing idiosyncratic risk rather than by increasing aggregate risk. Hence, (systemic) financial crises do not become more likely. Second, correlation reduces the costs of a crisis since it implies that less liquidity has to be reallocated between institutions.[9] Thus, in our paper more correlated financial institutions optimally attract lower capital requirements.

Our setup borrows several features from Holmström and Tirole (1998). First, crises are not driven by bank runs (or other forms of institutional failures) but by shortages of liquidity that cause discontinuation of projects. Second, there is both aggregate and idiosyncratic uncertainty in institutions' liquidity needs. An important difference is that in Holmström and Tirole idiosyncratic risk can be completely pooled through intermediaries (the source of inefficiency in their paper is aggregate risk). In our paper idiosyncratic risk can not be pooled in this way, causing unnecessary project discontinuations at originating institutions. This is what creates the scope for homogenization, which gradually removes this inefficiency by lowering the idiosyncratic risk at institutions.

3. 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 a risky asset (a 'project') gives an uncertain return η_i, where i ($i \in [0,1]$) indexes banks. The intermediate return η_i 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. Both the aggregate and the bank shock are observable but not contractible.

The intermediate return η_i can be written as

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

[9] Correlation generally reduces the need to form interlinkages among institutions in order to share risks. This can give rise to additional benefits because interlinkages can lead to costly spillovers in a crisis, such as through asset prices, credit exposures or interbank market contagion (e.g., Allen and Gale, 1998; Freixas et al., 2000; Aghion et al., 2000).

where w, $0 \leqslant w \leqslant 1$, 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.

In order to be continued, a project requires a liquidity injection of $l > 0$ at date 1.[10] 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 ($0 \leqslant \gamma < 1$) 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 project specific knowledge). In the case of $\gamma = 0$, projects cannot be employed at other banks at all.[11]

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 before borrowing and lending (denoted L_i) 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. A bank's 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 bank's (net) liquidity need $L_i^D - L_i$ has an idiosyncratic component.

From (2) we can derive the total (aggregate) amount of liquidity in the banking sector: $L := \int_0^1 L_i \,\mathrm{d}i = 1 - X + \varepsilon X + \int_0^1 \varepsilon_i X_i \,\mathrm{d}i$, where $X := \int_0^1 X_i \,\mathrm{d}i$ is the aggregate investment in the risky asset. From the Law of Large Numbers we have that the mass of banks that have received a positive and a negative idiosyncratic shock is $1/2$ each. Therefore, we can reorder banks using an index $j \in [0,1]$ such that for $j \leqslant 1/2$ we have a bank with a positive shock and for $j > 1/2$ we have a bank with a negative shock. We can then rewrite $\int_0^1 \varepsilon_i X_i \,\mathrm{d}i$ as $\int_0^{1/2} sX_j \,\mathrm{d}j + \int_{1/2}^1 -sX_j \,\mathrm{d}j = s(\int_0^{1/2} X_j \,\mathrm{d}j - \int_{1/2}^1 X_j \,\mathrm{d}j)$. This expression is zero because the X_j's will be identical across banks due to symmetry. Hence, we have that $L = 1 - X + \varepsilon X$. The aggregate demand for liquidity is given by $L^D = \int_i L_i^D \,\mathrm{d}i = Xl$.

When $L \geqslant L^D$, 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 smooth their liquidity needs at no cost. By contrast, when $L < L^D$, there is insufficient liquidity to finance all projects in the 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 lending at such high interest rates is not possible. The motivation is that the large repayment this would imply is likely to trigger asset substitution at deficit banks. Surplus banks would anticipate this and hence refrain from lending. Appendix A formalizes such a break-

[10] 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.

[11] An alternative interpretation of the continuation of projects at other banks is that firms (= projects in our setup) have to switch banks when they can no longer obtain financing at their original bank.

down of interbank lending in a liquidity crisis as the result of deficit banks being able to switch to inferior assets that give private benefits.[12]

Note that granting each other credit lines at low interest rates at date 0 cannot improve upon the interbank market allocation. This is because banks which do not have a liquidity deficit also benefit from liquidity, since they can use it to finance projects from deficit banks. Therefore, banks would always try to draw the credit line in a crisis regardless of whether they actually have liquidity needs. Since liquidity is not observable, credit lines can thus not provide interbank smoothing.

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

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

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

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

The date 2 returns are as follows. When there is no liquidity crisis at date 1 (i.e., $\varepsilon \geqslant \hat{\varepsilon}$), 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:

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

When there is a liquidity crisis at date 1 (i.e., $\varepsilon < \hat{\varepsilon}$), we presume that each bank holds an amount of liquidity such that when it has received a negative shock, it does not itself have sufficient liquidity to finance all its assets (we call such a bank a 'deficit bank'), whereas if it has received a positive shock, it does ('surplus bank') (hence, there is partial insurance against shocks). A deficit 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 has to be 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 that remaining liquidity is $L_i - X_i l$, it can purchase (at a zero price) and finance $(L_i - X_i l)/l = L_i/l - X_i$ assets, giving each a return of γR. The bank's overall return is then

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

[12] While we assume here that there is no lending in a crisis, we show in Section 6 that our results also hold when the breakdown of lending is only partial.

A bank's total expected return at date 0, W_i, is given by

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

Using Eqs. (5)–(7), this simplifies to

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

We denote with $\bar{\varepsilon}$ the expected level of the aggregate shock in a crisis, which is given by

$$\bar{\varepsilon} := E[\varepsilon \mid \varepsilon < \hat{\varepsilon}] = \int_{-1/2}^{\hat{\varepsilon}} \varepsilon \phi(\varepsilon)\,\mathrm{d}\varepsilon \Big/ \int_{-1/2}^{\hat{\varepsilon}} \phi(\varepsilon)\,\mathrm{d}\varepsilon = \frac{\hat{\varepsilon} - 1/2}{2} = \frac{\pi - 1}{2} \tag{10}$$

where we have used $\pi = \hat{\varepsilon} + 1/2$. We can then rewrite (9) as

$$W_i = RX_i + (1 - X_i) - \frac{\pi}{2} R\big[X_i - L_i(\bar{\varepsilon} - ws)/l\big] + \frac{\pi}{2} \gamma R\big[L_i(\bar{\varepsilon} + ws)/l - X_i\big]. \tag{11}$$

From (11) we have that W_i consists of the total expected return if all projects could be continued at zero costs, $RX_i + (1 - X_i)$, minus the expected foregone returns from having to sell or liquidate assets when a deficit 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 surplus bank in a crisis, $\frac{\pi}{2} \gamma R[L_i(\bar{\varepsilon} + ws)/l - X_i]$.[13]

3.1. Equilibrium and social inefficiency

Each bank chooses X_i in order to maximize its expected return W_i in (11), subject to its liquidity holdings given by Eq. (2) and taking as given the amount of aggregate investment X (and thus π and $\bar{\varepsilon}$). We presume that the bank's optimal choice of X_i is interior. Therefore, the optimal X_i fulfills the FOC

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

[13] Note that the financial system displays an (assumed) 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. However, this fragility is not necessary for our results, see the discussion in Section 6 ('Partial breakdown of interbank lending').

Note that because of constant returns on projects, 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.[14]

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

$$W = \int_0^1 W_i \, \mathrm{d}i = RX + (1 - X) - \frac{\pi}{2} R\big[X - L(\bar{\varepsilon} - ws)/l\big] + \frac{\pi}{2} \gamma R\big[L(\bar{\varepsilon} + ws)/l - X\big] \tag{13}$$

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.[15]

Proposition 1. *Banks' provision of liquidity is inefficiently low and we have*

$$\mathrm{d}W/\mathrm{d}X_i - \partial W_i/\partial X_i = -\frac{1}{2}(1 - \gamma) R \frac{wsX}{l} \pi'(X_i) < 0. \tag{14}$$

Proof. See Appendix C. □

The inefficiency of banks' liquidity holdings arises from an externality across banks: when a bank holds less liquidity (i.e., invests more in the risky asset), it reduces the net aggregate 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 ($\hat{\varepsilon}$ increases): $\pi'(X_i) > 0$. This is costly for all banks because in a liquidity crisis, liquidity cannot be allocated efficiently. Hence $\mathrm{d}W/\mathrm{d}X_i < \partial W_i/\partial X_i$ and banks invest too little in liquidity.

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 deficit 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 deficit banks, wsX/l. The latter is because for the new states in which a liquidity crisis occurs we have $\varepsilon = \hat{\varepsilon}$ and hence $L^D = L$. Thus, deficit banks have a liquidity deficit of $wsX_i = wsX$ and surplus 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.

4. The homogenization 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 $\bar{q}$ $(0 \leqslant \bar{q} \leqslant 1)$ of its total investment X_i at date 0 into an 'aggregate 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, since it does not contain a bank specific shock.

[14] 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.

[15] This underinvestment in liquidity is common in models of liquidity provision, see for example Bhattacharya and Gale (1987).

$\bar{q}$ thus represents banks' diversification opportunities. Changes in $\bar{q}$ 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 risks that were previously considered untradeable (e.g., BIS, 2004).

To incorporate such a homogenization 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 ($0 \leqslant q_i \leqslant \bar{q}$). 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

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

Note that for $w = 1 - q_i$, (15) is identical to (2). Hence, the setup of the previous section corresponds to an aggregate degree of diversification $q = 1 - w$ with $q := \int_0^1 q_i \, \mathrm{d}i$ (because of symmetry there will be $q_i = q$ in equilibrium).

What is the degree of diversification of activities banks will choose? From Eq. (11) 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 sX_i. Thus, if a bank has received a negative shock, diversification improves liquidity by sX_i and, as a result, the bank can continue sX_i/l more assets. If a bank gets a positive shock, liquidity is lowered by sX_i, implying that 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. It suffers then less from the inability of the interbank market to smooth liquidity in a crisis. Banks thus unambiguously benefit from diversification and they always choose the maximum degree of diversification. Thus, in equilibrium we have $q_i = q = \bar{q}$.

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

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 Eq. (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 setup implicitly assumes that banks fully extract 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. 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 Eq. (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 toward 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: $\mathrm{d}X_i/\mathrm{d}q_i > 0$. Thus, aggregate investment X increases and liquidity holdings L decrease. As a result, the likelihood of a liquidity crisis rises.

In the absence of any direct stabilizing effect it follows that

Proposition 2. *A homogenization 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 toward 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 homogenization 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 (Eq. (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 arranging 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 homogenization of activities has ambiguous implications for banking efficiency.*

Proof. See Appendix D. □

Taken together, Propositions 2 and 3 suggest that in an unregulated financial system, a homogenization of banks' activities is not necessarily beneficial because banks respond by increasing their risk. With some qualifications, this also applies 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, US 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 et al., 2005). Hence, banks may have room to respond to a homogenization of their activities by increasing their risk, as in an unregulated economy.

5. Financial regulation

In this section we study how regulation should respond to a homogenization of activities in the financial system. For this we presume that the regulator has no advantage over the interbank market, that is, he cannot improve upon the liquidity allocation in a crisis.[16] 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.

5.1. 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.[17] Since liquidity 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, this L^{CB} would somehow needed to be obtained from the 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 likelihood of crises.

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

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

[16] It may seem that there is a role for regulators in reallocating liquidity between banks (as in Castiglionesi, 2007) but this is not necessarily the case since banks' liquidity holdings are not observable.

[17] 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 (Goodhart and Schoenmaker, 1995) and thus lending at high interest rates may not be feasible. Our framework can explain this by the asset substitution problem that is caused by high interest rates.

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 (Eq. (12)); it enters only indirectly via π and $\bar{\varepsilon}$. Recalling that $\bar{\varepsilon} = (\pi - 1)/2$, 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. Therefore, 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 (note that this requires that banks have enough leeway to increase investment, that is $X_i \leqslant 1$ does not become binding). 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.[18]

5.2. *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 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 $\delta \geqslant 0$. When $\partial\delta'/\partial q_i = 0$ the regulator sets the charge independent of the bank's diversification, while if $\partial\delta'/\partial q_i < 0$ 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 (Eq. (11)) minus δX_i

$$\begin{aligned} W_i = {} & RX_i + (1 - X_i) - \frac{\pi}{2} R\big[X_i - L_i\big(\bar{\varepsilon}(\pi) - ws\big)/l\big] \\ & + \frac{\pi}{2}\gamma R\big[L_i\big(\bar{\varepsilon}(\pi) + ws\big)/l - X_i\big] - \delta X_i. \end{aligned} \tag{19}$$

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

$$\frac{\mathrm{d}W}{\mathrm{d}X_i} - \frac{\partial W_i}{\partial X_i} = -\frac{1}{2}(1-\gamma)R\frac{(1-q)sX}{l}\pi'(X_i) + \delta = -\frac{1}{2}(1-\gamma)R\frac{(1-q)s}{l}\frac{1}{X} + \delta \tag{20}$$

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

$$\delta = \frac{1}{2}(1-\gamma)R\frac{(1-q)s}{l}\frac{1}{X}, \tag{21}$$

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

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

From (21) it follows that

Proposition 5. *Optimal capital requirements*

(i) *are independent of a bank's degree of diversification q_i,*
(ii) *decrease in the degree of homogenization of the financial system q,*
(iii) *are zero when there is complete homogenization* ($q = 1$).

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 stance toward a bank's individual degree of diversification. This contrasts with the diversification relief that the new Basel accord allows for operational risk[19] and with practitioners' demands (e.g., FleetBoston Financial, 2003) to provide a full capital relief also for diversification of credit risk.[20]

The reason for why an increase in the homogenization of the financial system q reduces capital requirements is as follows. When banks are more homogeneous, 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 no longer any need for interbank smoothing. Imperfections in the interbank market become irrelevant and hence there are no longer externalities across banks. The scope for imposing capital requirements vanishes.

The reduced need for regulation for when the financial system becomes more homogeneous 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 (this may be, for example, by reducing banks' franchise value, e.g., Blum, 1999).

6. Discussion

Partial breakdown of interbank lending The analysis has focused on an extreme form of interbank market breakdown: on one side the interbank market functions perfectly, while on the other side it breaks down completely. This feature has simplified the exposition but is not crucial for the results.

First of all, it is not important that the interbank market works perfectly when there is no crisis. If surplus liquidity (that is the liquidity at surplus banks that could be lend to deficit banks) cannot be reallocated in normal times as well, there will be additional inefficiencies, similar to the ones that arise in a crisis. Diversification will help to alleviate these inefficiencies since it reduces

[19] 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).

[20] 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).

the need for smoothing idiosyncratic liquidity needs. This will further lower institutions' cost of investing in the risky asset, ultimately making liquidity crises more likely.

Moreover, the results do not hinge on the interbank market breaking down completely in a crises. Suppose that at the marginal liquidity shortage (that is when $\varepsilon = \hat{\varepsilon}$) deficit banks can still borrow, but not enough to reallocate all surplus liquidity. Diversification will continue to beneficial in that case as it reduces the heterogeneity in banks' liquidity holdings and thus the need to reallocate liquidity. This gives rise to the same effects as when there is a complete breakdown (the effects will simply be less pronounced as the breakdown is only partial).[21]

For our results it is also not important that the interbank externalities work through the marginal liquidity shortage (in our model, liquidity provision at a bank lowers $\hat{\varepsilon}$ and thus reduces the states of the world in which interbank lending breaks down). Suppose that all surplus liquidity could be reallocated at the marginal liquidity shortage and that only for larger shortages the interbank market gradually stops working. Then, the previous externality may no longer be present: it is still true that liquidity provision reduces the states of the world in which liquidity crises occur but this is no longer costly since in this states interbank market imperfections are only marginal.

However, an alternative externality may then arise because a bank's liquidity provision reduces the aggregate shortage in a crisis and hence reduces imperfections in the interbank market. Crises become then less costly for all banks (while with the previous externality crises became less likely). In Appendix E it is shown that our main results continue to hold in the presence of such an externality. Again, this is because diversification lowers the amount of liquidity that needs to be reallocated and thus makes the imperfections in lending less important. The only difference to the baseline model is that a liquidity injection is no longer neutral (Proposition 4). Its impact on the probability of a liquidity crisis is ambiguous. However, this does not imply that a liquidity injection changes welfare, since liquidity crises per se are no longer socially costly. This is because imperfections only arise for larger liquidity shortages.

Social 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 no longer completely remove the need for regulation, as it only overcomes the externalities arising from the interbank market failure.

Investing in new activities and the total risk in the financial system We have presumed that the activities banks are diversifying into carry the same risk as their original activities. If this were not the case, diversification could have a direct stability effect by changing the total risks (that is the consolidated balance sheet) of the financial system. Suppose, for example, that deregulation allows financial institutions to invest in a new activity, which is not fully correlated with existing activities in the financial system. Then, diversification could 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

[21] Calculations available on request.

expanding into activities that are already undertaken in the financial sector (e.g., a bank starting insurance activities or a European bank entering the American loan market). The ongoing broadening of activities may thus not lower aggregate risk in the financial system.[22]

Diversification and correlation In our analysis, an increase in diversification makes banks' risks more similar to each other. This is not necessarily the case. For instance, in the example in the previous paragraph of diversification into an activity that is not fully correlated with other activities in the financial system, banks may not necessarily become more alike. However, ultimately, ongoing diversification will increase similarities among institutions. This is because portfolio theory stipulates that in order to by fully diversified, institutions should hold the 'market portfolio'. Thus, if all institutions are completely diversified, they all have the same portfolio and their asset risks will be perfectly correlated.

Specialization and correlation There is some discussion in the literature whether banks have also become more specialized in recent years. For example, Boot and Thakor (2000) have argued that increased competition may drive banks to specialize more in their primary activities and Acharya et al. (2006) have provided evidence consistent with this. This, by itself, should reduce bank correlation.

However, even though banks may specialize more in their primary activities (e.g., lending), they may overall still become correlated as they may also increase their risk shedding (such as through credit risk transfer). In fact, it has been argued that it is precisely the new possibility for banks to transfer a wide range of risks which allows them to specialize more in the first place. Furthermore, the evidence on bank correlation cited earlier (i.e., that the correlation among the largest US banks has nearly doubled in recent years, see Group of Ten, 2001) suggests that, at least for large banks, any specialization trend has been outweighed by activities that increase bank correlation.

Diversification versus herding In a series of papers, Acharya and Yorulmazer have shown that banks have an incentive to herd, that is to invest in the same asset. For example, in Acharya and Yorulmazer (2007) this is because banks want to increase the likelihood of failing jointly in order to induce a regulator to bail them out. In Acharya and Yorulmazer (2006), bank owners choose the same asset because they do not internalize the costs of a joint failure due to limited liability.

Herding and diversification are related in that they make institutions more similar. However, they are not identical. Suppose that there are only two banks and two assets (asset A and asset B). Complete diversification would imply that banks hold a portfolio consisting of an identical mix of asset A and B. With herding we typically mean that banks collectively either invest in asset A or in asset B. Thus, under either diversification or herding, banks become fully correlated but diversification has the additional benefit of lowering banks' portfolio risk. Therefore, in our setup banks would not herd if they also have the opportunity to diversify.

Herding, as in the papers by Acharya and Yorulmazer, and diversification, as in the present paper, also have different policy implications. In the herding papers, correlation is socially undesirable since it increases the likelihood of the joint failure of institutions. Therefore, more correlated assets may optimally attract higher capital charges. In the present paper, increased

[22] Another reason why diversification may change the total risk in the financial system is simply that banks may diversify into activities that are more or less risky than their original activity. But then, strictly speaking, we look at the combined effect of a change in diversification and a change in risk taking.

correlation is beneficial from a social perspective. This is because it reduces the need for institutions to rely on interbank risk sharing, thus lowering any externalities that may operate through the interbank market. Therefore, there is less need to discourage risky investment. This can be appreciated from Proposition 5(ii), showing that optimal capital charges decrease in q (a measure of bank correlation).

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 liquidation of assets may depress 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[23] 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. For example, Wagner (2006) has shown that, overall, diversification becomes less beneficial when there are contagion effects.

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 exposures or banks exchanging deposits. The literature has emphasized that such risk sharing is also imperfect since it may give rise to costly spillovers in a crisis (e.g., Rochet and Tirole, 1996; Allen and Gale, 2000; Aghion et al., 2000; Freixas et al., 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.

7. 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 may make institutions' portfolios appear less risky, while from an aggregate perspective risks may only be shifted around. Regulators should thus not be tempted to equate reduced portfolio risk with improved stability. Contrary to what common sense may suggest, 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

[23] 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.

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 need for regulation due to interbank externalities diminishes. This may particularly be beneficial for when regulation is subject to imperfections itself.

Acknowledgments

I thank Charles Kahn, Harald Uhlig, the editor S. Viswanathan, the referee and participants at the International Finance Conference in Copenhagen and at a seminar at Tilburg University for useful comments.

Appendix A. Complete interbank lending failure when $L < L^D$

We provide here a mechanism for a failure of the interbank market to reallocate 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, these 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; see the discussion in Section 6). We assume that a bank has at date 1 the option to use its liquid funds to start a new (and inferior) project (the 'new' project), rather than injecting liquidity into the project started at date 0 (the 'old' project). The new project also requires an outlay of l but only returns $\alpha R + l$ at date 2, with $\alpha < 1$. This return cannot be seized by outsiders, and hence is a private benefit for the bank.

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 then $(R + l) - (1 + r)l = R - rl$. 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 i 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 Eq. (6))

$$RL_i/l + L_i + (R + l)B_i/l - (1 + r)B_i = R \cdot L_i/l + L_i. \tag{22}$$

Because the net gains from borrowing are zero, this return is independent of B_i. When the bank borrows funds B_i and invests all liquidity into new projects, its date 1 return is simply the total return on the new projects: $\alpha R(L_i + B_i)/l + L_i + B_i$. This is because their return cannot be seized and because the value of the non-continued old assets is zero. From comparing the pay-offs, one can see that a bank finds it optimal to engage in assets substitution if

$$R \cdot L_i/l + L_i < \alpha R(L_i + B_i)/l + L_i + B_i. \tag{23}$$

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, restricting its ability to borrow unlimited amounts. To incorporate this feature, we assume 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 there are no seizable returns at date 2. Hence, nobody would be willing to lend to the bank and interbank lending breaks down.

Consider next the case of no aggregate liquidity shortage ($L > L^D$). The return from borrowing at the interbank market and continuing the old projects is then $RX_i + L_i$ (from Eq. (5)) as all projects can then be continued at zero borrowing costs. The return from borrowing B_i and engaging in asset substitution is still $\alpha R(L_i + B_i)/l + L_i + B_i$. Banks then find it optimal *not* to engage in asset substitution when

$$R \cdot X_i + L_i > \alpha R(L_i + B_i)/l + L_i + B_i. \tag{24}$$

When this condition is fulfilled, lending can take place. Note that the gains from borrowing and investing are higher when there is no aggregate liquidity shortage ($R \cdot X_i + L_i > R \cdot L_i/l + L_i$ since we have $X_i > L_i/l$ for a deficit bank) 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

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 surplus bank always has excess liquidity, while a deficit bank has liquidity needs. The latter follows immediately from the fact that a deficit 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 surplus bank always has enough liquidity to finance its own assets is fulfilled whenever there is sufficient liquidity at the lowest possible asset shock $\varepsilon = -1/2$. This condition writes

$$L_i(\varepsilon = -1/2) - L_i^D = 1 - X_i + (-1/2 + ws)X_i - X_i l \geqslant 0. \tag{25}$$

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

To make use of the inequality $\pi \leqslant ws$, we first show that $\partial W_i/\partial X_i$ is decreasing in π. From comparing W_i and $\partial W_i/\partial X_i$ (Eqs. (11) and (12)) we find that

$$W_i = \frac{\partial W_i}{\partial X_i} X_i + 1 + (1+\gamma)\frac{\pi}{2} R/l. \tag{26}$$

Partially differentiating w.r.t. 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

$$\frac{\partial W_i}{\partial \pi} = \frac{\partial(\partial W_i/\partial X_i)}{\partial \pi} X_i + (1+\gamma)\frac{1}{2} R/l < 0 \tag{27}$$

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

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

$$\begin{aligned}\frac{\partial W_i(ws, ws)}{\partial X_i} &= R - 1 - \frac{ws}{2} R\left[1 - \left(-1 + \frac{ws-1}{2} - ws\right)/l\right] \\ &\quad + \frac{ws}{2}\gamma R\left[\left(-1 + \frac{ws-1}{2} + ws\right)/l - 1\right] \\ &= R - 1 + \frac{ws}{2}R(1-\gamma) - \frac{ws}{2}R/l\big[3/2(1+\gamma) \\ &\quad + ws(1/2 - 3/2\gamma)\big] \leqslant 0 \end{aligned} \tag{28}$$

is met, both the FOC and $\pi \leqslant ws$ 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.

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 (11),

$$\begin{aligned} W_i^{FI} &= RX_i + (1 - X_i) + \frac{\pi}{2}\gamma R\big[L_i(\bar{\varepsilon} - ws)/l - X_i\big] \\ &\quad + \frac{\pi}{2}\gamma R\big[L_i(\bar{\varepsilon} + ws)/l - X_i\big]. \end{aligned} \tag{29}$$

Taking derivative w.r.t. X_i and comparing to the FOC condition under partial insurance (Eq. (12)) we obtain

$$\frac{\partial W_i^{FI}}{\partial X_i} = \frac{\partial W_i}{\partial X_i} + \frac{\pi}{2}(1-\gamma)R\big[1 - (-1 + \bar{\varepsilon} - ws)/l\big] > 0 \tag{30}$$

where the inequality follows from $\partial W_i/\partial X_i = 0$ and $1 - (-1 + \bar{\varepsilon} - ws)/l > 0$ (since $\bar{\varepsilon} \leqslant 1/2$). 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

$$W_i^{NI} = RX_i + (1 - X_i) - \frac{\pi}{2}R\big[X_i - L_i(\bar{\varepsilon} - ws)/l\big] - \frac{\pi}{2}R\big[X_i - L_i(\bar{\varepsilon} + ws)/l\big]. \tag{31}$$

Taking derivative w.r.t. X_i and making use of Eq. (12) we find that

$$\frac{\partial W_i^{NI}}{\partial X_i} = \frac{\partial W_i}{\partial X_i} - \frac{\pi}{2}(1-\gamma)R\big[1 - \big(-1 + (\bar{\varepsilon} + ws)\big)/l\big] < 0 \tag{32}$$

because of $1-(-1+\bar{\varepsilon}+ws)/l>0$ (since $\bar{\varepsilon}\leqslant 1/2$, $s\leqslant 1/2$ and $w\leqslant 1$). 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 $\mathrm{d}W/\mathrm{d}X_i=\partial W_i/\partial X_i+\partial W/\partial\pi\cdot\pi'(X_i)$. Using W_i from (9) and $\pi=\hat{\varepsilon}+1/2$ (Eq. (4)) we can write $W=\int_0^1 W_i\,\mathrm{d}i$ as

$$W=RX+(1-X)-\frac{1}{2}\int_{-1/2}^{\pi-1/2}R\big[X-L(\varepsilon-ws)/l\big]\,\mathrm{d}\varepsilon$$
$$+\frac{1}{2}\int_{-1/2}^{\pi-1/2}\gamma R\big[L(\varepsilon+ws)/l-X\big]\,\mathrm{d}\varepsilon. \tag{33}$$

Differentiating w.r.t. 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 $\mathrm{d}W/\mathrm{d}X_i<\partial W_i/\partial X_i$, 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, Eq. (11) for bank returns becomes

$$W_i=RX_i+(1-X_i)-\frac{\pi}{2}R\big[X_i-L_i\big(\bar{\varepsilon}(\pi)-ws\big)/l\big]$$
$$+\frac{\pi}{2}\gamma R\big[L_i\big(\bar{\varepsilon}(\pi)+ws\big)/l-X_i\big]-\pi C. \tag{34}$$

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

$$W_i=1-\frac{\pi}{2}R[-1/l]+\frac{\pi}{2}\gamma R/l-\pi C=1+\frac{\pi}{2}(1+\gamma)R/l-\pi C \tag{35}$$

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 rises after an increase in banks' diversification possibilities, it follows that efficiency increase iff

$$\frac{1+\gamma}{2}R/l>C \tag{36}$$

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.

Appendix E. Partial lending breakdown when the borrowing capacity depends on the aggregate liquidity shortage

In the following we analyze the implications of an interbank externality which does not arise at the marginal liquidity shortage (as was the case in the baseline model) but because imperfections in the interbank market depend on the aggregate liquidity shortage. To this end we assume that deficit banks in a crisis can each borrow up to an amount $B_i(\varepsilon)$, where $B_i(\varepsilon) = b_0 - b(\hat{\varepsilon} - \varepsilon)$ and $b_0, b > 0$. Note that the difference between the marginal liquidity shortage shock $\hat{\varepsilon}$ and the actual shock ε is a measure of the liquidity shortage. $B_i(\varepsilon)$ thus implies that the borrowing capacity of deficit banks falls when the aggregate liquidity shortage widens.[24]

The borrowing capacity binds when not all surplus liquidity can be lend to deficit banks. Note that a binding constraint is an aggregate concept (of course, deficit banks are individually never able to finance all their projects whenever there is a crisis due to the aggregate shortage). We make the following assumptions about when the borrowing constraint is binding and when not. First, we assume that the constraint does not bind at the marginal shortage $\hat{\varepsilon}$ (in order to isolate the effects from the ones in the baseline model). Second, we assume that the constraint eventually binds when the aggregate shortage becomes sufficiently large (we discuss the case of the borrowing constraint not binding at all at the end of this appendix when we consider Proposition 5). It follows that there exists a shock $\tilde{\varepsilon} \in (-1/2, \hat{\varepsilon})$ at which the constraint starts binding.

To save notation we use L_i^- and L_i^+ as a short cut for the liquidity of a deficit ($L_i^- = L_i(\varepsilon - (1-q)s)$) and a surplus bank ($L_i^+ = L_i(\varepsilon + (1-q)s)$), respectively. $L^- := \int_{\{i|\varepsilon_i=-s\}} L_i^- \,\mathrm{d}i$ and $L^+ := \int_{\{i|\varepsilon_i=s\}} L_i^+ \,\mathrm{d}i$ denote the corresponding aggregate values, that is the total liquidity of all deficit banks and all surplus banks. Total surplus liquidity in the economy is then $L^+ - Xl/2$. The total amount deficit banks can borrow is $B := \int_{\{i|\varepsilon_i=-s\}} B_i \,\mathrm{d}i = \frac{b_0 - b(\hat{\varepsilon}-\varepsilon)}{2}$. The return $\tilde{\varepsilon}$ at which the constraint starts binding is hence implicitly defined by

$$L^+(\tilde{\varepsilon}) - \frac{Xl}{2} - \frac{b_0 - b(\hat{\varepsilon} - \tilde{\varepsilon})}{2} = 0. \tag{37}$$

Using $L^+(\tilde{\varepsilon}) = L^+(\hat{\varepsilon}) - (\hat{\varepsilon} - \tilde{\varepsilon})X/2$ and $L^+(\hat{\varepsilon}) = Xl/2 + (1-q)sX/2$ (from the definition of $\hat{\varepsilon}$) we can rearrange (37) to yield

$$\tilde{\varepsilon} = \hat{\varepsilon} - \frac{b_0 - (1-q)sX}{b - X}. \tag{38}$$

Furthermore, we assume that an increase in return ε makes the borrowing constraint less binding (that is, the surplus liquidity which cannot be lend out falls). From (37) we have

$$\frac{\partial\left(L^+(\varepsilon) - Xl/2 - \frac{b_0 - b(\hat{\varepsilon}-\tilde{\varepsilon})}{2}\right)}{\partial \varepsilon} = \frac{X - b}{2} < 0. \tag{39}$$

Eq. (39) guarantees that the borrowing constraint remains binding for $\varepsilon < \tilde{\varepsilon}$.

There are now two different situations in a crisis. When $\varepsilon > \tilde{\varepsilon}$, all surplus liquidity can be reallocated because borrowing is unconstrained. Hence, there is an excess demand for liquidity in the interbank market due to the aggregate shortage. The interest rate is then R/l (as in the

[24] This may be the case, for example, because larger shortages result in higher interest rates and thus lower banks' borrowing capacities.

baseline model) because the return from borrowing and financing projects has to be zero for deficit banks. When $\varepsilon < \tilde{\varepsilon}$, the constraint binds, causing deficit banks' effective demand to be less then the total surplus liquidity. Surplus banks then have to be indifferent between lending out liquidity and injecting liquidity into purchased assets. The interest rate is hence $\gamma R/l$, which is the return from injecting liquidity into assets purchased (at zero price).

The new equation for a bank's expected return is

$$\begin{aligned} W_i = RX_i + (1 - X_i) &- \frac{1}{2}\int_{\tilde{\varepsilon}}^{\hat{\varepsilon}} R\left[X_i - \frac{L_i^-(\varepsilon)}{l}\right] \mathrm{d}\varepsilon \\ &- \frac{1}{2}\int_{-1/2}^{\tilde{\varepsilon}} \left(\gamma R\frac{B_i}{l} + R\left[X_i - \frac{L_i^-(\varepsilon)}{l} - \frac{B_i}{l}\right]\right) \mathrm{d}\varepsilon \\ &+ \frac{1}{2}\int_{\tilde{\varepsilon}}^{\hat{\varepsilon}} R\left[\frac{L_i^+(\varepsilon)}{l} - X_i\right] \mathrm{d}\varepsilon + \frac{1}{2}\int_{-1/2}^{\tilde{\varepsilon}} \gamma R\left[\frac{L_i^+(\varepsilon)}{l} - X_i\right] \mathrm{d}\varepsilon. \end{aligned} \tag{40}$$

The first part, $RX_i + (1 - X_i)$, is the expected return on the bank's portfolio if there were no liquidity crises. The first and second integral are the losses from being a deficit bank in a crisis (compared to not being in a crisis). The first integral gives the losses when the borrowing constraint is not binding in a crisis ($\varepsilon > \tilde{\varepsilon}$). The interest rate is then R/l. Deficit banks thus do not obtain any return on the assets they cannot finance with own liquidity (as in baseline model). Thus, they lose the complete return on these assets: $R[X_i - L_i^-(\varepsilon)/l]$. The second integral relates to the case when the borrowing constraint is binding in a crisis ($\varepsilon < \tilde{\varepsilon}$). A deficit bank loses then $\gamma R/l$ on all projects that can be financed through borrowing B_i and completely loses the return on the remaining deficit projects ($X_i - L_i^-(\varepsilon)/l - B_i/l$) because those cannot be continued at the bank. The third and fourth integral represent the gains for surplus banks in a crisis. They arise because surplus banks can make use of their surplus liquidity ($L_i^+(\varepsilon) - X_i l$). The gains depend on whether the borrowing constraint is binding or not. When the constraint is not binding, all surplus liquidity can be lend out at R/l (third integral). When the constraint is not binding, surplus banks either lend out or use the liquidity to finance projects from other banks, which both yields a return of $\gamma R/l$ (fourth integral).

We can rearrange (40) to

$$\begin{aligned} W_i = RX_i + (1 - X_i) &- \int_{-1/2}^{\hat{\varepsilon}} R\left[X_i - \frac{\frac{1}{2}(L_i^-(\varepsilon) + L_i^+(\varepsilon))}{l}\right] \mathrm{d}\varepsilon \\ &- \frac{1}{2}\int_{-1/2}^{\tilde{\varepsilon}} (1-\gamma)R\left[\frac{L_i^+(\varepsilon)}{l} - X_i - \frac{B_i}{l}\right] \mathrm{d}\varepsilon \end{aligned} \tag{41}$$

showing that there are two types of costs of liquidity shortages here. First, in a crisis $X_i - \frac{1}{2}(L_i^-(\varepsilon) + L_i^+(\varepsilon))/l$ projects have to be liquidated because of the aggregate shortage (first integral). Second, when $\varepsilon < \tilde{\varepsilon}$, there are additionally also inefficient project discontinuations at originating banks because the liquidity surplus cannot be fully lend out, amounting to $L_i^+(\varepsilon)/l - X_i - B_i/l$ projects (second integral).

From (41) we can derive a bank's FOC for investment

$$\frac{\partial W_i}{\partial X_i} = R - 1 - \int_{-1/2}^{\hat{\varepsilon}} R\left[1 - \frac{-1+\varepsilon}{l}\right] \mathrm{d}\varepsilon - \frac{1}{2}\int_{-1/2}^{\tilde{\varepsilon}} (1-\gamma)R\left[\frac{-1+\varepsilon+(1-q)s}{l} - 1\right] \mathrm{d}\varepsilon = 0. \tag{42}$$

From integrating (41) over i we find that welfare is given by

$$W = RX + (1-X) - \int_{-1/2}^{\hat{\varepsilon}} R\left[X - \frac{L^{-}(\varepsilon)+L^{+}(\varepsilon)}{l}\right] \mathrm{d}\varepsilon \tag{43}$$

$$- \frac{1}{2}\int_{-1/2}^{\tilde{\varepsilon}} (1-\gamma)R\left[\frac{2L^{+}(\varepsilon)}{l} - X - 2\frac{B}{l}\right] \mathrm{d}\varepsilon. \tag{44}$$

We next analyze whether Propositions 1 to 5 still hold.

Proposition 1 *(Underprovision of liquidity)*. Consider the impact of investment at bank i on other banks. As in the baseline model, investment increases the return at which the marginal shortage occurs ($\hat{\varepsilon}'(X_i) > 0$). But this has no longer welfare implications since there is no imperfection at the marginal liquidity shortage anymore. The same holds true for the return at which the constraint starts binding ($\tilde{\varepsilon}$): it increases ($\tilde{\varepsilon}'(X_i) > 0$) but the additional imperfections are only marginal. However, by increasing the aggregate shortage $\hat{\varepsilon} - \varepsilon$, investment reduces deficit banks' borrowing capacity B ($B'(X_i) < 0$). This allows for less assets to be financed at their originating banks when $\varepsilon < \tilde{\varepsilon}$, and thus causes more unnecessary project discontinuations. Hence, there is a negative investment externality, from which it follows that there is overinvestment and underprovision of liquidity.

Formally we have that the investment externality is

$$\frac{\mathrm{d}W}{\mathrm{d}X_i} - \frac{\partial W_i}{\partial X_i} = \frac{\partial W}{\partial \hat{\varepsilon}}\hat{\varepsilon}'(X_i) + \frac{\partial W}{\partial \tilde{\varepsilon}}\tilde{\varepsilon}'(X_i) + \frac{\partial W}{\partial B}B'(X_i) + \frac{\partial W}{\partial X_i} - \frac{\partial W_i}{\partial X_i} = \frac{\partial W}{\partial B}B'(X_i)$$
$$= \frac{1}{2}\int_{-1/2}^{\tilde{\varepsilon}} (1-\gamma)R\frac{B'(X_i)}{l}\hat{\varepsilon}'(X_i)\,\mathrm{d}\varepsilon = -\frac{1}{2}(\tilde{\varepsilon}+1/2)(1-\gamma)R\frac{b}{l}\frac{1}{X^2} < 0. \tag{45}$$

Proposition 2 *(Stability falls)*. Analogous to Eq. (16) we have that a bank's return increases in its degree of diversification

$$\frac{\partial W_i}{\partial q_i} = \frac{1}{2}(\tilde{\varepsilon}+1/2)(1-\gamma)R\frac{sX_i}{l} > 0. \tag{46}$$

Hence, a rise in diversification opportunities $\overline{q}$ will still raise diversification in the banking system. Note that compared to the baseline model (Eq. (16)), diversification now brings lower gains since $\pi = \hat{\varepsilon} + 1/2 > \tilde{\varepsilon} + 1/2$. This is because there are now only inefficient project discontinuations in a crisis when $\varepsilon < \tilde{\varepsilon}$.

Analogous to Eq. (17) we have that diversification raises the return on investment

$$\frac{\partial(\partial W/\partial X_i)}{\partial q_i} = \frac{1}{2}(\tilde{\varepsilon} + 1/2)(1-\gamma)R\frac{s}{l} > 0. \tag{47}$$

Therefore, banks will increase their investment following an improvement of diversification opportunities, implying that stability falls.

Proposition 3 *(Ambiguous implications for banking efficiency)*. When there are costs $C > 0$ of being in a crisis, a bank's return becomes (from Eq. (41))

$$W_i = RX_i + (1 - X_i) - \int_{-1/2}^{\hat{\varepsilon}} R\left[X_i - \frac{\frac{1}{2}(L_i^-(\varepsilon) + L_i^+(\varepsilon))}{l}\right]\mathrm{d}\varepsilon - \frac{1}{2}\int_{-1/2}^{\tilde{\varepsilon}} (1-\gamma)R\left[\frac{L_i^+(\varepsilon)}{l} - X_i - \frac{B_i}{l}\right]\mathrm{d}\varepsilon - \pi C. \tag{48}$$

The FOC for X_i is unchanged and given by Eq. (42). Multiplying the FOC with X_i and subtracting from the bank's return above gives

$$W_i = 1 + \int_{-1/2}^{\hat{\varepsilon}} R/l\,\mathrm{d}\varepsilon + \frac{1}{2}\int_{-1/2}^{\tilde{\varepsilon}} (1-\gamma)R[-1/l + B_i/l]\,\mathrm{d}\varepsilon - \pi C. \tag{49}$$

Integrating over i and using $\int_0^1 B_i\,\mathrm{d}i = 2B$ (from the definition of B) we get for welfare

$$W = 1 + \int_{-1/2}^{\hat{\varepsilon}} R/l\,\mathrm{d}\varepsilon + \frac{1}{2}\int_{-1/2}^{\tilde{\varepsilon}} (1-\gamma)R[-1/l + 2B/l]\,\mathrm{d}\varepsilon - \pi C. \tag{50}$$

Differentiating with respect to π, we have that welfare increases iff

$$\frac{R}{l} + \frac{1}{2}(1-\gamma)(2B-1)\frac{R}{l}\tilde{\varepsilon}'(\pi) - \frac{1}{2}(\tilde{\varepsilon} + 1/2)(1-\gamma)\frac{R}{l}b > C. \tag{51}$$

Hence, we have on the one hand that efficiency increases if $C = 0$ and γ is close to one (the second and the third term in (51) then vanish). On the other hand, efficiency falls if C is sufficiently large.

Proposition 4 *(Neutrality of a liquidity injection)*. Consider that the central bank commits to a liquidity injection of $L_{CB} > 0$ in a crisis. Without an adjustment in banks' portfolios, this would reduce $\hat{\varepsilon}$ (Eq. (18)). Now suppose that banks increase their investment X such that $\hat{\varepsilon}$ remains constant. What does this imply for $\tilde{\varepsilon}$? Differentiating (38) with respect to X (holding $\hat{\varepsilon}$ constant) gives $-\frac{b_0-(1-q)sb}{(b-X)^2}$. This expression can be positive or negative. Hence, the impact on $\tilde{\varepsilon}$ is ambiguous. From (42) we have then that the total impact of the liquidity injection (including the assumed offsetting investment behavior) on the marginal return on investment $\partial W_i/\partial X_i$ is undetermined (as compared to the original equilibrium) since $\hat{\varepsilon}$ has remained constant. As the marginal returns were zero before the injection (since the FOC was then fulfilled), it follows that the marginal returns may now be smaller, larger, or equal to zero. Thus, it is undetermined whether and how banks would like to deviate from the a situation where $\hat{\varepsilon}$ is unchanged. It follows that the impact on the probability of a crisis is ambiguous.

Generally, a liquidity injection is hence not neutral but this has no direct welfare implications here. This is because changes in the likelihood of aggregate liquidity shortages do not affect welfare since inefficiencies only start when the borrowing constraint becomes binding.

Proposition 5 *(Capital requirements)*. The optimal capital charge has to offset the investment externality. From (45) we hence have

$$\delta = \frac{1}{2}(\tilde{\varepsilon} + 1/2)(1-\gamma)R\frac{b}{l}\frac{1}{X^2} \geqslant 0. \tag{52}$$

The externality thus increases with $\tilde{\varepsilon}$. The reason for this is that a higher $\tilde{\varepsilon}$ means that there is a wider range of returns for which the borrowing constraint is binding. Using Eq. (38) and $\hat{\varepsilon} = 1 + l - 1/X$ we obtain

$$\tilde{\varepsilon} = 1 + l - 1/X - \frac{b_0 - (1-q)sX}{b - X}. \tag{53}$$

From (20) it can first be seen that $\tilde{\varepsilon}$ (and thus also the externality) does not depend on an individual bank's diversification degree q_i. This is for the same reasons as in the baseline model. Second, the externality falls with q (this follows from $b > X$, which is guaranteed by Eq. (39)). The reason is that a more homogeneous banking system reduces the need to relocate liquidity, which makes borrowing constraint becomes less binding ($\tilde{\varepsilon}$ falls). This in turn reduces the range of shocks for which there are investment externalities, thus lowering the total externality.

Moreover, when q becomes sufficiently large, the liquidity that has to be redistributed to deficit banks becomes small and eventually vanishes. The borrowing constraint will then no longer be binding (formally, $\tilde{\varepsilon}$ in Eq. (40) will be $-1/2$). As a result, the externality will be zero (Eq. (52) for $\tilde{\varepsilon} = -1/2$) and hence there should not be a capital charge. This is in particularly true for $q = 1$, since banks are then identical ex post and there is then no surplus liquidity that could be reallocated.

References

Acharya, V., Yorulmazer, T., 2006. Limited liability and bank herding. Mimeo, London Business School, 2006.

Acharya, V., Yorulmazer, T., 2007. Too many to fail—An analysis of time-inconsistency in bank closure policies. J. Finan. Intermediation 16, 1–31.

Acharya, V., Hasan, I., Saunders, A., 2006. Should banks be diversified? Evidence from individual bank loan portfolios. J. Bus. 79, 1355–1412.

Aghion, P., Bolton, P., Dewatripont, M., 2000. Contagious bank failures in a free banking system. Europ. Econ. Rev. 44, 713–718.

Allen, F., Carletti, E., 2006. Credit risk transfer and contagion. J. Monet. Econ. 53, 89–111.

Allen, F., Gale, D., 1998. Optimal financial crises. J. Finance 53, 1245–1284.

Allen, F., Gale, D., 2000. Financial contagion. J. Polit. Economy 108, 1–33.

Allen, F., Gale, D., in press. Systemic risk and regulation. In: Carey, M., Stulz, R., (Eds.), The Risks of Financial Institutions. Chicago Univ. Press.

Allen, F., Carletti, E., Marquez, R., 2005. Credit market competition and capital regulation. Mimeo, Wharton School.

Bagehot, W., 1873. Lombard Street: A Description of the Money Market. H.S. King, London.

Bhattacharya, S., Gale, D., 1987. Preference Shocks, Liquidity and Central Bank Policy. Cambridge Univ. Press, New York.

BIS, 2004. Credit Risk Transfer. October.

BIS, 2005, International convergence of capital measurement and capital standards. November.

Blum, J., 1999. Do capital adequacy requirements reduce risks in banking? J. Banking Finance 23, 755–771.
Boot, A., Thakor, A., 2000. Can relationship banking survive? J. Finance 55, 679–713.
Castiglionesi, F., 2007. Financial contagion and the role of the central bank. J. Banking Finance 31, 81–101.
Flannery, M., 1994. Debt maturity and the deadweight cost of leverage: Optimally financing banking firms. Amer. Econ. Rev. 84, 320–331.
Flannery, M.J., 2002. Market forces at work in the banking industry: Evidence from the capital buildup of the 1990s. Mimeo. Graduate School of Business, University of Florida.
FleetBoston Financial, 2003. Letter to the Basel Committee on Banking Supervision. http://www.bis.org/bcbs/cp3/flefincor.pdf. July 31.
Freixas, X., Parigi, B., Rochet, J.-C., 2000. Systemic risk, interbank relations, and liquidity provision by the central bank. J. Money, Credit, Banking 32, 611–638.
Freixas, X., Lóránth, G., Morrison, A., in press. Regulating financial conglomerates. J. Finan. Intermediation.
Goldstein, I., Pauzner, A., 2004. Contagion of self-fulfilling financial crises due to diversification of investment portfolios. J. Econ. Theory 119, 151–183.
Goodhart, C., Schoenmaker, D., 1995. Should the functions of monetary policy and banking supervision be separated?. Oxford Econ. Pap. 39, 75–89.
Group of Ten, 2001. Report on consolidation in the financial sector. Bank for International Settlements. January.
Holmström, B., Tirole, J., 1998. Private and public supply of liquidity. J. Polit. Economy 106, 1–40.
Myers, S., 1977. Determinants of corporate borrowing. J. Finan. Econ. 5, 147–175.
Persaud, A., 2000. Sending the herd off the cliff edge: The disturbing interaction between herding and market-sensitive risk management practices. State Street Bank.
Rochet, J.-C., Tirole, J., 1996. Interbank lending and systemic risk. J. Money, Credit, Banking 28, 733–762.
Scharfstein, D., Stein, J., 1990. Herd behavior and investment. Amer. Econ. Rev. 80, 465–479.
Wagner, W., 2006. Diversification at financial institutions and systemic crises. Mimeo, Cambridge University.
Wagner, W., Marsh, I., 2006. Credit risk transfer and financial sector stability. J. Finan. Stability 2, 173–193.