Deposit insurance and money market freezes

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Abstract

In the presence of deposit insurance, a rise in counterparty risk may cause a freeze in interbank money markets. We show this in a general equilibrium model with regionally-segmented bank-based retail financial markets, in which money markets facilitate the reallocation of funds across banks from different regions. Counterparty risk creates an asymmetry between banks in savings-rich regions, which remain marginally financed by the abundant regional insured deposits, and in savings-poor regions, which have to pay large spreads in money markets. This asymmetry distorts the aggregate allocation of credit and, in the presence of demand externalities, can cause large output losses.

JEL codes: E2, E5, G2
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1   Introduction

Wholesale capital markets (including interbank money markets) perform an important economic function when not all banks have equal capabilities to raise funds among retail savers. If well-functioning, they facilitate that savings travel and are invested where they are most profitable. In this paper we argue that, in the presence of government-backed guarantees on retail deposits (i.e. deposit insurance), wholesale markets may fail to efficiently allocate funds across banks with and without access to abundant retail deposits. The problem remains latent and inconsequential in normal times (while the perceived risk of bank failure is insignificant), but can trigger a freeze of wholesale markets and cause important distortions to the allocation of credit during a bank solvency crisis. Intuitively, when the risk of bank failure becomes significant, the banks with access to abundant retail deposit funding can remain marginally financed at the relatively cheap rates paid on insured deposits, while the rest have to pay high spreads on uninsured wholesale funds (or high deposit rates as they attempt to increase their smaller deposit bases).

We analyze these distortions in the context of a tractable general equilibrium model in which households and firms operate in regionally-segmented bank-based financial markets. Wholesale capital markets facilitate the reallocation of funds across banks from different regions, so their partial or full freeze has implications for the allocation of credit across regions, and for aggregate variables such as wages, GDP, and the tax costs of deposit insurance. Under a realistic parameterization, the model allows us to assess the quantitative relevance of our predictions regarding these variables.

In the model, agents are risk-neutral and investment opportunities take the form of intertemporal production through a (commonly accessible) neoclassical technology that transforms capital and labor at some initial date into units of the numeraire at some final date. The labor market and the retail financial markets are regionally segmented. Labor is not mobile across regions. Regions have heterogeneous endowments of savings, which are channelled from households to perfectly-competitive regional banks in the form of retail deposits or bank equity. Regional firms are funded with bank loans. Banks can use an interregional *money market* to borrow from and lend to each other, thus producing a reallocation of

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savings across regions.[1] Counterparty risk in the money market (and the risk of default of bank deposits) is due to the fact that firms are exposed to regional shocks that compromise their solvency and can be negative enough to cause the failure of the corresponding regional banks.

In the theoretical part of our analysis, we compare the benchmark economy without deposit insurance (DI) to the economy with DI. Without DI, the equilibrium allocation of capital is always symmetric across regions, while in the second it is only symmetric if the probability of bank failure is zero. Otherwise, the effective marginal cost of funds faced by banks is lower in high-savings regions than in low-savings regions, which creates an asymmetry in the terms of financing that the banks can offer to the firms in their regions and, hence, the allocation of capital across regions. As a consequence, investment, wages, and output are larger in the high-savings regions than in the low-savings regions. As the underlying risk of bank failure increases, the money market spread increases, money market funding declines, and the implied asymmetries increase, up to the point in which interregional money market trade fully vanishes and the regions fall into financial autarky.

In the quantitative part, we focus on the economy with DI and compare a *pre-crisis* scenario in which the risk of bank failure is zero with several *crisis* scenarios that differ in the importance of that risk. Under our calibration, money markets spreads of around 200 basis points (resulting from a bank failure probability of roughly 2%) can be associated with reductions in the money market volume of over 75% (and a full collapse if the probability of bank failure reaches 3%). The increase in the risk of bank failure is caused by an increase in the risk of failure of firms, which always has a direct negative effect on the expected output of any region. However, in addition, the reallocation of capital away from borrowing regions and in favor of lending regions amplifies the fall in the output of the former (which reaches 7% instead of 2% in our central crisis scenario) and reduces (or even reverses) the fall in the output of the latter. In net terms, the effect of the asymmetry on total aggregate output is rather small.

The aggregate output effects of the asymmetry in the allocation of capital across regions

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[1]We could more generally refer to an interregional *capital market* but we focus on the money market because the typical maturity of money market instruments is more consistent with the short-run horizon of our analysis.

become much more significant when we extend the model to capture demand externalities due to, say, trade linkages between the regions.[2] The positive effects on the output of high-savings region are significantly lower, and the aggregate output losses due to the asymmetries turn out to explain more than half of the total output loss in our central crisis scenario (3.3% of GDP out of a total loss of 5.3% of GDP).

Several of the restrictions implied by our description of the financial system could be relaxed without substantially altering our results. As we explain below, only two of them are really key to sustain the distortions created by DI in a solvency crisis: banks' inability to attract *insured deposits* outside their region, and firms' inability to obtain *bank loans* outside their region.[3] These constraints are consistent with the fact that a large fraction of retail banking activities (especially in regards to households and small firms) are relationship- and informationally-intensive, and thus remain locally provided.

Taking these constraints as given, we also discuss reforms or interventions that, starting from an economy with DI, might allow the government to reduce the identified distortions in face of a solvency crisis: from the removal of DI or the introduction of fair risk-based deposit insurance premia (if at all feasible) to more "accommodating" policies that consist on making the government (or the central bank) absorb or subsidize the counterparty risk of the borrowing banks. The analysis of the effects of the latter sheds some light on the rationale for interventions such as the fixed-rate full-allotment facilities offered by major central banks during the 2007-2009 financial crisis.

Our paper contributes to the academic debate on the causes and consequences of sudden disruptions or freezes in financial markets. As for interbank money markets, most papers in the literature follow the tradition started by Bhattacharya and Gale (1987), who emphasize the role of these markets in facilitating the absorption of bank-specific liquidity shocks and analyze the distortions coming from asymmetric information. Freixas and Holthausen (2004) consider the issue of international integration of interbank markets for unsecured lending and emphasize the role of asymmetric information on the solvency of foreign banks as an obstacle

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[2]We capture these linkages in reduced form, by making the profitability of investment in any given region depend on the level of economic activity in the other regions.

[3]As we argue in Section 6.1, allowing firms to directly access the money market (e.g. to issue commercial paper) would not modify our results.

for the emergence of such market. Freixas and Jorge (2008) analyze the effects of monetary policy in a model in which asymmetric information can provoke credit rationing in the interbank market and cause a shortage of funding among bank-dependent final borrowers. Heider, Hoerova, and Holthausen (2009) also emphasize that adverse selection effects may impair the functioning of the interbank market, aggravating banks' tendency to respond to negative liquidity shocks by undertaking inefficient liquidation. In Allen, Carletti, and Gale (2009) there is no asymmetric information but (constrained efficient) interbank market freezes may occur when the liquidity accumulated by banks as a precaution against aggregate liquidity shocks turns out to be ex-post excessive.

The role of the funding problems of traders and intermediaries in financial market freezes have also been analyzed with models from other traditions. Huang and Ratnovski (2008), for example, consider a setup in which the short-term wholesale funding of banks plays a disciplinary role, like in Calomiris and Kahn (1991), and show that sudden refinancing problems may arise from the panic-like reaction of wholesale lenders (who underinvest in monitoring) to a noisy public signal on banks' solvency. Brunnermeier and Pedersen (2009) consider asset markets where traders face margin calls based on value-at-risk calculations, and show that liquidity dry-ups can emerge as a result of the mutually reinforcing deterioration of market liquidity and funding liquidity. Acharya, Gale, and Yorulmazer (2009) show that, when short-term lending is secured with long-term assets, small shocks can lead to large changes in the required haircuts, causing a freeze in that type of lending. Diamond and Rajan (2009) attribute credit freezes to the hoarding of liquidity by potential lenders who anticipate that they might profit from the fire-sale prices of the liquidated assets of distressed banks in a later stage of a crisis.

Our contribution differs from existing papers in that we point to DI as the key latent distortion that might lead to the freeze of money markets in response to an exogenous rise in the risk of bank failure.[4] Another distinguishing feature of our paper is that we explore our mechanism in the context of a simple general equilibrium model that brings the analysis closer to the macroeconomic tradition and opens up the possibility of assessing the

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[4]The literature on deposit insurance is aware of its multiple shortcomings, most notably in regards to moral hazard (see, for instance, Demirguc-Kunt and Detragiache, 2002) but, to the best of our knowledge, contains no reference to the distortions in regards to wholesale funding that we identify in this paper.

quantitative importance of our predictions.[5]

The rest of the paper is organized as follows. Section 2 describes the model. In Section 3, we analyze equilibrium in the benchmark economy without DI. In Section 4, we turn to the economy with DI, focusing on the differences that DI makes for the financing problems of banks and firms, and the equilibrium allocation of capital. Section 5 is devoted to the quantitative analysis of the response of the economy with DI to a rise in the risk of bank failure. Section 6 discusses the key distortions behind our results, the implications of their removal, and the effects of possible policy responses to a crisis. Section 7 concludes.

2   The Model

Consider a perfect competition model with two dates ($t = 0, 1$) and a continuum of measure one of regions indexed by $j \in [0, 1]$. In each region there are a representative household, a continuum of measure one of firms (each owned by an entrepreneur), and a representative bank. There is also a government that operates across regions. All agents are risk-neutral. There is a single good in each period which is the numeraire and can be used for both consumption and investment (i.e. as physical capital). Retail financial markets (i.e. for households and firms) are regionally segmented and bank-based, while there is a money market (MM) that allows banks to exchange funds across regions.

Households   The representative household in region j has some exogenous initial savings S_j and inelastically supplies one unit of labor in the regional labor market, where the regional wage rate is w_j. The household receives its salary income at $t = 0$ and its objective is to maximize its expected net worth at $t = 1$. For households, the financial claims issued by the regional bank (deposits and equity) are the only means of transferring wealth from $t = 0$ to $t = 1$. We consider below a benchmark economy without deposit insurance (DI) and a more realistic economy with DI. The *expected* net rate of return to depositors will be denoted by

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[5]In this dimension we connect with papers such as Romer (1985) and Van den Heuvel (2008), which introduce intermediaries in otherwise standard macroeconomic models. We also connect with papers in the tradition started by Bernanke and Gertler (1987) and Williamson (1987), who study the role of banks in the transmission of monetary and non-monetary shocks to the real economy. Recent contributions in this field include Holmstrom and Tirole (1997), Chen (2001), and Bolton and Freixas (2006). None of these papers consider interbank markets explicitly.

r_{dj} in both cases. Without DI, the *promised* deposit rate may have to incorporate a spread s_{dj} on r_{dj} in order to compensate depositors for possible losses in case of bank default. With DI, the promised deposit rate will just be r_{dj}.

For simplicity, we assume that there is a fraction π of high-savings regions with $S_j = S_H$ and a fraction $1 - \pi$ of low-savings regions with $S_j = S_L$, where $S_L < S_H$. It is convenient to refer to the aggregate exogenous savings of the whole economy as $\overline{S} \equiv \pi S_H + (1 - \pi) S_L$.

Firms   Each firm $i \in [0, 1]$ in a given region j operates a constant return to scale technology that allows it to transform the capital k_i and labor n_i employed at $t = 0$ into

$$z_{ij}[AF(k_i, n_i) + (1 - \delta)k_i] + (1 - z_{ij})(1 - \lambda)k_i \tag{1}$$

units of the consumption good at $t = 1$, where $z_{ij} \in \{0, 1\}$ is a binary random variable realized at $t = 1$ that indicates whether the firm's production process succeeds or fails, δ and λ are the rates at which capital depreciates when the firm succeeds and when it fails, respectively, A is total factor productivity, and

$$F(k_i, n_i) = k_i^{\alpha} n_i^{1-\alpha}, \tag{2}$$

with $\alpha \in (0, 1)$.[6]

Firms fail to produce output on top of k_i whenever $z_{ij} = 0$. To capture different degrees of dependence among firms' *failure* in a simple way, we assume that all firms in a region fail simultaneously with probability ε, while, otherwise, z_{ij} is independently and identically distributed across firms with $\Pr[z_{ij} = 0] = p > 0$. Hence, by the law of large numbers, the distribution of the fraction of failing firms in region j is as follows:

$$x_j = \begin{cases} p & \text{with prob. } 1 - \varepsilon, \\ 1 & \text{with prob. } \varepsilon. \end{cases} \tag{3}$$

Thus ε can be interpreted as a measure of the exposure to a negative regional solvency shock. We assume that these shocks are independently distributed across regions so that, by the law of large numbers, the ex-post fraction of affected regions is constant and equal to ε.

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[6]In Section 5, we will use A to capture regional interdependencies due to, for example, demand externalities.

Each firm i is owned and managed by a penniless *entrepreneur* who is interested in maximizing his expected net worth at $t = 1$. The firm uses a bank loan of size $l_{ij} = k_{ij} + w_j n_{ij}$ to pay in advance for the capital k_{ij} and labor n_{ij} utilized at $t = 0$. The loan is associated with a *promised* repayment R_{ij} at $t = 1$ and, as in a standard debt contract, involves an effective repayment R_{ij} if the firm does not fail and $\min\{R_{ij}, (1-\lambda)k_{ij}\}$ if the firm fails. The variables in the tuple $(k_{ij}, n_{ij}, l_{ij}, R_{ij})$ are set by a contract signed at $t = 0$. Since banks, as specified below, are perfectly competitive, this contract will maximize the expected value of the positive part of the firm's future profit (net of debt repayments), subject to the relevant participation constraints of the bank (and its security holders).

Banks   The representative bank in region j is owned and managed by a coalition of regional households which contribute equity capital e_j to the bank at $t = 0$, and become the bank's residual claimants at $t = 1$, under standard limited liability provisions. The bank maximizes its shareholders' expected net worth at $t = 1$. The bank complements its funding with regional deposits d_j, that yield an expected rate of return r_{dj}, and with funds borrowed from other banks in the interregional MM.

The bank can use its financial resources to make loans $l_j = \int_0^1 l_{ij} di$ to the regional firms and to lend to other banks in the interregional MM. The bank's balance sheet constraint imposes

$$l_j + a_j = d_j + e_j, \tag{4}$$

where a_j denotes its net lending position in the MM.[7]

The money market   Realistically, we assume that MM claims take the form of unsecured debt that is junior to retail deposits. Hence MM lenders are junior to depositors (or the government, when it provides DI). We restrict attention to parameterizations under which (in equilibrium) a bank fails when the negative regional shock is realized, which occurs with probability ε.

To deal with insolvency risk in a simple way, we assume that, for prudential reasons,

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[7]Net MM *lenders* have $a_j > 0$ and net MM *borrowers* have $a_j < 0$.

regulation requires MM lenders to hold regionally-diversified portfolios of MM loans.[8] Since regional shocks are independent, the aggregate return of these portfolios becomes not random, which eliminates the possibility of contagion (i.e. failure of the bank in one region induced by MM exposures to banks in other regions). MM lenders will require a common *expected* net return, say r, on individual MM claims. Obviously, to compensate for losses in case of default, the *promised* interest rate on MM borrowing may have to include a *spread* s_j over r.

Prudential regulation and the government   We assume that prudential regulation, in addition to obliging banks to hold well diversified portfolios of MM loans, also obliges them to diversify their lending across regional firms. For realism, we also assume that regulation establishes a minimum capital requirement of the form $e_j \geq \gamma l_j$.

In the economy with DI, the government provides full coverage (principal and interest) to the claims held by retail depositors in case of bank failure. The cost of DI is covered with (lump sum) taxes T raised at $t = 1$.

Parametric restrictions   To simplify the discussion on the determination of MM spreads, we restrict ourselves to parameter combinations for which the following two conditions hold in equilibrium.

A1 The capital requirement γ is low enough to guarantee that when all firms in a region fail $(x_j = 1)$, the corresponding regional bank goes bankrupt.

A2 Deposit liabilities in low-savings regions are large enough for the recoveries of MM lenders to be zero when the regional bank goes bankrupt.

Assumption A1 is necessary for us to talk meaningfully about counterparty risk in MM, while A2 makes MM spreads independent of the specific investment decisions of each borrower (it also makes DI relevant).[9] Specifically, under A1 and A2, the common spread s charged on

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[8]Notice that standard risk-shifting incentives might induce MM lenders to prefer non-diversified MM portfolios.

[9]Neither assumption turns out to be restrictive for the calibration of the model in Section 5. From the derivations in Sections 3 and 4, one could check that a simple sufficient condition for A1 is $\gamma < \lambda$, and for A2 is $S_L/\overline{S} > 1 - \lambda + \gamma$ as long as the equilibrium deposit interest rate is positive.

MM funds will satisfy the relationship:

$$(1 - \varepsilon)(1 + r + s) = 1 + r, \tag{5}$$

since MM lenders get paid $1 + r + s$ with probability $\Pr(x = p) = 1 - \varepsilon$ and zero otherwise, and $1 + r$ is, by definition, the lenders' required expected gross rate of return. Clearly, the spread s implicitly defined by (5) does not depend on specific decisions of the borrowing bank.

3   The Economy without Deposit Insurance

We devote this section to the analysis of equilibrium in the benchmark economy without DI. First we carefully describe the main ingredients of the problem that determines the terms of the relationship between firms and banks (and between banks and their financiers). Then we describe the partial equilibrium in any region j for a given level of the expected net rate of return on MM lending r, as well as the determination of r at the interregional general equilibrium level, and the key properties of the aggregate equilibrium outcome.

Notice that all firms in a given region j are ex ante equal and operate under constant returns to scale. The requirement that any representative regional bank holds a well diversified portfolio of regional loans implies that it finances a continuum of firms, so that firm-idiosyncratic risk is fully diversified. In the analysis below we assume, without loss of generality, that all firms $i \in [0, 1]$ in a region are funded under exactly the same contract (k_j, n_j, l_j, R_j), where we have already removed the firm subscript i, for brevity. The regional subscript j will also be dropped except if needed to avoid confusion.

We organize the contents of this section in a number of short subsections. Many of the derivations will remain valid for the analysis of the economy with DI (and will not be repeated there).

3.1 Bank owners' payoffs

When the representative regional bank is a *MM borrower* $(a = d + e - l < 0)$, the payoffs of its shareholders under limited liability are:

$$P = \begin{cases} (1-p)R + p(1-\lambda)k - (1+r+s)(l-d-e) - (1+r_d+s_d)d, & \text{if } x = p, \\ 0, & \text{if } x = 1. \end{cases} \quad (6)$$

When all firms default $(x = 1)$, the bank's net worth becomes negative, and the bank goes bankrupt. When a fraction $x = p$ default, $(1-p)R$ are the repayments from performing loans, $p(1-\lambda)k$ are the recoveries on defaulted loans, and the terms subtracted are the bank's liabilities vis-a-vis MM lenders and regional depositors, respectively.

If the bank is a *MM lender* $(a = d + e - l > 0)$, its shareholders obtain

$$P = \begin{cases} (1-p)R + p(1-\lambda)k + (1+r)(d+e-l) - (1+r_d+s_d)d, & \text{if } x = p, \\ 0, & \text{if } x = 1, \end{cases} \quad (7)$$

where the only difference with respect to (6) is that, for $x = p$, the prior liability term $(1+r+s)(l-d-e)$ is replaced by the asset term $(1+r)(d+e-l)$, which reflects the fact that the portfolio of MM lending is diversified (and, hence, its return is $1+r$ with certainty).

3.2 Deposit spreads

In the absence of DI, the spread s_d paid on the deposits of a MM borrower must satisfy

$$(1-\varepsilon)(1+r_d+s_d)d + \varepsilon(1-\lambda)k = (1+r_d)d, \quad (8)$$

since depositors get paid $1+r_d+s_d$ if with probability $\Pr(x = p) = 1-\varepsilon$ and recover $(1-\lambda)k$ with probability $\Pr(x = 1) = \varepsilon$, while $1 + r_d$ is, by definition, the expected gross rate of return on deposits.

For a MM lender, the gross returns on MM lending $(a = d + e - l > 0)$ add to the recoveries of the depositors if the bank fails, so the spread paid on its deposits s_d must satisfy instead

$$(1-\varepsilon)(1+r_d+s_d)d + \varepsilon[(1-\lambda)k + (1+r)(d+e-l)] = (1+r_d)d. \quad (9)$$

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3.3 The bank's participation constraint

Bank owners' are regional households who contribute equity funding e to the regional bank and could get an expected gross return $1 + r_d$ on those funds by investing them in regional deposits. Thus, banks' participation constraint will establish that the expected payoffs emerging from (6) and (7) must be at least as high as $(1 + r_d)e$. Hence, the participation constraint of a MM borrower will establish

$$(1 - \varepsilon)[(1 - p)R + p(1 - \lambda)k - (1 + r + s)(l - d - e) - (1 + r_d + s_d)d] \geq (1 + r_d)e, \quad (10)$$

while the participation constraint of a MM lender will require

$$(1 - \varepsilon)[(1 - p)R + p(1 - \lambda)k + (1 + r)(d + e - l) - (1 + r_d + s_d)d] \geq (1 + r_d)e. \quad (11)$$

However, if we use (8) and (9) to substitute for the terms in s_d that appear in each of these inequalities, and (5) to substitute for the term in s in the first of them, an identical participation constraint emerges for both classes of banks:

$$(1 - \varepsilon)[(1 - p)R + p(1 - \lambda)k] + \varepsilon(1 - \lambda)k - (1 + r)(l - d - e) - (1 + r_d)d \geq (1 + r_d)e. \quad (12)$$

The first two terms on the left hand side collect the total expected payoffs that the bank receives from its loans; the third term reflects the total expected payoffs associated with MM borrowing $(l - d - e > 0)$ or lending $(l - d - e < 0)$; and the fourth term is the total expected payoff to depositors. Quite intuitively, (12) says that the bank's total expected net payoffs must be sufficient to reward its owners for their equity investment.

The emergence of a common participation constraint for borrowing and lending banks is crucial to the results obtained in the remainder of this section. This feature, which will not arise in the economy with DI, is due to the fair pricing of default risk in *all* sources of bank funding, deposits included.

3.4 The firm-bank contract problem

The problem that determines the terms of the relationship between the bank and the firm (k, n, l, R), as well as the optimal financing decisions of the bank (d, e), can be formally

stated as follows:

$$\max_{(k,n,l,R,d,e)} \quad (1-\varepsilon)(1-p)[AF(k,n) + (1-\delta)k - R]$$

$$\text{s.t.} \quad (1-\varepsilon)[(1-p)R + p(1-\lambda)k] + \varepsilon(1-\lambda)k - (1+r)(l-d-e) - (1+r_d)d \geq (1+r_d)e \quad (13)$$

$$l = k + wn$$

$$e \geq \gamma l$$

from whose solution the bank's MM position can be residually obtained as $a = d + e - l$. The contract maximizes the entrepreneur's expected profit at $t = 1$, which is only positive if his or her firm does not default; otherwise, the entrepreneur, who is protected by limited liability, receives zero. Since both physical capital and labor are pre-paid at $t = 0$ using the loan l, the profit when the firm does not fail equals the output, $AF(k,n)$, plus the depreciated capital, $(1-\delta)k$, minus the previously agreed repayment to the bank, R. The first constraint in (13) is the bank's participation constraint (12). The second constraint establishes that the loan must cover the cost of the physical capital and labor used by the firm. The last constraint reflects the existence of a minimum capital requirement γ.

3.5 Equilibrium analysis

The following proposition establishes some properties of equilibrium which fix the bank's optimal capital structure decisions and simplify the rest of the analysis. All proofs are in the Appendix.

Proposition 1 *In the absence of deposit insurance, in equilibria with $d > 0$ the required expected rate of return on deposits and MM lending must be equal, $r_d = r$, banks are indifferent between deposit and equity financing, and the capital requirement is not binding.*

Intuitively, Proposition 1 involves two distinct results. The first refers to the implications of the existence of money markets for the pricing of regional deposits. It turns out that without DI, depositors and MM lenders (borrowers) fully price the implications of bank insolvency, and then the effective expected cost (return) of MM borrowing (lending) and deposits are always r and r_d, respectively. In this case, we need to have $r_d = r$, because with $r_d > r$ banks would strictly prefer MM borrowing to deposit funding, which is incompatible with $d > 0$, while with $r_d < r$ banks would find it strictly profitable to take an unlimited amount of deposits so as to lend in MM, which cannot be an equilibrium. The second result

is a type of Modigliani-Miller irrelevance result applied to banks' choice between deposits and equity funding, and is hardly surprising given the absence of frictions that make one source of funding cheaper than the other.

After imposing $r_d = r$, the terms in d and e drop out from the bank's participation constraint in (13), the constraint setting the size of the loan can be simply substituted into the simplified participation constraint, and the capital requirement constraint can be ignored. Finally, using the resulting expression of the participation constraint to substitute for R in the objective function, the problem can be written as one of unconstrained optimization:

$$\max_{(k,n)} \quad (1{-}\varepsilon)(1{-}p)AF(k,n) + (1{-}\varepsilon)[(1{-}p)(1{-}\delta){+}p(1{-}\lambda)]k + \varepsilon(1{-}\lambda)k - c(r)(k{+}wn), \quad (14)$$

where the term

$$c(r) = 1 + r \quad (15)$$

represents the *gross marginal cost of funds* to any firm that borrows from banks. Intuitively, in the economy without DI, the expected rate of return on MM lending r is the marginal funding rate faced by all banks, irrespectively of their net position in the MM.

According to (14), firm-bank contracts will determine the production plan (k,n) that, from the point of view of each firm-bank coalition, maximizes the expected gross output of the firm (inclusive of recovered physical capital) net of the cost of funding the firms' inputs.[10] The next proposition summarizes the (partial equilibrium) outcomes that result from first solving (14) and then imposing the clearing of the regional labor market ($n = 1$) to find the equilibrium regional wage rate w.

Proposition 2 *In the absence of deposit insurance, for a given required expected rate of return on MM lending r, all regions are characterized by identical aggregate investment $k(r)$, wages $w(r)$, and expected output $y(r)$.*

The Appendix contains, together with the proof, specific expressions for $k(r)$, $w(r)$, and $y(r)$. These expressions are all decreasing in r, as well as in the exposure of regions to negative solvency shocks, ε, which is also the probability of bank failure. Counterparty risk

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[10]Given some optimal plan (k,n), the remaining elements of the original contract tuple (k,n,l,R) can be recursively obtained using $l = k + wn$ to find l and the bank's participation constraint to find R.

in the MM (and, hence, the spread s paid by MM borrowers for a given r) increases with ε, but this does not create any asymmetry across regions in terms of investment, wages, and expected output. The same will not be true in the economy with DI.

The last proposition in this section refers to the equilibrium value of the MM rate and the properties of the allocation of capital across regions that emerges once we take into account the remaining regional and interregional market-clearing conditions.

Proposition 3 *In the absence of deposit insurance, the equilibrium required expected rate of return on MM lending r^* satisfies $k(r^*) = \overline{S}$. In equilibrium, all regions invest the same amount $\overline{S}$ and total expected output cannot be increased by reallocating $\overline{S}$ across regions.*

Hence, in equilibrium, the representative bank of a high-savings region lends $S_H - \overline{S}$ in the MM, while that of a low-savings region borrows $\overline{S} - S_L$. Given the underlying symmetry of regions in technologies and labor supply, the equilibrium allocation implies an equal marginal return to capital in all regions and, hence, the impossibility of getting any gain in expected output by reallocating the total initial savings $\overline{S}$ across regions. So, in the economy without DI, the MM contributes to an efficient allocation of capital across regions.[11]

4   The Economy with Deposit Insurance

For the analysis of the economy with DI, we will build extensively on what has been done in the previous section for the benchmark economy without DI. Rather than repeating the steps that led to the formulation of the firm-bank problem there, we will comment on the points at which the presence of DI makes a difference.

In terms of substance, this section shows that when counterparty risk is positive ($\varepsilon > 0$), the presence of DI creates an asymmetry between high-savings and low-savings regions which is relevant for the allocation of capital across them: firms from high-savings regions end up investing more than firms from low-savings regions. If counterparty risk is large enough, the

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[11]Since $k(r)$ is decreasing in both r and ε, but physical investment is the only possible use for the initial exogenous savings $\overline{S}$, an increase in counterparty risk, ε, will *reduce* the equilibrium required expected rate of return on MM lending r^* (so as to keep satisfying $k(r^*) = \overline{S}$) but will not modify the allocation of capital across regions.

difference in investment can be so large that trade in MM completely freezes, so that the banks in each class of region operate as in financial *autarky*.

4.1 The firm-bank contract problem with deposit insurance

The expressions of bank shareholders' payoffs, (6) and (7), and banks' participation constraints, (10) and (11), conditional on whether banks are borrowers or lenders in MM remain valid. With DI, however, depositors do not demand any spread on top of their required expected rate of return r_d, so (8) and (9) do not apply. In this case, we can properly refer to r_d as the *deposit rate*. A bank's participation constraint can be compactly written as

$$(1 - \varepsilon)[(1 - p)R + p(1 - \lambda)k - (1 + r + s\xi)(l - d - e) - (1 + r_d)d] \geq (1 + r_d)e, \qquad (16)$$

where ξ takes value 1 if the bank is a MM borrower ($l - d - e > 0$) and 0 otherwise. Intuitively, bank shareholders only care about the net payoffs obtained if the bank is solvent, which happens with $\Pr(x = p) = 1 - \varepsilon$. From shareholders' perspective, each unit of MM lending yields in expectation $(1 - \varepsilon)(1 + r)$, while each unit of borrowing costs in expectation $(1 - \varepsilon)(1 + r + s)$. This is essentially different from what we obtained in (12) without DI, where the fair pricing of uninsured deposits (via deposit spreads) made both the effective expected return of MM lending and the effective expected cost of MM borrowing equal to $1 + r$.

The problem that determines the terms of firm-bank relationships in a given region (and the optimal financing decisions of the bank) is now contingent on $\xi = 0, 1$:

$$
\begin{aligned}
\max_{(k,n,l,R,d,e)} \quad & (1 - \varepsilon)(1 - p)[AF(k, n) + (1 - \delta)k - R] \\
\text{s.t.} \quad & (1-\varepsilon)[(1-p)R + p(1-\lambda)k - (1+r+s\xi)(l-d-e) - (1+r_d)d] \geq (1+r_d)e \\
& l = k + wn \\
& e \geq \gamma l \\
& \xi(l - d - e) \geq 0; \ (1 - \xi)(d + e - l) \geq 0
\end{aligned}
\qquad (17)
$$

where the last two constraints guarantee that ξ properly describes the sign of the position of the region's representative bank in the MM. Except for them and the expression of the bank's participation constraint, this problem is tantamount to (13) and we can proceed with the analysis of equilibrium as in Section 3.

4.2 Equilibrium analysis with deposit insurance

The following proposition is the analogue of Proposition 1.

Proposition 4 *With deposit insurance, in equilibria with $d > 0$ the deposit rate r_d must be equal to $r + s$ for borrowing banks ($\xi = 1$) and r for lending banks ($\xi = 0$). With $\varepsilon > 0$, both classes of banks strictly prefer deposit to equity financing, so the capital requirement is binding ($e = \gamma l$).*

This proposition involves two distinct results. The first is on the implications of MM rates for the pricing of deposits. Quite intuitively, the deposit rate r_d paid by MM borrowers must be equal to the rate $r + s$ paid on their MM borrowing, since otherwise one of the two sources of funding would be strictly dominant. Similarly, the deposit rate r_d paid by MM lenders must be equal to the expected return r received on their MM lending, since otherwise these banks would gain by either reducing (if $r_d > r$) or increasing (if $r_d < r$) their deposit taking and MM lending in parallel.

The second result refers to the bank's optimal capital structure. With $\varepsilon > 0$, insured deposits dominate equity funding because the rate paid on deposits r_d does not include compensation for the losses that the government incurs if the bank defaults, while the returns on equity must compensate bank owners for their losses if the bank defaults. So with DI, the irrelevance result obtained in Proposition 1 no longer holds.

Substituting $r_d = r + s\xi$, $e = \gamma l$, and $l = k + wn$, in the bank's participation constraint, and abstracting for brevity from the last two constraints in the optimization problem (that one can check ex post for each class of bank), we can solve for R in the resulting participation constraint and substitute it into the objective function. This leads to

$$\max_{(k,n)} \quad (1{-}\varepsilon)(1{-}p)AF(k,n) + (1{-}\varepsilon)[(1{-}p)(1{-}\delta){+}p(1{-}\lambda)]k - c_{DI}(r{+}\xi s)(k{+}wn), \qquad (18)$$

where

$$c_{DI}(r + \xi s) = (1 + r + s\xi)[1 - \varepsilon(1 - \gamma)]. \qquad (19)$$

This problem differs from (14) in two dimensions. The first is that, relative to (14), the term $\varepsilon(1{-}\lambda)k$ is missing in (18). Without DI, the term represents recoveries that go to depositors

if the bank fails, and are priced in by them when determining the deposit spread s_d, so that the term eventually appears in the objective function of the firm-bank problem. With DI, these recoveries go to the government, as the insurer of deposits, and are not properly priced in.

The second difference refers to the gross marginal cost of funds to firms in a region, $c_{DI}(r + \xi s)$, which, in contrast to $c(r)$ in (15), depends on whether the representative bank in that region is a borrower or a lender. With counterparty risk ($\varepsilon > 0$), the implied positive MM spread s makes that cost higher in the former case than in the latter. Additionally, the factor $1 - \varepsilon(1 - \gamma)$ that appears in (19) is related to the fact that, because the losses incurred by the government when the bank fails are not internalized in the problem, bank shareholders care less about the state in which the bank is insolvent. The factor is increasing in γ because bank shareholders do internalize the loss of equity capital suffered when the bank fails.

The next proposition summarizes the outcomes that result from solving (18) and imposing the clearing of regional labor markets.

Proposition 5 *With deposit insurance, the aggregate investment, wages and expected output of a region that operates in the money market are given by some decreasing functions $k_{DI}(r + s\xi)$, $w_{DI}(r + s\xi)$ and $y_{DI}(r + s\xi)$, where ξ indicates whether the region operates as a lender ($\xi = 0$) or a borrower ($\xi = 1$).*

The proof, provided in the Appendix, contains specific expressions for the relevant functions. This result shows that, for given r, a positive MM spread s is a source of asymmetries in aggregate investment, wages, and expected output across borrowing and lending regions. If the spread increases, the asymmetries increase.

In Proposition 5, we explicitly refer to regions that *operate* in the MM because if the spread s becomes sufficiently large, potentially borrowing regions may want to invest so little given $r + s\xi$ that they no longer trade in the MM. Specifically, $k_{DI}(r + s)$ may be lower than the region's exogenous savings S_j, which in the logic of the market clearing conditions discussed in the proof of Proposition 3 would imply that the representative bank in the region is not a MM borrower. However, if simultaneously $k_{DI}(r) > S_j$, such a bank will not

be a MM lender either. In this case, the region remains in financial autarky.

To encompass the possibility of reaching an autarkic equilibrium in which the MM does not operate (in which case r is not well-defined), the following proposition establishes the existence and uniqueness of equilibrium in reference to the pair (r_H, r_L) that describes the equilibrium deposit rates for high-savings and low-savings regions, which are always well defined.

Proposition 6 *With deposit insurance, an equilibrium with an operative MM exists (and is unique) if the solution $\widehat{r}$ to the equation*

$$\pi k_{DI}(\widehat{r}) + (1-\pi)k_{DI}\left(\frac{\widehat{r}+\varepsilon}{1-\varepsilon}\right) = \overline{S}, \tag{20}$$

satisfies $k_{DI}(\widehat{r}) < S_H$. In this case, the equilibrium deposit rate is $r_H = \widehat{r}$ in high-savings regions and $r_L = (\widehat{r}+\varepsilon)/(1-\varepsilon)$ in low-savings regions. Otherwise, the equilibrium is autarkic, and deposit rates solve $k_{DI}(r_H) = S_H$ and $k_{DI}(r_L) = S_L$.

Clearly, in the absence of counterparty risk ($\varepsilon = 0$), the equilibrium involves $r_H = r_L$, the MM is operative, and the allocation of capital is symmetric across regions.

For positive but not too large counterparty risk, the MM remains operative, but deposit rates satisfy $r_H < r_L$, and the allocation of capital becomes asymmetric across regions. In fact, one can check that (20) implies that, as ε increases, $\widehat{r}$ decreases, which per se means allocating more capital to high-savings regions and, hence, less capital to low-savings regions (since total capital is always equal to $\overline{S}$). Clearly, these moves imply a reduction in the volume of MM funding that we will associate with a *partial* MM freeze. For sufficiently large values of ε, $\widehat{r}$ becomes so low and $(\widehat{r}+\varepsilon)/(1-\varepsilon)$ becomes so high that MM funding is fully inhibited and the equilibrium becomes autarkic. In this case, counterparty risk produces a *full* MM freeze.

Therefore, with deposit insurance and counterparty risk, capital is asymmetrically allocated across regions. Given the underlying symmetry of regions in terms of technologies and labor supply, this implies that the expected marginal return to capital is also different across regions. In this situation, the aggregate expected output of the economy might be increased by inducing a more symmetric allocation of capital across regions.

5 Quantitative Analysis

In this section we focus on the economy with DI and explore the quantitative implications of a solvency crisis. To this end, we compare a pre-crisis scenario in which the probability of bank failure is zero ($\varepsilon = 0$) with several crisis scenarios in which this probability becomes positive ($\varepsilon > 0$). Assuming that the single period considered in the model corresponds to a calendar year, the central crisis scenario (with $\varepsilon = 2\%$) is chosen to produce a MM spread of about 200 basis points, in line with the spreads observed in the US and European interbank markets in September and October of 2008.

For a realistic calibration of our baseline model, the exercise in the first subsection below shows that such a crisis can produce a substantial decline in the funding channeled via money markets and, in some cases, a full MM freeze. It also shows that the implied reallocation of capital comes along with a dramatic drop in the expected output of low-savings regions and, not so realistically, a moderate increase in the expected output of high-savings regions. In this first exercise, the expected aggregate output loss attributable to the asymmetry in the allocation of capital is rather small.

The apparent inconsistency of the prediction for the output of high-savings regions with the 2007-2009 experience motivates the second subsection. There, we extend the model to incorporate demand externalities whereby the profitability of investment in each region depends positively on the level of activity in other regions. For a calibration in which the crisis produces just a mild recession in high-savings regions, about half of the (larger) aggregate output losses can be attributed to the asymmetry in the allocation of capital across regions.

5.1 Calibration

The parameters of our calibration appear in Panel A of Table 1. Most of them are tightly linked to the target variables listed in Panel B and can be calibrated according to macroeconomic convention. The first two parameters in Panel A determine the allocation of savings across regions. We choose to have just half of the regions of each type ($\pi = 0.5$) so as to focus all the exogenous asymmetry between regions on their initial savings. The savings asymmetry parameter, $\mu \equiv \pi S_H / \overline{S}$, is set equal to 60%, in order for pre-crisis money market

funding to represent around 30% of aggregate GDP. Given the values of all remaining parameters, we set the exogenous savings $\overline{S}$ (not reported in the table), so as to get a pre-crisis MM rate of 4%.

[Table 1 about here.]

We choose the capital elasticity parameter α to match a labor share of 70%. The depreciation rates in case of firm success, δ, and in case of firm failure, λ, are chosen so as to produce, respectively, an aggregate capital-to-output ratio of around 3 (which is a conventional choice) and a loss-given-default on loans to firms of around 45% (which is the LGD assumed in the foundation internal-ratings-based approach of Basel II for unrated corporate loans of one-year maturity). The probability of idiosyncratic firm failure, p, produces a pre-crisis loan default rate of 3% which jumps to slightly above 5% in the central crisis scenario. Finally, the capital requirement γ is set at 8%, to match the requirement for commercial and industrial loans of Basel I (which is similar to that of the standardized approach of Basel II for unrated one-year corporate loans).

5.2 Counterparty risk and money market freezes

Table 2 compares the scenario without counterparty risk in MM ($\varepsilon = 0$) with three scenarios with subsequently larger values of the parameter that determines the probability of bank failure ($\varepsilon = 1\%$, 2%, and 3%). The first rows in Panel A report for each class of region the equilibrium deposit rate, which coincides with the marginal rate at which the corresponding representative regional bank is financed (and, with an operative MM, depends on the position of the bank in that market). As ε increases, the difference between the rates faced by the banks from each class of region increases and the volume of MM funding shrinks dramatically. In fact, for $\varepsilon = 3\%$, we obtain a full MM freeze: regions fall into financial autarky.

[Table 2 about here.]

The differences in loan rates offered by banks to the firms in each class of region open up in proportion to the differentials in banks' marginal funding costs, acting as a channel of transmission of the financial distortions from banks to firms. Panel B shows the implications

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for the allocation of capital and for expected output in each class of region and at the aggregate level. With the underlying parameter values, output falls dramatically in the low-savings regions and increases in the high-savings region. As theoretically predicted, aggregate output falls, but the fall attributable to the asymmetry in the allocation of capital across regions is rather small: for the central crisis scenario, 2% out of the obtained 2.25% fall in GDP is a direct (unavoidable) implication of the extra 2% firm failure rate associated with the crisis value of ε.

Of course, the choice of the savings imbalance parameter μ influences the initial volume of MM funding and the importance of the effects produced by the rise in counterparty risk. Alternative values such as $\mu = 0.55$ (less asymmetry) and $\mu = 0.65$ (more asymmetry) will produce an initial MM size of 15% and 45% of aggregate pre-crisis GDP, respectively. With $\mu = 0.55$, $\varepsilon = 2\%$ is enough to induce autarky but, consistently with the lower initial importance of MM funding, the associated change in GDP is more moderate and less asymmetrically distributed across regions (GDP rises 0.84% in H regions, and falls 5.05% in L regions and 2.10% in the aggregate).

Table 2 also reports the expected tax costs of deposit insurance (*DI costs*) in each scenario. These costs amount to around 3% of pre-crisis GDP with $\varepsilon = 2\%$. These figures are not simply proportional to ε and the amount of initial savings in each region for various reasons. First, DI covers both the principal and the interest of the regional retail deposits, and both are endogenously affected by various forces (equilibrium wages, equilibrium deposit rates, etc.). Second, and quantitatively more importantly, changes in banks' loans and money market assets affect the recoveries of the government in case of failure.

5.3   Amplification via demand externalities

The exercise described in the prior subsection illustrates that, in face of increases in counterparty risk, the economy with DI may experience sharp falls in the volume of MM funding and significantly asymmetric changes in the allocation of capital and in output across regions. However, in such an exercise, the aggregate output loss due to the asymmetric allocation of capital across regions seems unrealistically small. This is partly due to the fact that the crisis comes along with a moderate increase in the output of former lending regions (which benefit

from devoting more physical capital to domestic production). But such regional "booms" are inconsistent with the significant slowdowns observed in high-savings economies such as Germany, Japan, and, to a lesser extent, China during the 2007-2009 financial crisis.

Many observers partly attribute the global nature of the 2009 recession to trade linkages.[12] The profitability of investment in each region, the story goes, depends positively on the level of activity in other regions via trade or other demand or technological interdependencies that generate complementarities among the regions. We introduce these complementarities in a reduced form manner, by making the productivity factor A that appears in (1) a function of all regions' levels of activity.[13] Specifically, we postulate

$$A = \left[\int_0^1 k_j^\rho dj \right]^{\frac{\tau}{\rho}}, \tag{21}$$

where k_j is the total amount of physical capital invested in region j, $\rho \leq 1$ is an elasticity parameter, and $\tau < 1 - \alpha$ is a returns-to-scale parameter. Thus, the levels of activity in the various regions (measured by k_j) contribute to A through a CES aggregator where, intuitively, ρ measures the importance of distributing total aggregate capital evenly across the various regions.

We now repeat the same exercise as in Table 2 but for an economy in which A is determined as in (21) with $\tau = 0.5$ and $\rho = -4$; all other parameters are as specified in Table 1. The value of τ keeps the overall returns to capital, $\alpha + \tau$, below one but is irrelevant for the results reported below.[14] We choose ρ so as to obtain a mild reduction in the output of high-savings regions in the central crisis scenario.[15]

[Table 3 about here.]

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[12]See e.g. the *IMF World Economic Outlook* of April 2009, Ch. 4, p. 145, and the references therein.

[13]As happens with the aggregate demand externalities of Blanchard and Kiyotaki (1987) or the cross-country linkages considered by Obstfeld and Rogoff (1995), the decline in the level of activity in one country cannot be perfectly substituted for the increase in the level of activity in another one. Our reduced-form formalization resembles the approach taken in the literature on endogenous growth to capture technological externalities (Romer, 1986; Lucas, 1988).

[14]τ affects the size of $\overline{S}$ compatible with a pre-crisis MM rate of 4% and, hence, has an effect on the *level* of real variables such as wages and output. However, it has no effect on *relative* magnitudes and, hence, on any of the variables reported in the tables below.

[15]Letting A depend on the physical capital k_j used in each region complicates the computation of equilibrium. In equations such as (20), one needs to consider objects such as $k_H(r_H, r_L)$ and $k_L(r_H, r_L)$ instead of $k_{DI}(r_H)$ and $k_{DI}(r_L)$, respectively, in order to properly describe the fixed point (k_H, k_L) that describes partial equilibrium in the situation where firms in each region solve their production problems taking as given the production decisions of firms from other regions.

The results appear in Table 3. Most variables in Panel A show little qualitative and quantitative differences with respect to those in the same panel of Table 2. There are also little differences in terms of the reallocation of capital across regions produced by the rise in counterparty risk. The big differences appear in the variables that are associated with the (larger) size and (more even) cross-regional distribution of output losses. Out of the 5.28 percentage points of baseline GDP lost in the central crisis scenario, 3.28 percentage points are now attributable to the asymmetric allocation of capital across high-savings and low-savings regions.

6 Discussion and Robustness of the Results

In this section we first discuss the various restrictions on the structure of the financial system present in our model and the extent to which they contribute to produce the distortions to the allocation of capital that emerge when DI is in place and the probability of bank failure becomes significant. Then we comment on possible ways in which, without touching the structure of the financial system, the effects of the distortions could be ameliorated or eliminated.

6.1 Regionally-segmented banking

Several of the restrictions implied by our description of the financial system could be relaxed without substantially altering our results. For instance, our results would not change if firms could directly raise funds in an interregional capital market. To understand this, notice that the key distortion produced by DI is the implicit subsidy it provides to the banks that use (abundant) deposits as their marginal source of funding (i.e. the banks from high-savings regions in the model). These banks make loans that, for the firms that benefit from them, would dominate other sources of funding. Such an advantage would not be eliminated by the direct access of the firms that cannot benefit from those cheap loans to an interregional (or international) capital market. Equity or debt issued in such a market would still be more expensive than the loans made by the deposit-rich banks. So not having considered those financing alternatives explicitly in the model actually goes without loss of generality.

The really crucial assumptions regarding the structure of the financial system are those

referred to the segmentation of the markets for retail bank products: (i) banks' inability to attract *insured deposits* outside their region, and (ii) firms' inability to obtain *bank loans* outside their region.

If banks could attract insured deposits outside their region, deposits would tend to flow from the regions with abundant savings to the most needy banks, facilitating the equalization of the marginal return to capital across regions. In reality, there is some flow of deposits across regions (or countries) but the deposit market is far from integrated even within countries such as the US or monetary areas such as the European Monetary Union.[16] The importance of several dimensions of payment services associated with deposits that are best provided through branches placed next to depositors, the heterogeneity of legal systems, and the potential discrepancies between the effective coverage provided by deposit insurance systems to residents and non-residents (especially during a systemic crisis) pose limitations to the degree of mobility required to fully remove the friction that we capture.

If firms could obtain bank loans outside their region, loans would tend to flow interregionally from the banks with cheaper marginal sources of funding to the most needy firms, pushing also in favor of the equalization of the marginal return to capital across regions. In reality, some firms (especially large firms) have access to an interregional or international loan market (e.g. the market for syndicated loans), but many others (especially small and medium-size firms) do not. Here, informational frictions together with the monitoring and relationship aspects of bank lending emphasized by the financial intermediation literature are obvious obstacles to integration.[17] All in all, we believe that the constraints imposed on the structure of retail bank markets capture well the fact that for most households and for most small and medium-size firms the relevant banking services remain locally provided.[18]

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[16]See Becker (2007) for recent evidence on the regional segmentation of US retail bank markets.

[17]Interregional or global banks, with presence in all regions, should help achieve integration via their own "internal capital market." However, the current financial crisis has raised strong concerns about international "megabanks," especially in connection with the likely inability (or unwillingness) of their home governments to take effective responsibility for supervision, deposit guarantees, and other interventions needed if one of those banks gets into trouble.

[18]To be sure, if the distortions created by the assumed structure when the risk of bank insolvency rises are large and were anticipated in advance, we could expect banks to try to ameliorate their impact by means of contractual arrangements (e.g. obtaining lines of credit at pre-determined rates or simply securing long-term financing) or changes in their own organization (e.g. via mergers directed to create interregional banks). These precautions are unlikely to be sufficient to fully offset the impact of a crisis if the risk of a crisis is ex ante considered small, as it possibly was the case in developed economies prior to the 2007-2009 financial

6.2 Remedies to the deposit insurance distortions

Taking these constraints as given, and assuming that DI is in place, the next issue in this discussion is whether and how a government could reduce the distortions that emerge in case of a solvency crisis. The obvious theoretical remedy of removing DI, in addition to being an unrealistic short-run policy option (especially in times of a crisis), could also be a precipitate recommendation from a longer-run perspective since our model does not capture the standard panic-prevention advantages that DI might certainly have (Diamond and Dybvig, 1983). Extracting balanced normative prescriptions from the model would first require extending it so as to formally capture the reasons that might justify the existence of DI in the first place.

A solution to the distortions that we identify that would be compatible with keeping DI in place would be to introduce fair risk-based premia. In the logic of our model, such premia should replicate the spreads that uninsured depositors would demand in the absence of DI, in which case, by the logic of the results in Section 3, the distortions associated with DI would be eliminated. The main practical difficulty with this approach would be to find and apply the proper formula for the risk-based premia, especially taking into account that some of the relevant inputs might not be readily observable or verifiable.

Another alternative for ameliorating the distortions that emerge when the risk of bank failure becomes significant, is to directly subsidize money market spreads or, equivalently, to make the government partly or fully absorb the risk that the possibility of failure of the banks that borrow in the MM imposes on their lenders. Intuitively, partly or fully subsidizing such *counterparty risk* would offset the distortions derived from the differences between the marginal funding costs of borrowing and lending banks, which in turn come from the fact that the latter benefit more from the (already implicitly subsidized) access to insured deposit funding.

The subsidization of counterparty risk in practice might take many forms. For example, the central bank might temporarily undertake an active intermediation function, accepting deposits from banks at a given rate and lending to other banks at the same rate plus a reduced or zero spread (like in the fixed-rate full-allotment facilities offered during the 2007-2009

crisis.

financial crisis); this activity might temporarily eliminate all interbank MM transactions.[19] Equivalently, the government could guarantee money market liabilities (charging zero or below-market insurance premia) or directly borrow from lending banks (or from households in lending regions) in order to directly extend loans to firms from low-savings regions (or to any firm willing to accept the established financing terms).

Table 4 illustrates the effects of these policies by summarizing the quantitative effects of fully subsidizing counterparty risk in the various crisis scenarios considered in Tables 2 (for an economy without demand externalities) and 3 (for an economy with demand externalities). The simplest way to think of this full subsidization is to consider the case in which the government (or the central bank) becomes the counterparty of all interbank transactions, charging no spreads to the borrowers. That is, the government takes funds from the lending banks at some rate r and uses them to lend to the borrowing banks at the *same* rate.

[Table 4 about here.]

Both with and without demand externalities, the full subsidization policy restores the pre-crisis amount of "interbank" funding, as well as the symmetry in the allocation of capital across regions. In the central crisis scenario (i.e. with a bank failure probability of 2%), the direct expected cost of the subsidies (which coincides with the net losses that the government would incur at $t = 1$ if embarked in the intermediation activity described above) is equivalent to roughly 0.7% of pre-crisis GDP. This cost is fairly modest in comparison e.g. to the costs of deposit insurance, which is above 3% of pre-crisis GDP without the subsidy (see Tables 2 and 3). In fact, the subsidization policy has positive side effects on the costs of deposit insurance, whose importance in the central crisis scenario declines in an amount equivalent to about 0.5% of pre-crisis GDP.[20] As a result, the *net* tax cost of the adoption of the policy in the economic without and with demand externalities is of just 0.15% and 0.19% of pre-crisis GDP, respectively. In terms of GDP, the aggregate gains from restoring a symmetric

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[19]Our analysis suggests that effectively correcting the distortions due to DI when the risk of bank default becomes significant may require the central bank to follow a full-allotment policy at the relevant rate, since the terms of bank loans will eventually depend on banks' *marginal* funding costs. Injecting cheap funding in a *rationed* manner might have no effect on banks' marginal funding costs and, then, be tantamount to simply giving pure rents to the receiving banks.

[20]This variation is due to various factors, of which the most important are the changes in what the government, as the insurer of the deposits, recovers in case of bank failure. These recoveries change as the loans and money market assets held by the banks from each class of region change.

allocation of capital in the central crisis scenario are 0.25% without demand externalities and 3.28% with demand externalities.

7   Conclusions

We have developed a model that emphasizes the role of interbank money markets in allocating capital efficiently in an economy in which not all banks have equal capabilities to raise funds among retail investors. Well-functioning money markets can ensure that savings travel and are invested where they are most profitable. We have shown that a rise in the risk of bank failure, coupled with the existence of retail deposit insurance, can distort the functioning of these markets. Specifically, it can produce a sudden decline or freeze in money market funding and an asymmetric allocation of capital across the banks with and without access to abundant deposit funding.[21] Intuitively, the former can remain marginally funded at the relatively cheap (and implicitly subsidized) rates paid on insured deposits, while the latter have to pay high spreads on money market funds (or high deposit rates as they attempt to expand their small deposit bases). This has negative repercussions on the efficiency of the aggregate allocation of capital.

Our calibration-friendly general equilibrium model features a financial system where retail transactions are bank-based and regionally-segmented, and the money market facilitates the flow of funds across banks located in different regions. The model allows us to evaluate the quantitative importance of the impact of a bank solvency crisis on the volume of money market funding, deposit and loan rates, and aggregate variables such as wages, GDP, and deposit insurance liabilities.

Our paper contributes to the literature on the causes and consequences of financial market freezes. We add to the list of frictions already considered (including maturity mismatches, deposit or market lender runs, adverse selection effects, fire sales, and margin calls) by pointing to the distortions associated with deposit insurance (and its coverage of some but not all bank liabilities). Our results suggest that these distortions might be both conceptually and

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[21]Huang (2009) and Ivashina and Scharfstein (2009) provide empirical evidence on the positive relationship between banks' availability of core deposit funding and their lending during the initial phases of the 2007-2009 financial crisis.

quantitatively relevant. They also suggest that policies that imply a subsidized absorption of the risk of bank default on money market liabilities by the government (or the central bank), like some of the policies seen during the 2007-2009 financial crisis, might improve the allocation of capital by effectively reducing the asymmetries across banks with and without access to abundant deposit funding.

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Appendix

Proof of Proposition 1 The deposit decision d only enters the bank's participation constraint (12). Thus, any change in d that could allow reducing R would help increase the objective function in (14) and, hence, be optimal. It follows from the linearity of the terms in d in (12) that $r_d < r$ would lead to $d \to \infty$, which is not compatible with equilibrium, while $r_d > r$ would lead to $d = 0$. So equilibrium with $d > 0$ requires $r_d = r$. But with $r_d = r$, not only the terms in d but also the terms in e cancel out from (12), implying that any decision on e that satisfies the capital requirement, $e \geq \gamma l$, is optimal.■

Proof of Proposition 2 We have shown in the text that the problem (14) that determines firms' optimal production plans is identical for all regions. In such a problem, firms and banks take r and w as given, where r is considered as exogenous in this proposition. The regional wage w, however, is determined taking into account the market clearing condition for the corresponding regional labor market. This condition will also fix the region's expected output as a function of r.

Optimal production plans. It follows from the homogeneity of degree one of the production function $F(k,n)$, as well as the linearity in k and n of the cost terms that appear in (14) that, by Euler's theorem, the various cost terms will exhaust the expected gross returns obtained by the firm at $t = 1$ (inclusive of recovered capital), so the expected profits of entrepreneurs in an interior optimum will be zero. The first order conditions for an interior optimum are:

$$(1 - \varepsilon)(1 - p)AF_k(k,n) + (1 - \varepsilon)[(1 - p)(1 - \delta) + p(1 - \lambda)] + \varepsilon(1 - \lambda) = c(r), \qquad (22)$$

$$(1 - \varepsilon)(1 - p)AF_n(k,n) = c(r)w. \qquad (23)$$

Conditions (22) and (23) have the standard interpretation: the expected value of the marginal product of each factor is equalized to its gross marginal funding cost.

Regional labor market clearing. In addition to market clearing conditions already subsumed in the constraints of the representative firm-bank problem (e.g. for the regional loan market), the relevant condition here is $n = 1$, since the representative household has an inelastic supply of labor equal to 1. Imposing $n = 1$ directly in (22) and solving for k yields:

$$k = k(r) \equiv \left[\frac{(1 - \varepsilon)(1 - p)\alpha A}{r + (1 - \varepsilon)[(1 - p)\delta + p\lambda] + \varepsilon\lambda} \right]^{\frac{1}{1-\alpha}}. \qquad (24)$$

Now, using (23), we can recursively find the labor-market clearing wage

$$w = w(r) \equiv \frac{(1 - \varepsilon)(1 - p)(1 - \alpha)A}{c(r)}[k(r)]^\alpha, \qquad (25)$$

and, following standard accounting conventions, the expected output (or expected GDP) in the region can be recursively written as

$$y = y(r) \equiv (1 - \varepsilon)(1 - p)A[k(r)]^\alpha.■ \qquad (26)$$

Proof of Proposition 3 Since households from any region j are indifferent between investing their savings $S_j + w_j$ (which include the wages w_j paid in advance by regional firms to regional workers at $t = 0$) in deposits or equity, the clearing of regional deposit and equity markets requires

$$d_j + e_j = S_j + w_j. \tag{27}$$

On the other hand, according to Proposition 1, the representative bank in region j will set (a_j, d_j, e_j) so that the balance sheet constraint $a_j = d_j + e_j - l_j$ and the capital requirement constraint $e_j \geq \gamma l_j$ are satisfied for $l_j = k_j + w_j$ (where we have imposed $n_j = 1$). This implies

$$a_j = d_j + e_j - k_j - w_j. \tag{28}$$

But then, substituting (27) in (28) we get

$$a_j = S_j - k_j. \tag{29}$$

Now, by Proposition 2, where we already took into account firm-bank optimization and regional labor market clearing, high-savings regions will have $a_H = S_H - k(r)$, and low-savings regions will have $a_H = S_L - k(r)$. But, then, the condition for MM clearing,

$$\pi a_H + (1 - \pi)a_L = 0, \tag{30}$$

collapses, after some rearrangement, into

$$k(r) = \overline{S}, \tag{31}$$

which is the market clearing condition for the interregional goods' market at $t = 0$.[22] The existence and uniqueness of the solution r^* to (31) follows from standard arguments given the properties of $k(\cdot)$. Finally, by prior arguments, feasible reallocations (k_H, k_L) of capital across high-savings and low-savings regions should satisfy the resource constraint

$$\pi k_H + (1 - \pi)k_L = \overline{S} \tag{32}$$

and would produce an aggregate expected output Y that, using (2) with $n_j = 1$ in all j, could be written as

$$Y = \pi(1 - \varepsilon)(1 - p)Ak_H^\alpha + (1 - \pi)(1 - \varepsilon)(1 - p)Ak_L^\alpha. \tag{33}$$

Clearly, the maximization of (33) subject to (32) is attained at $k_H = k_L = \overline{S}$.∎

Proof of Proposition 4 This proposition refers to a lending bank ($\xi = 0$) and a borrowing bank ($\xi = 1$) separately, meaning that we abstract from the case of banks that find it optimal

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[22]This is an instance of Walras' Law.

to remain in autarky ($l-d-e=0$), which can be treated as a limit case of the other two. For fixed ξ, ignoring the forth set of constraints in (18), the proof of this proposition is parallel to that of Proposition 1 and we omit it for brevity.∎

Proof of Proposition 5 The analysis of regional equilibrium for a given r can be made along exactly the same lines as in the proof of Proposition 2, but taking into account the expressions in (18) and (19) rather those in (14) and (15). Proceeding accordingly, we find:

$$k = k_{DI}(r+\xi) \equiv \left[\frac{(1-\varepsilon)(1-p)\alpha A}{(1-\varepsilon)[(1-p)\delta+p\lambda]+[1-\varepsilon(1-\gamma)](r+s\xi)+\gamma\varepsilon}\right]^{\frac{1}{1-\alpha}}, \qquad (34)$$

$$w = w_{DI}(r+s\xi) \equiv \frac{(1-\varepsilon)(1-p)(1-\alpha)A}{c_{DI}(r+s\xi)}[k(r+s\xi)]^\alpha, \text{ and} \qquad (35)$$

$$y = y_{DI}(r+s\xi) = (1-\varepsilon)(1-p)A[k(r+s\xi)]^\alpha, \qquad (36)$$

which are all decreasing in $r+s\xi$.∎

Proof of Proposition 6 Consider first the possibility of having an equilibrium in which the MM is operative and $\widehat{r}$ is the expected rate of return on MM lending. Then, by Proposition 5 and using (5) to write the equilibrium MM spread in terms of $\widehat{r}$ and ε, we must have $r_H = \widehat{r}$ and $r_L = (\widehat{r}+\varepsilon)/(1-\varepsilon)$. But then, using exactly the same steps a in the proof of Proposition 3, we can summarize the relevant market clearing conditions in (20). The existence and uniqueness of the solution $\widehat{r}$ to such an equation follows from standard arguments, given the properties of $k_{DI}(\cdot)$. Now, if $k_{DI}(\widehat{r}) < S_H$, (20) will imply $k_{DI}((\widehat{r}+\varepsilon)/(1-\varepsilon)) > S_L$, so we will have a situation with $a_H > 0$ and $a_L < 0$, which corresponds to a well-defined equilibrium in which the MM is operative. In contrast, if $k_{DI}(\widehat{r}) \geq S_H$, (20) will imply $k_{DI}((\widehat{r}+\varepsilon)/(1-\varepsilon)) \leq S_L$ in which case we have $a_H \leq 0$ and $a_L \geq 0$, which is inconsistent with having high-savings regions as active MM lenders and low-savings regions as active MM borrowers.

Now, an autarkic equilibrium can be defined as a pair (r_H^A, r_L^A) that (i) solves the autarky conditions $k_{DI}(r_H^A) = S_H$ and $k_{DI}(r_L^A) = S_L$, and (ii) leaves no unrealized private gains from MM trade. Formally, since $S_H > S_L$ implies $r_H^A < r_L^A$, condition (ii) reduces to having $r_L^A \leq (r_H^A+\varepsilon)/(1-\varepsilon)$, so that there are no gains from a deal in which a bank from a low-savings region borrows at a promised rate lower than r_L^A from a bank from a high-savings region that, by doing so, obtains and expected rate of return higher than r_H^A. But when $k_{DI}(\widehat{r}) \geq S_H$ (i.e. when there is no equilibrium with an operative MM) we necessarily have $S_H \leq k_{DI}(\widehat{r}) \leq k_{DI}((\widehat{r}+\varepsilon)/(1-\varepsilon)) \leq S_L$, which implies that (r_H^A, r_L^A) satisfies $r_L^A \leq (r_H^A+\varepsilon)/(1-\varepsilon)$ and, hence, that the autarkic equilibrium exists. Conversely, when $k_{DI}(\widehat{r}) < S_H$ (i.e. the equilibrium with an operative MM exists), the candidate autarkic equilibrium does not exist. This proves the overall existence and uniqueness of equilibrium.∎

List of Tables

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Table 1
Baseline parameterization

Panel A. Parameter values

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Parameters			Baseline values
Savings:	Measure of savings-rich regions	π	0.5
	Savings asymmetry	$\mu \equiv \pi S_H / \bar{S}$	0.6
Technology:	Capital elasticity parameter in F	α	0.3
	Depreciation rate if success	δ	4.5%
	Depreciation rate if failure	λ	35%
Default risk:	Probability of idiosyncratic firm failure	p	3%
	Probability of bank failure	ε	0%-2%
Frictions:	Capital requirement	γ	8%

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Panel B. Calibration targets

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Variables		Values
Macroeconomic:	Pre-crisis money market funding / GDP	30%
	Pre-crisis money market rate	4%
	Labor share	70%
	Capital / GDP ratio	3
Financial:	MM spread	0%-2%
	Loan default probability	3%-5%
	Loan loss-given-default	45%

Table 2
Effects of counterparty risk

Panel A reports key financial variables for scenarios with subsequently larger values of the parameter that determines the risk of bank failure ε. Other parameters are as in Table 1. MM is the aggregate amount of money market lending. DI costs are the expected tax costs of deposit insurance. Panel B reports percentage changes in capital and output relative to the baseline scenario with $\varepsilon=0\%$. We provide values for high-savings (H) and low-savings (L) regions, and the aggregate economy (Aggr.).

Panel A. Financial variables (%)

| | | Probability of bank failure (ε) | | | |
		0%	1%	2%	3%
Deposit rates	H	4.00	3.43	2.92	2.62
	L	4.00	4.48	5.02	5.33
MM / baseline GDP	Aggr.	31.86	19.29	6.93	0.00
Loan rates	H	5.56	5.04	4.59	4.36
	L	5.56	6.15	6.82	7.24
DI costs / baseline GDP	H	0.00	1.70	3.53	5.41
	L	0.00	1.14	2.63	4.24
	Aggr.	0.00	1.42	3.08	4.83

Panel B. Change in capital and output relative to baseline scenario (%)

| | | Probability of bank failure (ε) | | |
		1%	2%	3%
Capital	H	7.89	15.65	20.00
	L	-7.89	-15.65	-20.00
GDP	H	1.28	2.37	2.45
	L	-3.41	-6.88	-9.28
	Aggr.	-1.06	-2.25	-3.41

Table 3
Amplification via demand externalities

This table considers the effects of counterparty risk in an economy with reduced-form demand externalities parameterized by $\tau=0.5$ and $\rho=-4$. Other parameters are as in Table 1. Panels A and B are organized as in Table 2

Panel A. Financial variables (%)

		Probability of bank failure (ε)			
		0%	1%	2%	3%
Deposit rates	H	4.00	3.36	2.64	2.23
	L	4.00	4.40	4.73	4.82
MM / baseline GDP	Aggr.	31.86	19.20	6.22	0.00
Loan rates	H	5.56	4.96	4.29	3.95
	L	5.56	6.07	6.51	6.70
DI costs / baseline GDP	H	0.00	1.69	3.48	5.27
	L	0.00	1.13	2.60	4.12
	Aggr.	0.00	1.41	3.04	4.70

Panel B. Change in capital and output relative to baseline scenario (%)

		Probability of bank failure (ε)		
		1%	2%	3%
Capital	H	7.95	16.10	20.00
	L	-7.95	-16.10	-20.00
GDP	H	0.51	-0.67	-2.30
	L	-4.18	-9.89	-13.49
	Aggr.	-1.84	-5.28	-7.89

Table 4
Effects of subsidizing counterparty risk

This table reports the effects of a full government subsidization of the spreads that borrowing banks would have to pay in money markets due to counterparty risk. The direct expected tax costs of the subsidies are reported as % of baseline GDP. DI costs and GDP are reported as % variation relative to the situation without the subsidy. Those situations are described in Tables 2 and 3 for the economies without and with demand externalities, respectively.

		Probability of bank failure (ε)		
		1%	2%	3%
Cost of subsidies / baseline GDP	Aggr.	0.33	0.66	0.99
Reduction in DI costs / baseline GDP				
– Without demand externalities	H	0.08	0.30	0.57
	L	0.18	0.72	1.39
	Aggr.	0.13	0.51	0.98
– With demand externalities	H	0.07	0.25	0.43
	L	0.17	0.69	1.27
	Aggr.	0.12	0.47	0.85
Improvement in GDP / baseline GDP				
– Without demand externalities	H	-2.28	-4.37	-5.45
	L	2.41	4.88	6.28
	Aggr.	0.06	0.25	0.41
– With demand externalities	H	-1.51	-1.33	-0.70
	L	3.18	7.89	10.49
	Aggr.	0.84	3.28	4.89