Banking Concentration: Implications for Systemic Risk and Safety-net Design

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The 1990s saw a global trend toward increased banking concentration. Given that this emergence of larger financial institutions seems to be a permanent change, understanding the implications of the trend is a highly relevant exercise, in particular for small countries like Chile. This paper analyzes safety net issues for a highly concentrated banking system in which, in addition, the total number of players (banks) is low. The safety net is commonly understood as the set of institutions created to guarantee the proper functioning of the financial system (financial institutions and markets) in the economy. It is typically considered to serve the following functions: regulation and supervision, lender of last resort, and deposit insurance. Regulation includes mechanisms for bank closure. One point of this paper is that the importance of these functions and the way they have to be designed or executed is not independent of either the level of concentration or the total number of banks in the system. Recommendations of best practices, then, have to take these considerations into account.

This paper analyzes two dimensions of the impact of concentration on the banking safety net. The first is deposit insurance. In recent years, important efforts in understanding deposit insurance and deriving best practices for it has been made (see Demirgüç-Kunt and Detragiache, 1999; Demirgüç-Kunt and Huizinga, 2000; Financial

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Stability Forum, 2001). This paper contributes to this literature by exploring the implications of concentration for deposit insurance design. One conclusion of the paper is that deposit insurance design cannot be thought of as a stand-alone instrument, but rather must be understood as an element of the intervention and resolution policy.

The second issue refers to systemic risk. I use the Eisenberg and Noe (2001) approach to model a banking network to assess the impact of banking concentration on systemic risk. A working metric of the "too big to fail" situation can be derived in the model. The model also allows testing measures that can contain systemic risk.

The organization of the paper is straightforward. Section 1 discusses deposit insurance. Section 2 presents the model and explores the relation between systemic risk and concentration. A final section summarizes the main results.

1. Deposit Insurance, Resolution Methods, and Banking Concentration

This section discusses the essential characteristics of a deposit insurance system in the case of a highly concentrated banking system featuring a low number of banks. The section starts by considering the role of deposit insurance as an element of the financial system's safety net. It then describes the design of such a system for a country like Chile. Finally, the current situation of the deposit insurance scheme in Chile is analyzed in the light of the previous discussion.

1.1 The Role of Deposit Insurance in the Safety Net

Deposit insurance is one of the most visible elements of the safety net for the public—maybe even the only visible element. Conventional wisdom typically considers the prevention of bank runs as the main role of deposit insurance. Understanding the extent to which a bank run can happen is crucial for designing an efficient deposit insurance system and setting realistic goals for it. In addition to this role, deposit insurance protects small depositors. While this may sound less grandiose, it may, in fact, be the more realistic objective.

The argument linking deposit insurance and bank runs was first formally presented by Diamond and Dybvig (1983), who hold that runs can be a self-fulfilling equilibrium. This idea has been influential in safety net design and has contributed to the view that financial markets are essentially unstable and prone to crises not necessarily backed by fundamentals. Their paper shows that a certain level of deposit insurance can make the "no run" strategy the dominant one, thus eliminating the equilibria with runs. They acknowledge that lender-of-last-resort functions can have the same effect, although they do not explore it formally.

Two elements have to be considered for policy design, however. First, empirical evidence indicates that historically, bank runs have not necessarily been the expression of unfounded panics, but rather have usually occurred in a context of real bank insolvency (Calomiris and Mason, 1997; Gorton, 1988; Kaufman, 1994). Moreover, solvent banks apparently have not suffered from contagion in these events—that is, depositors have discriminated, and there have not been runs on solvent banks. Second, if panics were a high probability event, the only deterrent would be a back-up fund equal to total deposits. In the absence of such a fund, rational depositors would know that the deposit insurance fund was limited, and they would have incentives to run if they believe that others would run. The panic hypothesis thus has clear predictions about the type of deposit insurance that should be in place.

In this context, an alternative to deposit insurance is lending by the central bank. If there is a run on a bank not based on fundamentals, the central bank can step in and provide the required liquidity against good collateral—as per the classical recommendation by Bagehot (1873). If the run is based on fundamentals, then it is optimal to close the bank. Moreover, if this is the case, the bank will have been closed promptly and no run will ever have taken place. There is hardly any reason to believe that the public will know about a bank's insolvency before the regulator.

The latter argument is incomplete, though, in that it leaves out a case that points to a role for deposit insurance. This case arises when a bank is weak and the regulator cannot fully discern whether the bank is viable. A run is a possible response here, this time granted by fundamentals. The central bank will have to make a decision about whether to lend to this bank when it may not have full information. It would risk losses if it lends and the bank is not solvent. On the other hand, if the central bank does not lend, the economy may experience efficiency losses when projects with a positive net present value are shut down. The need for a possibly inefficient decision can be avoided with deposit insurance, which can contain the run on the bank. What is needed to contain the run is a credible promise that deposits will be repaid. The promise is credible as long as the deposit insurance system has—or has credible access to—sufficient funds to cover insured deposits. In this context, credibility implies that the deposit insurance system should have sufficient funds to pay the deposits of weak banks and not of the entire system.

A corollary of this line of reasoning is that the type of crisis for which the deposit insurance system could be useful is determined by the amount of funds that the deposit insurance can credibly offer. If policymakers expect the deposit insurance system to help in situations of widespread weakening of the banking system, then it should have credible access to enough funds to cover all deposits in the system. This would likely be a very large amount, which is why most deposit insurance systems in the world are not expected to be useful in cases of systemic crisis, but rather are used to deal with isolated bank failures.[1]

An alternative approach leads to a similar conclusion. Dewatripont and Tirole (1994) develop a theory of banking regulation based on what they call the representation hypothesis. By this they mean that regulation is necessary to represent a large number of small depositors who may find it costly to monitor a bank individually, in particular if their deposits are small. Regulation and supervision will restore adequate incentives for good corporate governance of a bank in the presence of an atomized principal. Deposit insurance arises in this context to protect small depositors by minimizing their losses in case of bank failure.

In reality, most deposit insurance systems seem closer to the second approach than to the first. The first approach calls for protection for those most likely to run—arguably, large depositors. The second is consistent with limits on protection per depositor.

1.2 Deposit Insurance in a Highly Concentrated System

The key message of the previous section is that a deposit insurance system should be designed to deal with isolated bank failures. In contrast, deposit insurance should not be counted on in the face of systemic problems, that is, when a substantial fraction of the banking system is in trouble. This has two implications for highly concentrated

1. A recent report by the Financial Stability Forum (2001) explicitly recommends that deposit insurance systems should not be expected to deal with systemic crises.

systems with a low number of institutions. First, such systems are likely to be characterized by the presence of so-called systemic banks—that is, banks that control a significant fraction of the systems assets. The large size of these banks implies that the deposit insurance fund necessary to cover the potential losses generated in paying the deposit insurance guarantee is too big. Moreover, the systemic importance of a large bank may be such that authorities would decide not to close it even in the face of insolvency, and the bank's problems would have to be addressed in a way that does not imply depositor repayments. This implies that the liabilities generated by the deposit insurance should not be expected to be paid in the case of large banks. Second, in the case of systems with a low number of banks, the system will basically be relevant for only a few banks. Since failure is an unusual event from an individual bank's perspective, the deposit insurance guarantee should not need to be executed too often.

To illustrate this point, I compare the deposit insurance system in the United States (the Federal Deposit Insurance Corporation, or FDIC) with a hypothetical deposit insurance system in Chile. The Chilean banking system contains far fewer banks than the United States, with 25 and 8,505, respectively. The Chilean system is also much more concentrated, as shown in table 1.

For the case of Chile, I consider the current structure of coverage, under which all demand deposits are covered in full, while term deposits of natural persons are covered up to UF108 (approximately US$2,600 at the current exchange rate). For simplicity, I assume that all depositors qualify for insurance, that is, I make no distinction between natural and legal persons. I leave comments on this coverage structure and room for improvement for the next section.

Table 1. Chile and the United States: Concentration Measured as Share of Total Loans
Percent

	Share of total loans	
Size group	*Chile 2002*	*United States 1999*
Largest single bank	26	8
Largest five banks	74	27
Largest ten banks	92	37
Largest fifteen banks	99	43

Source: SBIF (Sept. 2002); Group of Ten (2001).

Next, I assume that the Chilean system follows a similar rule to that of the United States, namely, that its target fund is 1.25 percent of covered deposits. This gives an approximation of the effective protection that the deposit insurance system is prepared to give for failures in the system. An alternative metric would be obtained by considering effective premiums charged by deposit insurance systems around the world. The data in the Demirgüç-Kunt and Sobaci (2000) world database on deposit insurance shows that 58 out of the 68 countries with explicit deposit insurance charge premiums (the others rely on ex post funding from surviving institutions or government funding). The average maximum rate is 0.36 percent of deposits while the median maximum rate is 0.24 percent. The problem is that it is not possible to know from the database whether countries target a fund of a determined size. However, a deposit insurance scheme charging the median rate will reach a target similar to that of the United States in five years. Considering that the fund is, in fact, used to pay out the guarantee, the United States target seems a reasonable order of magnitude for the funds that real deposit insurance systems should have in their steady states.

Table 2 compares the extent of protection under a concentrated versus a decentralized system. In the case of Chile, coverage is determined from data on distribution of deposits by size. Coverage limits are more generous in the United States, implying that the fraction of deposits covered is more than twice that of Chile under the current limits. The comparison is startling, however, when based on banks that are effectively protected, that is, those whose insured deposits are less than or equal to the deposit insurance fund. In the United States the fund is relevant for almost eight thousand banks, whereas

Table 2. Protection in Chile and in the United States

		Chile	
Measure of protection	*United States (FDIC)*	*Current limits*	*Proposed limits*
Insured deposits as percent of total	67.2	28.7	28.1
Banks that are effectively covered[a]	7,888[b]	14	14
Banks in the deposit insurance system	7,966	25	25
Ratio (expressed as percent)	99	56	56
Total deposits in effectively covered banks as percent of total	33.8[b]	8.6	8.6

Source: FDIC (2002); SBIF (2002).
a. Banks whose insured deposits are equal to or lower than the deposit insurance system fund, estimated as 1.25% of covered deposits.
b. At least.

in Chile it would be relevant for only 14. These effectively protected banks hold at least 34 percent of total deposits in the United States, while that figure would be only 8.6 percent in Chile.

This analysis implies that the question of how to design and organize a deposit insurance system becomes less relevant in the case of a highly concentrated system. This question has received a lot of attention from multilateral institutions in recent years, and sets of recommendations and best practices have been produced (García, 1999; IMF, 1998; Financial Stability Forum, 2001). However, the necessary elements for a country's decision on whether to have deposit insurance and what to expect from it typically are not part of the discussion.

Deposit insurance policy must be seen as an element of a broader policy encompassing the optimal intervention and resolution of distressed banks. The design of the specific elements of the deposit insurance should be carried out as part of this broader context. While the challenges of intervention and resolution policy in a highly concentrated system are beyond the scope of this paper, some elements to be considered are that the likelihood of banks being closed or liquidated is low and that bank resolution will most likely come in the form of purchase and assumption (P&A) operations. To minimize the cost of these operations, regulation should stress early intervention. The focus of the deposit guarantee management switches toward this type of issues.

I now revisit three questions: Does deposit insurance make sense in a highly concentrated system? If yes, should the deposit insurance system have a fund? And finally, should the public sector participate in the funding of the deposit insurance system? The answer to the first question is yes. The two arguments put forward in support of an explicit guarantee (Dewatripont and Tirole's representation hypothesis and the prevention of a run when it is difficult to discern the solvency of a distressed bank) remain valid. In addition, depositors can rationally anticipate that the likelihood of a large bank being liquidated is lower than that of a small bank being liquidated, and they may therefore prefer the large bank. This implies that an explicit deposit guarantee would correct a bias against small banks and become a force against concentration.

The answer to the second question is also yes, but with a limit. As explained before, a fund will definitely be used for depositors' repayment less in a concentrated than in a decentralized system. A fund will also be needed, however, to cover potential losses in P&A operations. In either case, the frequency of these operations will be low, which raises the question of whether the cost of maintaining a contingency fund is justified. The alternative would be to raise funds from the industry (and maybe from the government, as well, as discussed later) to cover the losses derived from the guarantee in the case of a bank failure. This may be seen as unfair, however, as long as the failed banks that caused the losses do not pay. The highly concentrated case thus calls for maintaining a fund, but at a lower level than in a less concentrated system.

With regard to the third question, the answer depends on the rationale that supports the existence of the deposit insurance. If it is only expected to protect small depositors, then the deposit insurance should be funded by the industry. Protecting small depositors will attract them as customers, which benefits the industry. If the deposit insurance is expected to give the regulator the necessary time to discern the viability of a bank, then a case can be made for partially funding the deposit insurance through the public sector. Such a fund would allow the authority to avoid the risk of acting as lender of last resort to a bank that is potentially insolvent. At the same time, it avoids the risk of closing a solvent bank, which would lead to efficiency losses if projects with a positive net present value are cancelled.

1.3 Comments on the Current Deposit Insurance Guarantee in Chile

The main facts of deposit insurance in Chile were described in the previous section. Demand deposits are covered in full, while term deposits are covered with a low limit (approximately US$2,600) and for natural persons only. Table 2 shows the coverage implied by the size distribution of deposits.

The main criticism of this structure is that protection to demand deposits is unlimited. Depositors facing a situation of distress could move from term to demand deposits massively, in search of full protection. The effective guarantee that the central bank is giving to the public can thus be multiplied several times in a short period. In the extreme case, all deposits could be moved to demand deposits, with the effective coverage being multiplied by a factor of 3.5.

The logic of protecting demand deposits in full is that they are deemed key for not generating disruptions in payments in the economy in the case of a bank failure. This seems rather limited as a measure for containing the systemic implications of such an event. Presumably, a current account holder would also have term deposits.

Protecting current account deposits only does not mean that all expected payments by this holder in the future will be fulfilled.

This criticism notwithstanding, the real problem with the full guarantee is the potential increase in the cost of closing a bank as a result of shifting deposits.[2] The logical solution is to limit the coverage of demand deposits. A second issue is the low limit on term deposits, which makes the threat of closing a bank less credible since it would be politically difficult to implement.

A sensitive scheme would raise the protection of term deposits and reduce that of demand deposits. The last column in table 2 shows the effective protection granted when the limit on both types of deposit is set at 500 UF (approximately US$12,000). The size of the guarantee is similar to that of the previous case, so the total protection granted to the system is similar. A key difference, though, is that a major channel through which exposure could be artificially inflated has been eliminated.

2. Systemic Risk and Banking Concentration

This section is concerned with the relation between banking concentration and systemic risk. Despite the lack of a specific definition, systemic risk is the most common single argument used to justify the regulation of the financial sector in general and the banking system in particular. Explicitly or implicitly, systemic risk is usually understood as the failure or risk of failure of a significant part of the financial system.

Although systemic risk is widely employed as a primordial justification for banking regulation, efforts to model it explicitly and consider it explicitly in regulation design and evaluation are surprisingly recent. The consensus view on banking was largely associated with liquidity transformation as the main rationale for the existence of banks and, from there, as the key characteristic determining their risks. A seminal and largely influential paper in this tradition is Diamond and Dybvig (1983). Their approach, however, does not leave any room for a systemic analysis.

2. The extent to which this is a real possibility can be verified in Japan, where term deposits shifted to demand deposits when it was announced that the full guarantee on deposits would be eliminated for term deposits but maintained for

Dow (2000) proposes a simple classification of the different forms that systemic risk can take. Dow distinguishes four forms for thinking about systemic risk: contagion à la Diamond and Dybvig, in which problems in one bank can generate a change in expectations and thus produce runs on solvent banks; direct linkages, in which direct exposures via interbank lending, deposits and derivatives contracts can cause the transmission of problems in or the failure of one bank to otherwise healthy banks; endogenous prices, in which problems in one bank or group of banks can lead to changes in asset prices, which, in turn, can cause problems in previously unaffected banks; and common shocks, in which a large fraction of the banking sector can be weakened if they face similar risks.

The discussion in the previous section showed that pure expectations contagion (case 1) does not seem to be found in the historical evidence. Efforts should therefore focus on the other three cases. In this paper, I use a simple model that incorporates the second form of systemic risk, in order to assess the impact that banking concentration can have on that risk. In addition, the model aims at deriving possible regulatory measures that could be used to reduce systemic risks. Future work should add cases 3 and 4 into the analysis.

2.1 Relevant Literature for this Paper

Theoretical models for analyzing banking systems have recently been put forward by Rochet and Tirole (1996), Freixas, Parigi, and Rochet (2000), and Allen and Gale (2000). Important results from these works include the importance of a diversified set of linkages among banks to increase the system's resilience to shocks and the importance of unsecured direct linkages to promote cross-monitoring and market discipline among banks.

Applied studies of the systemic risk implicit in interbank markets have appeared in recent years applied to different countries. Furfine (1999) for the United States, Upper and Worms (2001) for Germany, Elsinger, Lehar, and Summer (2002) for Austria, and Wells (2002) for the United Kingdom all use a framework described in Eisenberg and Noe (2001) to assess this risk. Findings typically show that the probabilities of systemic crises are low. Also, the systemic importance of different banks can be determined.

This paper is related to this literature, but its goals are different. Specifically, I am not interested in assessing the extent of systemic risk implied by the current bilateral exposures of the Chilean banking system, but rather examine whether the tendency toward concentration has fundamentally affected the fragility of the system.

2.2 The Model

The interbank structure can be described by the following $N \times N$ matrix:

$$\mathbf{X} = \begin{bmatrix} x_{1,1} & \cdots & x_{1,j} & \cdots & x_{1,N} \\ \vdots & & \vdots & & \vdots \\ x_{i,1} & \cdots & x_{i,j} & \cdots & x_{i,N} \\ \vdots & & \vdots & & \vdots \\ x_{N,1} & \cdots & x_{N,j} & \cdots & x_{N,N} \end{bmatrix}$$

Matrix **X** summarizes interbank cross-exposures, with x_{ij} representing the loans that bank i has made to bank j. Summing horizontally I obtain the total liabilities of bank i, while the vertical sum gives us all the interbank assets of bank j:

$$a_k = \sum_i x_{i,k}$$

$$l_k = \sum_j x_{k,j}$$

In addition, elements on the diagonal have to be zero; otherwise, it would mean that banks are lending to themselves:

$$x_{i,i} = 0 \quad \forall i$$

Eisenberg and Noe (2001) provide crucial elements for using this model to assess the stability of a banking system in the context of a payments problem. Specifically, they are interested in finding the clearing vector for a system of nodes that hold liabilities among each other, that is, the vector of payments from each node to the rest of the system that clears the system. The clearing vector is what banks actually pay in equilibrium. If a bank defaults, its payments would be ex post lower than its original liabilities. Using a fixed-point argument, the authors prove that a clearing vector always exists and that it is unique under mild conditions. This is important given the cyclical interdependence of the model. Because the solution is unique, it is independent of the procedure taken to find the solution.

In the Eisenberg and Noe setup, payments are modeled in accordance with bankruptcy law. If the node (bank) has not defaulted payments are made in full. If the node has defaulted, the remaining value of the node is distributed among claim holders in proportion to their claims, that is, liquidation rules assume limited liability.

In addition to the proof of existence and uniqueness, a useful outcome of Eisenberg and Noe's paper is the algorithm they use to find the clearing vector, which they call the fictitious default algorithm. This algorithm starts by assuming that all payments are fulfilled. If no node has total income below payments, then total payments made by each node form the unique clearing vector that solves the system, and the algorithm stops. If a bank defaults, a new round is run, in which liabilities by the failed node are distributed proportionally among the creditor nodes. After this, it is checked whether other nodes fail and so on. This algorithm is iterated until no bank fails. Eisenberg and Noe's procedure for finding a clearing vector in a network of bilateral exposures thus becomes a natural procedure for measuring the systemic risk imposed by a given bank.

To measure the systemic importance of each bank and, more generally, the stability of a certain banking structure, I allow banks to fail one at a time. In each failure, I assume that a certain fraction, θ, of the value of the failing bank is lost, and this amount constitutes the loss that the failed bank's creditors experience (that is, the loss-given-default ratio). I assume that each bank has a certain amount of capital and that a bank fails when its total losses from failed banks are larger than its capital.

The sequential nature of the algorithm gives us important information about the stability of the system, such as the extent to which failures are caused by contagion rather than direct exposures, the number of rounds of failures that the failure of a large bank can generate, and so on.

2.3 Simulations

The object of study of this paper is the concentration of banks in Chile. This is approximated by the distribution of Tier 1 capital among banks. This concentration structure is compared with other structures with varying degrees of concentration. The objective is to determine the extent to which the systemic risk implied by a system's members varies with the level of concentration.

Two scenarios are run in the simulations. In the first scenario, limits to interbank borrowing and lending are purposely kept high in order to generate many different possible scenarios for interbank linkages. Allowing high levels of interbank exposure makes contagion more likely. These scenarios are generated randomly, as explained below. The objective of this step is to test different metrics to measure systemic risk in a given system of interbank linkages. The second scenario simulates the Chilean banking system more realistically. In particular, limits to interbank lending are set at levels corresponding with current regulation in Chile.

2.4 Parameters

This subsection presents the parameters chosen for the model in order for it to reasonably resemble the case of Chile. In some cases, data for the Chilean banking system are available. When data are not available, Chilean regulation is used to define the limits within which random draws are obtained for simulation.

Capital Structure

The base case is the effective capital structure in September 2002. The alternative scenarios are generated following a simple rule: I sequentially reduce the rate of growth of bank sizes by a factor of 0.2 of the original size distribution. The scenarios generated are summarized in table 3.

Table 3. Capital Structures Used in Simulations
Percent share

Size group	*Baseline*	*Case b*	*Case c*	*Case d*	*Case e*	*Case f*
Largest single bank	23.7	19.4	14.8	10.8	7.3	4.0
Largest five banks	65.0	58.7	48.7	40.0	29.3	20.0
Largest ten banks	84.7	80.6	71.3	64.6	53.7	40.0
Largest fifteen banks	95.4	92.9	87.8	81.5	75.6	60.0
Summary statistic						
Herfindahl index	1,157	937	702	556	458	400
No. banks	25	25	25	25	25	25

Source: FDIC (2002); SBIF (2002).
a. Banks whose insured deposits are equal to or lower than the deposit insurance system fund, estimated as 1.25% of covered deposits.
b. At least.

Limits to Interbank Lending

Current regulation imposes limits to interbank credit on both the borrowing and lending side. On the lending side, Chilean banking law establishes that interbank lending to a single bank cannot exceed 30 percent of the Tier 2 capital of the lender. Because Tier 2 capital can be up to 50 percent larger than Tier 1 capital, this limit implies that lending to a single bank can be as much as 45 percent of Tier 1 capital. These limits refer to lending and not to total exposure. Exposure can be larger than lending as a result of deposits and derivative contracts. There is no limit to overall interbank exposure.

On the borrowing side, overall interbank term (as opposed to demand) liabilities with residual maturity of less than one year cannot exceed 10 percent of assets. In addition, term liabilities with a specific bank cannot exceed 3 percent of the assets of either the borrower or the lender, whichever is the largest. In a concentrated banking system, this limit becomes less relevant, since it is determined by the size of the largest bank in a credit relationship. In particular, medium and small banks can have large exposures to a big bank. Finally, liabilities payable on demand or with a residual maturity of over a year are not subject to any limit.

Limits to interbank exposures thus are not very restrictive on either side of the balance sheet. On the lending side, total lending is not limited and individual exposure can be increased by means other than lending. On the liabilities side, limits can be exceeded via long-term borrowing. Long-term interbank lending can be high in some countries: Upper and Worms (2001) report that in Germany as of December 1998, 36 percent of all interbank liabilities have a maturity of four years or more.

For the first scenario I assume a limit of 30 percent on interbank assets and liabilities. For the second scenario, I impose a 10 percent limit to interbank assets and liabilities.

Interbank Linkages

In the first scenario, interbank lending is generated randomly. I assume that the ratios of overall interbank assets and liabilities to total assets are random variables for each bank, distributed uniformly between 0 and the defined upper limit. This implies that the interbank assets and liabilities of a given bank are not related in a predictable way—that is, that the level of a bank's interbank assets does not say anything about the level of its liabilities. This may not be true for certain banks that typically operate on either the lending or borrowing side of the market (money center banks, for example), but it is a reasonable assumption for most banks.

From the two ratios obtained for each bank, total interbank assets and liabilities for each bank are obtained using the level of the bank's total assets. The next step is to generate the matrix **X**, which will tell us how the interbank connections are. Since assets and liabilities are generated randomly, an adjustment has to be made to ensure that they add up to the same amount.

Banks can be connected to each other in a number of ways. According to Allen and Gale (2000), the more diversified are the links of each bank, the more resilient is the system to shocks. I generate interconnections through an algorithm that generates maximum diversification or "connectedness" of the structure *given the total assets and liabilities that each bank wishes to hold*.

The algorithm starts by randomly determining a vector of total interbank assets (vector **a** of elements a_k) and one of total interbank liabilities (vector **l** of elements l_k). They represent, respectively, the total interbank assets and liabilities that a bank wishes to hold. From them, I would like to generate matrix **X**. This may not be possible, since it amounts to solving N x $(N – 1)$ unknowns with $2N$ equations.

Given this, I follow an algorithm to build a matrix **X** that is as consistent as possible with vectors **a** and **l**. Each element of vector **a** is distributed as liabilities of the other banks (that is, in a column of matrix **X**) in proportion to vector **l**. In the next step, allocated liabilities are summed for each recipient bank (horizontal sum in matrix **X**) and compared to the desired liabilities indicated by vector **l**. Allocated and desired liabilities may differ. When the allocated liabilities of a recipient bank are larger than its desired liabilities, the excess is subtracted proportionally from each creditor bank and the desired liabilities for the recipient bank are set to zero for the next round. The assets allocated in excess are marked as pending for each creditor bank. Should the allocated liabilities be less than desired liabilities, this difference will be the desired liabilities for the next round.

In the next round, a similar allocation takes place where the pending assets of each creditor bank are distributed among recipient banks in proportion to their remaining desired liabilities. Excesses are determined and a new round is run until either all assets are allocated or all desired liabilities are fulfilled. Whichever happens first will determine the total size of the interbank market. The algorithm allocates assets in a few rounds.

Note that the algorithm as described generates total interbank assets and liabilities independently of each other, and it stops when the lower of the two is allocated. It thus biases randomly generated interbank relations to the conservative side, which is assuming a low level of interconnectivity among banks.

Loss-given-default Ratio

Simulations are run considering loss ratios between 10 percent and 50 percent. James (1991) calculates loss ratios in bank failures at 40 percent. The latter is a standard value for calibrated models in this literature. This is a conservative value, in the sense that it calculates the final loss after a long period during which assets are liquidated. The stress imposed on a creditor bank at the time of the bank failure can be a lot larger.

Total Assets

Total assets are generated from capital assuming the regulatory ratio of Tier 1 capital to assets of 3 percent.

2.5 Results

As mentioned earlier, results are obtained in two stages. In the first, constraints on interbank borrowing are relaxed in order to generate a large number of banking failures and contagion. This stage attempts to test the accuracy of different metrics for systemic risk. The second stage explores the Chilean system more realistically and uses the results of the first stage to explore measures to contain systemic risk.

First Simulations

The objective of the first simulations is to explore the dynamics of the model and to determine metrics for measuring the systemic risk implicit in a given system. Table 4 provides a summary of some of the findings. For each possible capital structure, I simulate a hundred different interbank markets. The resilience of each case of interbank market is determined through the fictitious default algorithm. If at least one bank in this algorithm generates the failure of at least

Table 4. Systemic Risk

		Capital structure			
System indicator	*Baseline*	*Case b*	*Case c*	*Case d*	*Case e*
Average interbank assets over total assets (percent)	15.2	15.0	15.0	14.9	14.8
Cases of contagion out of 100	70	42	14	0	0
Average no. banks affected given contagion[a]	15.8	15.0	15.8	0	0
Average assets affected given contagion (percent)[a]	52.1	51.3	59.6	0	0
Assets failed in worst contagion case (percent)	79.8	80.1	76.5	0	0

a. The baseline capital structure generates six cases in which two banks can generate contagion for a given interbank matrix; the worst case was taken for the table.

one other bank, the whole interbank structure is marked as capable of generating contagion.

Table 4 reports the average size of the interbank market generated in each case, which is similar across capital structures. The second line shows that systemic risk differs considerably across structures. For the baseline capital structure, in 70 out of 100 scenarios there is at least one bank whose failure can lead to the failure of a second bank. The next line shows that the total number of banks affected in each case is large, as is the average level of assets damaged when contagion exists.

The incidence of contagion drops considerably as the capital structures become less concentrated. Beginning with structure d, in which the largest bank accounts for about 11 percent of the system, there are no more cases of contagion under the parameters of this exercise. However, while reducing concentration lowers the incidence of contagion considerably, when contagion does occur (structures b and c), it causes a similar level of damage as measured by number of banks and assets affected. In fact, the damage increases slightly, suggesting that the worst contagion cases are the last to disappear.

Next, I run regressions based on the data generated in the simulations to determine possible metrics for assessing the systemic risk embedded in a given system of interbank linkages. I define the dependent variable as the worst loss in total assets that can occur in a certain system of interbank linkages. I try different metrics as potential explanatory variables, focusing on variables that could be constructed from balance sheet data by a regulator.

Two metrics seem to give interesting information. One is an attempt to measure interconnectedness; it is defined as the standard deviation of the exposure of each bank to each other bank as a percentage of its capital. In practical terms, it consists of dividing each row *i* of matrix **X** by the capital stock of the i^{th} bank and taking the standard deviation of this matrix without considering elements in the diagonal. A better-connected (that is, more diversified) system will have a lower standard deviation of exposures, so I expect a positive relation between this metric and the dependent variable. The second variable captures the risk imposed on the system by the bank that causes the worst systemic crisis when it fails. I define this measure of "risk imposed" as the total liabilities of a bank (the column sum of matrix **X**) over the combined capital stock of all the other banks. Again, the higher the risk imposed by a bank, the higher the potential damage, so I again expect a positive coefficient.

Table 5 shows the results of the regressions. Each regression is run a second time with dummy variables for the type of capital structure. The first metric (standard deviation of exposure) is significant and gives a relatively good account of systemic risk when combined with the total size of the interbank market. *R* squared increases when dummy variables are included. This is due to cases *d* and *e*, in which failures never occur. The "risk imposed" variable has an even better explanatory power. As it turns out, including other variables in this specification does not help. This finding is useful for policy purposes, as discussed in the next section.

Second Simulations

The second set of simulations assesses the risks of the current structure of concentration in Chile in a more meaningful way. Measures of both bank failures and damaged assets are reported. Damaged assets are defined as the assets of banks that suffer a capital loss of at least 50 percent but less than 100 percent. The idea is to measure not only absolute failures, but also banks that have been substantially weakened. In these situations, the supervisor will most likely have to take some corrective action.

Interbank assets and liabilities are limited to 10 percent, and I assume that banks are close to that number. This assumption may seem extreme, but it is in the extreme scenarios that resilience is tested. Moreover, as reported above, interbank assets and liabilities can be higher than 10 percent of assets according to current regulation in Chile.

Table 5. Key Determinants of Asset Loss[a]

	(1)	(2)	(3)	(4)
Explanatory variable	*Coeff.*	*Coeff.*	*Coeff.*	*Coeff.*
Constant	–0.842	–1.134	–0.282	–0.340
	(–14.7)	(–12.6)	(–17.7)	(–9.5)
Interbank/total assets	2.459	2.708		
	(7.5)	(8.4)		
Std. dev. of exposure	0.416	0.550		
	(23.3)	(16.3)		
Risk imposed			0.401	0.448
			(28.7)	(21.4)
Dummy *b*		–0.002**		0.028**
		(–0.1)		(–1.3)
Dummy *c*		0.031**		0.027**
		(1.0)		(–1.1)
Dummy *d*		0.088*		0.008**
		(2.5)		(0.3)
Dummy *e*		0.191		0.09
		(4.7)		(3.2)
Summary statistic				
R^2	0.54	0.58	0.62	0.65
Adjusted R^2	0.54	0.57	0.62	0.64
Standard error	0.17	0.16	0.15	0.15
No. observations	500	500	500	500

All variables significant at 1 percent unless otherwise noted.
a. The dependent variable is the fraction of total assets failed to total assets in the worst-case scenario of a given system of interbank linkages. The explanatory variables are as follows: Interbank/total assets is the standard deviation of the exposure of each bank to each other bank as a percentage of its capital; risk imposed is the total liabilities of a bank (the row sum of matrix **X**) over the combined capital stock of all the other banks.
* Significant at 2 percent.
** Not significant at 10 percent.
t statistics in parentheses.

In these simulations, I also explore the impact of different structures of interconnections. In particular, I study the impact of varying the number of counterparties with which banks interact. I analyze cases for a number of counterparties ranging from three to twenty. These need not to be the same on the borrowing and lending side. Nor do they form closed sets, in the sense that the counterparties of a given bank do not have the same counterparties as that bank. Limiting the number of counterparties adds realism to the exercise, in that it does not seem plausible that banks have relations with all existing banks.

For a given number of counterparties, the interbank matrix can take many possible forms. In other words, there are many ways to pick C counterparties from $N - 1$ banks, when C is lower than ($N - 1$).

I thus randomly generate 1,000 interbank matrices for each number of desired counterparties. I focus on symmetric cases only. That is, if bank 1 has interbank liabilities with, say, banks 4 and 5, then bank 2 has interbank liabilities with banks 5 and 6. This ensures that all banks have the same systemic importance in terms of their connections, and they only differ in their size.

Results are presented in figures 1 to 9. First, I present the effect of different capital structures on systemic risk, measured as both damaged assets (as defined earlier) and the assets of failed banks. I then present the effect on systemic risk of limiting the risk that banks can impose on the rest of the system under the current capital structure of banks in Chile. In all cases, the average of the fraction of damaged or failed assets across the 1,000 cases is presented, as well as the tenth and ninetieth percentiles.

Figures 1 and 2 present the results for the cases of loss-given-default ratios (θ) of 20 percent and 30 percent, respectively. At these levels of θ, there are no failures by contagion. The figures show the fraction of damaged assets for three cases of the capital structure (the baseline case, case *c*, and case *e*) and for a number of counterparties ranging from three to twenty. The most important result is that systemic damage increases with the concentration of the banking system. In the less concentrated system (case *e*), damage is low and it appears only in cases of a small number of counterparties (less than 6). This implies that concentration increases systemic damage in the event of failure.

Figure 1. Damaged Assets under Different Levels of Concentration, θ = 0.2

Average, 10th percentile, and 90th percentile

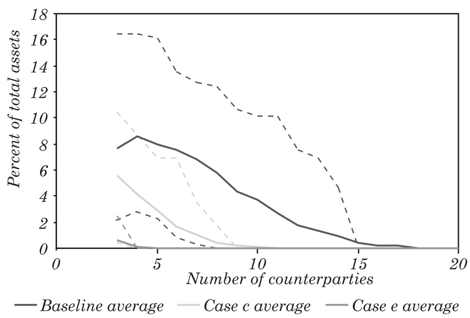
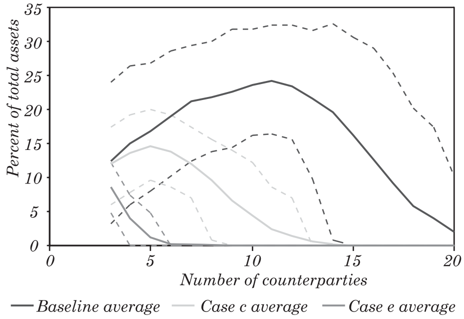


Figure 2. Damaged Assets under Different Levels of Concentration, θ = 0.3

Average, 10th percentile, and 90th percentile



The second interesting result is that for the more concentrated banking systems, the relation between total damage and the number of counterparties is not monotonic. Figure 3, in particular, shows that for the baseline case, increasing the number of counterparties from the lowest figure (three) increases the damage caused in the system by the failure of a bank; this continues until 11 counterparties are reached, after which systemic damage falls. This result is contrary to the conventional wisdom that a better-connected system is always safer than a less connected one. Here, the increase in interconnections—rather than spreading the shock of the initial failure over a larger number of counterparties and thereby making it more difficult for the event to lead other banks into default—is dominated by the effect of more interconnections increasing the number of banks that can be affected by the initial bank failure. This result is more likely to occur with greater heterogeneity of bank sizes. This is confirmed by the fact that the inverted-U shape disappears when the concentration in the banking system is reduced.

Figures 3 and 4 report cases with θ equal to 40 percent and 50 percent, respectively. These figures report the assets of failed banks as a proportion of total assets. Results are analogous to those shown in figures 1 and 2. Damage is higher the higher the concentration of banks for a given number of counterparties in almost all the cases.[3]

3. The only exceptions are the cases of θ = 0.5 with three and four counterparties.

Figure 3. Failed Assets under Different Levels of Concentration, θ = 0.4

Average, 10th percentile, and 90th percentile

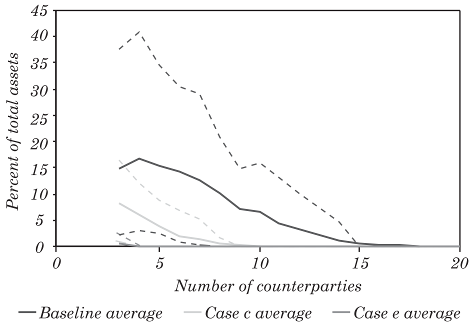
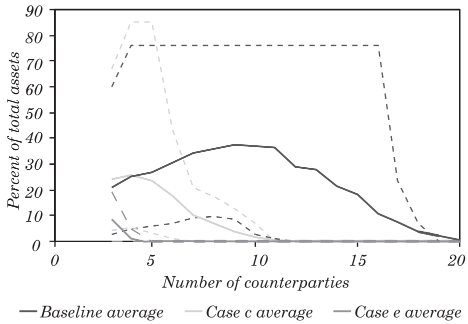


Figure 4. Failed Assets under Different Levels of Concentration, θ = 0.5

Average, 10th percentile, and 90th percentile



The relation between damage and the number of counterparties has an inverted-U shape that disappears as concentration is reduced. Finally, note that going from the base structure to case *c* involves larger benefits than going from case *c* to case *e*. Gains in moving from the base structure to case *c* can be large. The case θ = 0.4 shows that case *c* has no systemic failures in up to 90 percent of the cases with eight counterparties. Reaching this level of stability under the baseline structure requires increasing the number of counterparties to fifteen.

Results from the first set of simulations showed that "risk imposed" was a key determinant of systemic risk. Consequently, systemic risk can be contained by limiting the level of risk imposed on the rest of the system. I searched through the simulations to find the largest value for the “risk imposed” variable that generates no failures by contagion in 95 percent of the cases given θ = 40 percent and ten counterparties. It turns out that this number is 0.25. This is the maximum ratio of liabilities in the interbank market to the combined capital of all other banks in the system. This number can be translated into a maximum ratio of interbank liabilities to total assets as a function of the fraction of capital that a given bank represents in the total. The latter representation is easier to interpret intuitively than the former.

Figure 5 shows the rule of the maximum liabilities as a function of the ratio of a bank’s capital to total system capital. A 10 percent maximum is exogenously imposed. The rule implies that banks whose capital represents more than 7.5 percent of total capital should have a limit on total interbank liabilities below 10 percent of their assets. A bank whose capital represents 20 percent of the system, for example, should not have more than 3.7 percent of its assets as interbank liabilities.

The effect of the rule is shown in figures 6 through 9, which can be directly compared with figures 1 through 4. The rule effectively reduces systemic damage in all cases. Failures by contagion virtually disappear in all cases with ten or more counterparties, even in the case of θ = 50 percent. This contrasts sharply with the case of the base structure of concentration.

The rule leaves the system with a measure of potential systemic damage lower than that achieved under concentration structure *c*, in some cases by a large amount. Incidentally, it has an analogous effect on reducing concentration in eliminating the inverted-U shape of the impact of increasing connections over systemic damage.

Figure 5. Maximum Interbank Liabilities

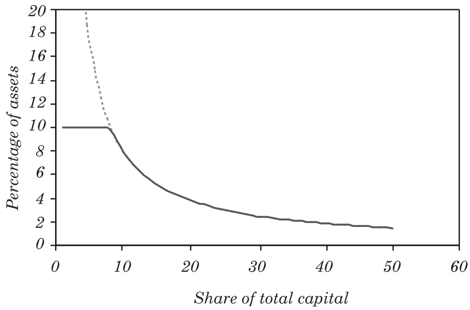


Figure 6. Damaged Assets, with and without Rule, θ = 0.2

Average, 10th percentile, and 90th percentile

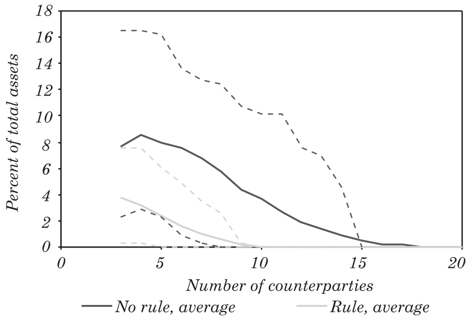


Figure 7. Damaged Assets with and without Rule, θ = 0.3

Average, 10th percentile, and 90th percentile

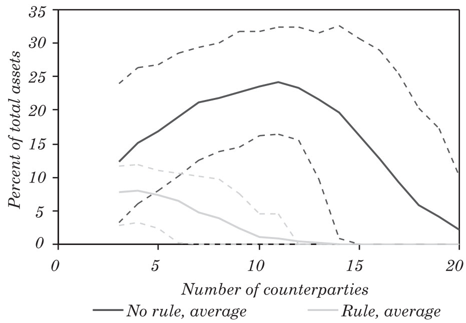


Figure 8. Failed Assets with and without Rule, θ = 0.4

Average, 10th percentile, and 90th percentile

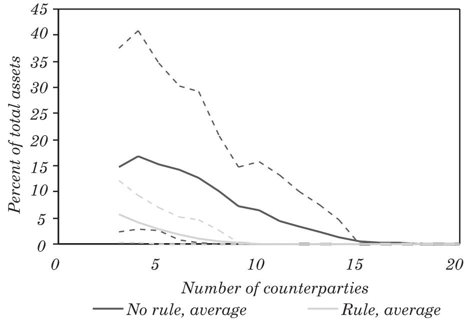
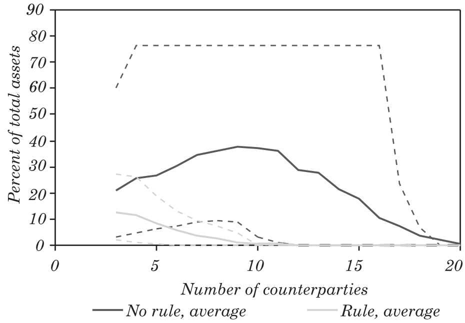


Figure 9. Failed Assets with and without Rule, θ = 0.5

Average, 10th percentile, and 90th percentile



3. Final Remarks

This paper has analyzed the key characteristics of a safety net for a financial system characterized by high concentration and a low total number of banks. The first section discussed the role of deposit insurance, highlighting the diminished importance of deposit insurance in the case of a system with a low number of banks. The design of a deposit insurance system should therefore be embedded in a more general policy of intervention and resolution.

A second message from the first section is that the issue of systemic risk becomes crucial in a highly concentrated banking system. The second section thus analyzed systemic risk in the case of the Chilean banking system and proposed regulatory measures to help contain it. Specifically, this section showed how the risk of idiosyncratic shocks spreading through the system are substantially higher in concentrated systems than in decentralized ones. It then described a specific regulatory measure that can reduce this risk.

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