Deposit Insurance, Systemic Risk and Banking Concentration[1]

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I. Introduction

This paper attempts to make a contribution on the appropriate design of the safety net of the financial system when this system is highly concentrated. In particular, it considers issues that arise in the case of a system that not only is highly concentrated, but also where the total number of players (banks) is low.

The Safety Net is commonly understood as the set of institutions that the government puts in place in order to guarantee the well functioning of the financial system (financial institutions and markets) in the economy. The Safety Net is typically considered to be composed by the following functions: regulation and supervision, lender of last resort and deposit insurance. Regulation includes different 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 may deviate from 'standard' forms in the case of a highly concentrated banking sector as the Chilean.

Concentration has been a tendency throughout the world in the nineties. As long as the emergence of larger financial institutions seems to be a permanent change, it seems of high relevance to understand what are the implications that that may have, in particular for small countries like Chile.

This paper analyses two dimensions of the impact of concentration on the banking safety net. The first is deposit insurance. Recent years important efforts in the understanding of deposit insurance and best practices about it has been made (see Demirgüç-Kunt and Detriagache, 1999, Demirgüç-Kunt and Huizinga, 2000). This paper attempts to contribute to this literature exploring the implications of concentration for deposit insurance design. It is a conclusion of this paper that in this case deposit insurance design can not be thought of as a stand-alone instrument, but as an element of the intervention and resolution policy.

The second issue refers to systemic risk. This paper uses 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 studying potential measures that can contain systemic risk.

The organisation of this paper is straightforward. Section II of this paper discusses deposit insurance. Section III presents the model and discusses the relation between systemic risk and concentration. A final section summarises the main results of the paper.

II. Deposit Insurance, Resolution Methods and Banking Concentration

This section discusses the characteristics that a deposit insurance system should have in the case of a system with high concentration and low number of banks. The section starts discussing the role of deposit insurance as an element of the safety net of the financial system. Considering this, the design of it for the case of a country like Chile is discussed. Finally, the current situation of the deposit insurance scheme in Chile is analysed in the light of what was previously discussed.

1. The role of deposit insurance in the safety net

As part of the safety net, deposit insurance (DI) is one of the most visible for the public. In fact, may be is the only visible. The contribution of deposit insurance is typically referred to as that of "preventing bank runs". It is important to determine the real dimension of this in order to design a DI system that aims at realistic goals. In addition to this role, DI protects small depositors. While this may sound less grandiose, we will ague that it may be the more realistic one.

The argument that links DI and bank runs is well known and was first formally presented by Diamond and Dybvig (1983). In a highly influential paper, Diamond and Dybvig argue that runs can appear as 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.

But when moving towards policy design, two elements have to be considered. On the one hand there is empirical evidence that says that in history banks runs have not been the expression necessarily of unfunded panics, but most usually they have occurred in a context of real insolvency of banks (Calomiris, Gorton). Similarly, it seems that in this events solvent banks have not suffered runs.

Second, if panics were really a possibility the only solution would be a back up fund equal to total deposits. If this was not the case, then rational depositors would know that there is a limited DI fund, and they would have incentives to run anyway, in the case when they believe that other would run.

In this context, an alternative to DI 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 provided the required liquidity against good collateral (as recommended by Bagehot (1873)). If the run is based on fundamentals, then it is optimal for the bank to fail, and therefore there is no need to prevent the run. As a matter of fact if the bank is really insolvent, the bank should have been closed promptly and no run would have ever taken place. There is hardly any reason to believe that the public will know before than the regulator about the insolvency of a bank.

The latter argument is incomplete though, and leaves out a case that can leave a role for a DIS. This case is when a bank is weak and the regulator can not discern fully whether the bank is viable or not. In this case a run is a possible response, this time granted by fundamentals. The central bank will have to make a decision about lending or not to this bank in a situation where it may not have full information. It would risk losses if it lends and the bank was not solvent. On the other hand, if the central bank does not lend, there can be efficiency losses to the economy for shutting down projects with a positive value.

To avoid this situation of a possible inefficient decision, a DIS can contain the run on the bank. Notice that what is needed to contain the run is a credible promise that deposits will be repaid. The promise is credible as long as the DI system has funds or credible access to funds enough to cover insured deposits. In this context, it is clear that DI is not meant to be an antidote to systemic crisis, but an element of the tools needed to deal with idiosyncratic crisis of banks.

An alternative way of thinking 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 in order to represent a large number of small depositors who may find it costly to monitor a bank, 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 atomised principal. Deposit insurance arises in this context to protect small depositors.

In reality, most DIS seem to be closer to the second approach. The first approach calls for protection to those more likely to run. Arguably, large depositors are in this situation. The second is consistent with limits to protection per depositor.

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 when there are systemic problems, that is, when a substantial fraction of the banking system is in problems.

For systems highly concentrated and with a low number of institutions this has two implications. First, the existence of 'systemic banks' is more likely. This is, banks whose large size implies that the deposit insurance fund necessary to cover the potential losses generated in the payment of 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 anyway, and their problems being faced in a way that does not imply depositor repayments. This would imply that the liabilities generated by the deposit insurance should not be expected to be paid in many cases.

Second, in the case of systems with a low number of banks the system will be in effect relevant for a few banks. Since failure is an unusual event from an individual's bank perspective, we should not expect that there will be need of executing the guarantee too often.

To illustrate this point, let us analyse the comparative situation of the DIS in the US (the FDIC) and a hypothetical DIS in Chile.

Table 1: Concentration measured as share of total loans and number of banks, Chile and United States

	Chile Sept 2002	US 1999
Largest	26%	8%
Largest 5	74%	27%
Largest 10	92%	37%
Largest 15	99%	43%
Number of Banks	25	8,505

Source: Report on Consolidation in the Financial Sector, Group of Ten (2001), and SBIF, 2002.

For the case of Chile we will consider the current structure of coverage. Under the current rules, all demand deposits are covered in full, while term deposits of natural persons are covered up to 108 UF (approximately US$ 2,600 at current exchange rate). For simplicity, I assume that all depositors qualify for insurance, i.e. that there is no distinction between natural and legal persons. I leave comments on this coverage structure and room for improvement for the next section.

We assume that the system in Chile follows a similar rule than that of the US, that is, that it has as a target a fund of 1.25% of covered deposits. This will give us an approximation of the effective protection that the DIS is prepared to give for failures in the system. An alternative metric would be obtained from considering effective premiums charged by the DIS's 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 expost funding from surviving institutions or government funding). The average maximum rate is 0.36% of deposits while the median maximum rate is 0.24%. The problem is that it is not possible to know from the database whether countries target a fund of a determined size or not. However, if we consider charging the median rate will reach a target similar to that of the US in 5 years. Considering that the fund is actually used in paying out the guarantee, the US target seems a reasonable order of magnitude of the funds that DI system should have in steady-state situation.

Table 2: Protection Compared, Chile vs USA

	USA FDIC	Chile Current Limits	Chile Proposed Limits
Insured Deposits as % of total	67.2%	28.7%	28.1%
Banks Effectively covered [a]	7,888 [b]	14	14
Banks in the DI System	7,966	25	25
Ratio	99%	56%	56%
Total Deposits in banks effectively covered as % total	33.8% [b]	8.6%	8.6%

a: Banks whose insured deposits are equal or lower than the DIS fund, estimated as 1.25% of covered deposits.
b: At least.
Sources: FDIC (2002), SBIF (2002).

Table 2 compares the meaning of protection under a concentrated versus a decentralised system. In the case of Chile, coverage is determined from data of distribution of deposits by size. Coverage limits are more generous in the US, implying that the fraction of deposits covered more than double that of Chile. However, if we consider banks that are effectively protected, that is, those whose insured deposits are less or equal than the deposit insurance fund, the comparison is startling. While in the US the fund is relevant for almost eight thousand banks, in Chile it would be only for 14. Banks effectively protected hold at least 34% of total deposits in the US, while that ratio would be only 8.6% in Chile.

These facts imply that the question of how to design and organise a deposit insurance system becomes less relevant in the case of a highly concentrated system. The former question has devoted a lot of attention from multilateral institutions in recent years. Sets of recommendations and best practices have been produced (Garcia, 1995; IMF, 1998; FSF, 2001). However, the necessary elements for the decision of a country to have one or not, and what to expect from it are typically not part of the elements of the discussion.

This implies that deposit insurance policy becomes an element of a broader policy: that of optimal intervention and resolution of distressed banks. The design of the deposit insurance specific elements should be now done with an eye to this broader context.

The challenges of intervention and resolution policy in a context of high concentration are beyond the scope of this paper. Some elements to consider will be the following: Likelihood of banks being winded up or liquidated is low. Resolution of banks will come most likely in the form of Purchase and Assumption (P&A) operations. To minimise the cost of these operations, regulation should stress early intervention. Focus of the deposit guarantee management switches towards this type of issues.

In this context, we can revisit three questions: should there be changes in the nature of the guarantee offered to the public?, should a fund be collected in this context?, and if the answer to the latter is yes, on what basis should banks pay premiums?

The answer to the first question is yes. The two arguments that we put forward in support of an explicit guarantee (Dewatripont and Tirole's representation hypothesis and prevention of runs in cases where is difficult to discern 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 therefore they may prefer the large bank. This implies that an explicit deposit guarantee would help the emergence of small banks and become a force against those of concentration.

The second question is less clear. As mentioned before, a fund will definitely be less used for depositors' repayment in a concentrated than in an unconcentrated system. But a fund would also be needed to cover potential losses in P&A operations. In any case the frequency of these operations will also be low, therefore the question of keeping a contingency fund for this is still valid. The trade-off is that keeping the fund can be too costly considering that it would be seldom used. The alternative would be to raise funds from the industry (and may be from the government as well, as we will see later) to cover the losses derived from the guarantee in the case of a failure of a bank. The main problem with this is that failed banks, which caused the loss, do not pay.

The third question is also unclear. If losses are derived from the liquidation of a small bank with no systemic consequences, then it is clear that the industry should pay. Whether this is done ex-ante or ex-post subjects to the same caveat explained before. The problem is with the systemic banks. If the bank is not liquidated because the negative externalities of this would be too large, i.e. the loss of value to society is larger than the cost of supporting the bank, then part of these costs should be born by the government. Taxpayers should pay in order to preserve the 'social value' of a bank. On the other hand big banks should pay more if they are being saved for the 'systemic risk' that they impose.

The 'social value' of a given bank is difficult to assess. Part of it is related to the importance that the bank has in the banking system as a whole. The next section explores this dimension.

3. Comments on the current deposit insurance guarantee in Chile.

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

The main criticism to this structure is that protection to demand deposit is unlimited. The problem with this is that in situation of distress depositors could move from term to demand deposits massively, in search for full protection. This would imply that the effective guarantee that the central bank is giving to the public can be multiplied several times in a short period of time. 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 in order not to generate disruptions of payments in the economy in the case of a failure of a bank. As a measure to contain systemic implications this seems rather limited. Presumably, a current account holder would also have term deposits. Protecting their current account deposits does mean that all expected payment 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 via deposits shifting[2]. The logical solution is to limit coverage on demand deposit. A second issue is the low limit of term deposits. This 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 5 shows the effective protection granted when limit is raised to 500 UF (US$ 12,000 aprox.). The size of the guarantee is similar to that of the previous case. Therefore, total protection granted to the system is similar. A key difference though, is that a major channel via which exposure could be artificially inflated has been eliminated.

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[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 finished on term deposits only.

III. Systemic Risk and Banking Concentration

This section is concerned with the relation between banking concentration and systemic risk.

Despite of the lack of a specific definition, systemic risk concerns is the most typical 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.

It is surprising then, that despite the seemingly widespread regard of it as a primordial justification of banking regulation, efforts to model it explicitly and consider it explicitly on regulation design and evaluation are only recent.

Despite the concerns on systemic risk, the consensus view on banking was largely associated with liquidity transformation as the main rational for the existence of banks, and, from here, as their key characteristic determining their risks. Diamond and Dybvig (1983), for example, is a seminal and largely influential paper in this tradition. Their approach, however, does not lead to any room for a systemic analysis.

A possible classification of different forms that systemic risk can be considered is proposed by Dow (2000). Dow distinguishes three forms in which systemic risk that can be thought of:

1. Common shocks: A large fraction of the banking sector can be weakened if they face similar risks.
2. Endogenous prices: Problems in one bank or a group of them may lead to changes in asset prices. This may in turn cause problems in previously unaffected banks.
3. Direct Interlinkages: Direct exposures via lending, deposits and derivatives contracts may imply that problems in or the failure one bank transmit to other otherwise healthy banks.

This paper is interested in constructing a simple model in which the basic forms of systemic risks can be incorporated, in order to assess the impact that banking concentration can have on those risks. In addition, it aims at deriving possible regulatory measures that could be used to reduce systemic risks.

1. Relevant literature for this paper

Theoretical models to analyse systems of banks have been recently put forward by Rochet and Tirole (1996), Freixas, Parigi and Rochet (2000) and Allen and Gale (2000). Important results from them are the importance of a diversified set of interlinkages among banks to increase resilience of the system to shocks, and the importance of unsecured direct interlinkages 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 US, Upper and Worms (2001) for Germany, Elsinger *et al* (2002) for Austria and Wells (2002) for UK, use a framework formalised by Eisenberg and Noe (2001) to assess this risk. Findings typically show that probabilities of systemic crises are low. Also, systemic importance of different banks can be determined.

This paper is related to this literature but it is different on its aims. The main difference is that it is not interested in assessing the extent of systemic risk implied by the current bilateral exposures of the Chilean banking system, but to understand whether the tendency towards concentration has affected in a fundamental way the fragility of the system.

2. The model

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

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

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

$$a_i = \sum_j x_{i,j} \,,\; l_j = \sum_i x_{i,j} \;.$$

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

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

In the context of a payments problem, Eisenberg and Noe (2001) provide elements crucial for the use of this model to assess the stability of a banking system. In the context of a payments problem, in that a system of nodes holds liabilities among each other, they are interested in finding a clearing vector, i.e. the vector of payments from each node to the rest of the system that clears the system. In other words, the clearing vector is what actually banks pay in equilibrium. If a bank defaults, its payments would be expost lower that its original liabilities. Using a fixed point argument they prove that a clearing vectors always exists and that, under mild conditions, it is unique. This is important given the cyclical interdependence of the model. Knowing that the solution is unique we know that the solution is independent of the procedure we have taken to find the solution.

In the Eisenberg and Noe set up, payments are modelled in accordance to bankruptcy law. This means that if the node (bank) has not defaulted, payments are made in full. If the node has defaulted, the value of the node is distributed among claim holders in proportion to their claims. In addition, it assumes 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 'ficticious 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, on the contrary, a bank defaults a new round is run. In this, liabilities by the failed nodes are distributed proportionally among the creditor nodes. After this, it is checked whether some node fails and so on. This algorithm is iterated until no bank fails.

In this way, Eisenberg and Noe's procedure to find a clearing vector to a network of bilateral exposures becomes a natural procedure to measure 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, we allow banks to fail each at a time. In each failure we assume that a certain fraction q of the value of the failing bank is lost, and therefore that is the loss that the creditors to the failed bank experience as a consequence. We assume that each bank has a certain amount of capital and that a bank fails when the total loses from failed banks are larger than its capital.

The sequential nature of the algorithm gives us important information about the stability of the system, 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.

3. Simulations

The object of study of this paper is the concentration of banks in Chile. This will be approximated by the distribution of Tier 1 capital among banks. This concentration structure will be compared with other structures with varying degrees of concentration. The objective is to determine the extent to which different levels of concentration differ in the systemic risk implied by their members.

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. By allowing high levels of interbank exposures we make contagion more likely. These scenarios are generated randomly as will be explained later. The objective of this step is to test different metrics to measure systemic risk in a given system of interbank interlinkages.

The second scenario simulates the Chilean banking system in a more realistic way. In particular, limits to interbank lending are set at levels corresponding with current regulation in Chile.

4. Parameters

Capital structure

The base case is the effective capital structure in September 2002. To generate our other scenarios I follow a simple rule. I sequentially reduce the rate of growth of bank size by 0.2 of the original capital structure. The scenarios generated are summarised in table 3:

Table 3: Capital structures used in simulations

	Baseline	b	c	D	e	f
Largest	23.7%	19.4%	14.8%	10.8%	7.3%	4.0%
Largest 5	65.0%	58.7%	48.7%	40.0%	29.3%	20.0%
Largest 10	84.7%	80.6%	71.3%	64.6%	53.7%	40.0%
Largest 15	95.4%	92.9%	87.8%	81.5%	75.6%	60.0%
Herfindahl Index	1,157	937	702	556	458	400
Number of Banks	25	25	25	25	25	25

Limits to Interbank lending

Current regulation imposes limits on the borrowing and lending side. On the lending side, Banking law determines that interbank lending to a single bank can not exceed 30% of Tier 2 capital of the lender. As Tier 2 capital can be up to 50% larger than Tier 1 capital, this limit implies that lending to a single bank can be as much as 45% of Tier 1 capital. These limits refer to lending and not to total exposures. Exposure can be larger that via deposits and derivative contracts. There is no limit to overall interbank lending.

On the borrowing side, overall interbank term (as opposed to demand) liabilities with residual maturity of less than one year can not exceed 10% of assets. In addition, term liabilities with a specific bank can not exceed 3% of assets of the borrower or the lender, whichever the largest. Liabilities payable on demand or with a residual maturity over a year are not subject to any limit.

We can see that in both sides of the balance sheet, limits to interbank exposures are not very restrictive. On the lending side, total lending is not limited and individual exposures can be increased by ways 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 by December of 1998 in Germany 36% of all interbank liabilities have a maturity of 4 years or more.

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

Interbank links

In the first scenario, the 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 upper limit assumed. Therefore I am assuming that interbank assets and liabilities for a given bank are not related in a predictable way, i.e. that the level of interbank assets of a bank does not say anything about the level of its liabilities. This may not be true for certain banks that typically are in particular 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 total assets of the bank. The next step is to generate the matrix X, which will tell us how are the interbank connections. In addition, since assets and liabilities are generated randomly, an adjustment will have to be made to ensure that they add up to the same amount.

There are multiple forms in which banks can be connected to each other. 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 from the vector of interbank assets and distributes them into each other bank in proportion to their desired total liabilities. Therefore, the vector A is being distributed horizontally in the rows of matrix X. In the next step, liabilities allocated in this way are summed for each recipient bank (horizontal sum in matrix X) and compared to the totals initially generated randomly. Let us call the latter the ‘desired’ liabilities. In some cases they will differ. In cases when total allocated liabilities are larger than desired liabilities, the excess is reduced proportionally from each creditor bank and the desired liabilities for this bank are set to zero for the next round. The assets allocated in excess for each bank are marked as ‘pending’ for each creditor bank. In the cases where allocated liabilities are less than desired liabilities, the desired liabilities for each bank are set equal to the remaining desired liabilities.

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 new round run until either all assets are allocated or all desired liabilities are fulfilled. Whatever happens first will determine the total size of the interbank market. The algorithm allocates assets in a few rounds.

Loss ratio
Simulations are run considering loss ratios between 10% and 50%. James (1991) calculates loss ratios in bank failures in 40%. The latter is a standard value for calibrated models in this literature.

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

5. Results

First simulations
The objective of these simulations is to explore the dynamics of the model and to determine metrics to measure the systemic risk implicit in a given system. Table 4 provides a summary of some findings. For each possible capital structure, we simulate 100 different interbank markets. For each case of interbank market we determine its resilience through the ficticious default algorithm. If at least one bank in this algorithm generates the failure of at least one other bank, the whole interbank structure is marked as capable of generating contagion.

Table 4 reports 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. In the base case scenario, in 70 out of 100 banks there is at least one bank that can lead to the failure of a second one if it fails. The next line shows that the total number of banks affected in each case is large, as is the assets damaged on average when contagion exists.

When moving towards less concentrated capital structures, the incidence of contagion is reduced considerably. Starting from structure d, where the largest bank is about 11% of the system, there are no more cases of contagion under the parameters of this exercise. It is interesting to note that while the incidence of contagion is reduced considerably by reducing concentration when it occurs, damage --as measured by number of banks and assets affected-- is similar. In fact, there is a slight increase, suggesting that the worst contagion cases are the last to disappear.

Table 4: Systemic risk

	Capital Structure				
	Base	b	c	d	e
Average Interbank assets over total assets	15.2%	15.0%	15.0%	14.9%	14.8%
Cases of Contagion out of 100	70	42	14	0	0
Average banks affected given contagion	15.7	15.0	15.8	0	0
Average assets affected given contagion	50.7%	51.3%	59.6%	0	0

With the data generated in the simulations, I run regressions in order to determine possible metrics to assess the systemic risk embedded in a certain system of interbank interlinkages. I define the variable to explain as the worst loss in total assets that can occur in a certain system of bank interlinkages. I try different metrics as potential explanatory variables, focusing on variables that could be constructed from balance sheet data by a regulator.

There are two metrics that seem to give interesting information. One is an attempt to measure interconnectedness and 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 system will have a lower standard deviation of exposures, then we would expect a positive relation between this metric and the dependent variable.

The second variable captures the risk imposed in the system by the bank that causes the worst systemic crisis when it fails. I define this measure of 'risk imposing' as total liabilities of a bank (the column sum of matrix X) over the capital stock *of all the other banks*. Again, the higher the risk imposed by a bank, the higher the potential damage, therefore we also expect a positive coefficient.

Table 5 shows the results of the regressions. The lower panel of the table shows the regressions including a dummy variable for the type capital structure.

Table 5: Regressions of fraction of total assets failed to total assets on variable indicated

	Coeff.	*St. Error*	*t Stat*	*P-value*		*Coeff.*	*St. Error*	*t Stat*	*P-value*
Constant	-0.842	0.057	-14.7	4.6E-41	Constant	-0.282	0.016	-17.7	9.5E-55
Interbank/Total Assets	2.459	0.329	7.5	3.4E-13	Risk Imposed	0.401	0.014	28.7	1.5E-107
St. Dev exposures	0.416	0.018	23.3	1.0E-81					
R Square	0.54				R Square	0.62			
Adjusted R Sq	0.54				Adjusted R Sq	0.62			
Standard Error	0.17				Standard Error	0.15			
Observations	500				Observations	500			

	Coeff.	*St. Error*	*t Stat*	*P-value*		*Coeff.*	*St. Error*	*t Stat*	*P-value*
Constant	-1.134	0.090	-12.6	1.3E-31	Constant	-0.340	0.036	-9.5	8.9E-20
Interbank/Total Assets	2.708	0.322	8.4	4.3E-16	Risk Imposed	0.448	0.021	21.4	1.3E-72
St. Dev exposures	0.550	0.034	16.3	5.1E-48	Dummy b	-0.028	0.021	-1.3	1.9E-01
Dummy b	-0.002	0.024	-0.1	9.3E-01	Dummy c	-0.027	0.024	-1.1	2.6E-01
Dummy c	0.031	0.029	1.0	3.0E-01	Dummy d	0.008	0.027	0.3	7.6E-01
Dummy d	0.088	0.035	2.5	1.3E-02	Dummy e	0.095	0.030	3.2	1.5E-03
Dummy e	0.191	0.040	4.7	3.1E-06					
R Square	0.58				R Square	0.65			
Adjusted R Sq	0.57				Adjusted R Sq	0.64			
Standard Error	0.16				Standard Error	0.15			
Observations	500				Observations	500			

The first metric (st. dev. of exposures) is significant and gives a relatively good account of systemic risk when combined with total size of the interbank market. R square increases when dummy variables are included. This is due to cases d and e, where we know that 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 we will see in the next section.

Second Simulations

This set of simulations attempts to assess the risks of the current structure of concentration in Chile in a more meaningful way. In addition to measure failure of banks, measures of assets ‘damaged’ are also reported. Damaged assets are defined as the assets of those banks that suffer a loss of at least 50% of its capital, but less than 100%. The idea is to measure not only absolute failures, but also those situations where banks have been substantially weakened. In these situations, the supervisor most likely will have to take some corrective action.

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

In these simulations, I also explore the impact of different forms of the structure of interconnections. In particular, I restrict banks to have a fixed number of counterparties. I analyse cases where banks interact with 3, 4, 6, 8 and 12 counterparties. These need not to be the same in the borrowing and lending side. Nor they form closed sets, in the sense that the counterparties of a given bank do not have the same counterparties as that bank. This adds realism to the exercise, in that it is difficult to think that a situation where a bank interacts with all the others in the interbank market is a realistic one.

Figures 1 and 2 shows the results for the cases of loss ratios (q) of 20 and 30%, respectively. Both show the extent of damage as well as the size of the interbank market for three cases of the capital structure: baseline, c and e. Points in the graph represent the average result for structures with the given number of counterparties. With these levels of q, there are no failures by contagion. The case of q=10% shows that damage is higher the highest the concentration, a result in line with the findings of the previous section. With one exception, moving towards a larger number of counterparties reduces damage, our alternative measure of systemic risk. In this case, a higher number of counterparties helps to spread the risk imposed by large banks.

However, this need not be always the case. An increase in the number of counterparties may initially have an adverse effect, in that it helps to spread the damage. This happened in one case in Figure 1 (Base case going form 3 to 4 counterparties) and happens more frequently with higher q. Figure 2 shows that this is the case. With the base case of concentration, increasing the number of counterparties always increases damage.

Figure 3 and 4 report cases with q =40% and 50%, respectively. For each case of concentration assets of failed banks (solid line) and damaged banks are reported. Consider the first the base case in Figure 3 (square marks). Failed assets increase at the beginning with the number of counterparties and then goes down. Damage, in turn, follows an almost exact opposite pattern. In case c of concentration, there are failures by contagion with low number of counterparties, but they decrease monotonically with the increase in the number of counterparties. Finally, case e shows no failures by contagion and damage that decreases monotonically with the increase in counterparties.

Results seem to indicate that there may be non-linearities in the effect of increased interlinkages in a network of banks on its resilience to shocks. Future research should explore this point. The trade-off seems to come from the fact that increasing interlinkages may help to transmit an adverse shock rather than absorb it. Figure 4 shows another case with these properties.

However, all results in this set of simulations indicate that systemic risk is lower in less concentrated structures, as measured by either contagion failures or damage. In what follows, a measure to contain systemic risk is proposed.

Results from the first set of simulations showed that risk imposed was a key determinant of systemic risk. Therefore by limiting the amount of risk imposed on the rest of the system, systemic risk can be contained. I search through simulations, the larger number for the risk imposed definition that generates no failures by contagion in the case q =40% and Counterparties=6. It turns out that this number is 0.25. This is the maximum ratio of liabilities in the interbank market to capital of all other banks in the system. This number can be translated into a maximum fraction of interbank liabilities to total assets as a function of the fraction of capital that a given bank represents in the total.

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

The effect of the rule is shown in figures 6 to 9, which can be directly compared with figures 1 to 4. Dashed lines indicate the original situation while solid lines indicate situation under the rule. Also, square markers indicate failures by contagion while diamonds indicate damage. Figures show that the rule effectively reduces systemic risk in all cases. Failures by contagion virtually disappear in all cases with six or more counterparties, even in the case of q =50%.

IV. Summary conclusions

(to be provided)

V. References (to be completed)

Allen, Franklin and Douglas Gale (2000), “Financial Contagion”, *Journal of Political Economy* 108 (1).

Bagehot, W. (1873), *Lombard Street: a Description of the Money Market*, London: H S King.

Calomiris

Demirgüç-Kunt, Asli and Detragiache (1999), “Does Deposit Insurance increase Banking System Stability? An empirical investigation”, Working paper 2247, The World Bank.

Demirgüç-Kunt, Asli and Harry Huizinga (2000), “Market Discipline and Financial Safety Net Design”, Working paper 2183, The World Bank.

Demirgüç-Kunt, Asli and Tolga Sobaci (2000), “Deposit Insurance Around the World: A Data Base”, mimeo, The World Bank.

Dewatripont, Mathias and Jean Tirole (1994), *The Prudential Regulation of Banks*, MIT Press.

Diamond, Douglas and P. Dybvig (1983), “Bank runs, deposit insurance and liquidity”, *Journal of Political Economy* 91, 401-19.

Dow, James (2000), What is systemic risk? Moral hazard, initial shocks and propagation, *Monetary and Economic Studies*, December.

Elsinger, Helmut, Alfred Lehar and Martin Summer (2002), “Risk Assessment of Banking Systems”, mimeo, Oesterreichische Nationalbank, August.

FDIC (Federal Deposit Insurance Corporation) (2002), *Annual Report 2001*, Washington D.C.

Financial Stability Forum (2001), *Guidance for Developing Effective Deposit Insurance Systems*, Basel.

Freixas, Xavier, Bruno Parigi and Jean-Charles Rochet (2000), “Systemic risk, Interbank relations, and Liquidity Provisions by the Central Bank”, *Journal of Money Credit and Banking* 32 (3), August.

Furfine, C. (1999), BIS paper

García, Gillian (1999), “Deposit Insurance: Actual and Good Practices”, *IMF Working Paper* wp/99/54.

Gorton,

IMF (1998), *Towards a Framework for Financial Stability*, World Economic and Financial Surveys, Washington, D.C.

James, Cristopher (1991), “The losses realized in bank failures”, *The Journal of Finance* XLVI(4) September.

Rochet, Jean-Charles and Jean Tirole (1996), “Interbank lending and Systemic risk”, *Journal of Money Credit and Banking* 28 (4), November.

SBIF (Superintendencia de Bancos e Instituciones Financieras) (2002), *Información Financiera*, several months.

Upper, Christian, and Andreas Worms (2001), "Estimating bilateral exposures in the German interbank market: Is there a danger of contagion?", *BIS Papers* No1, Bank for International Settlements, March.

Wells, Simon (2002),

Figure 1

Assets damaged and Interbank Market size

Loss ratio = 20%

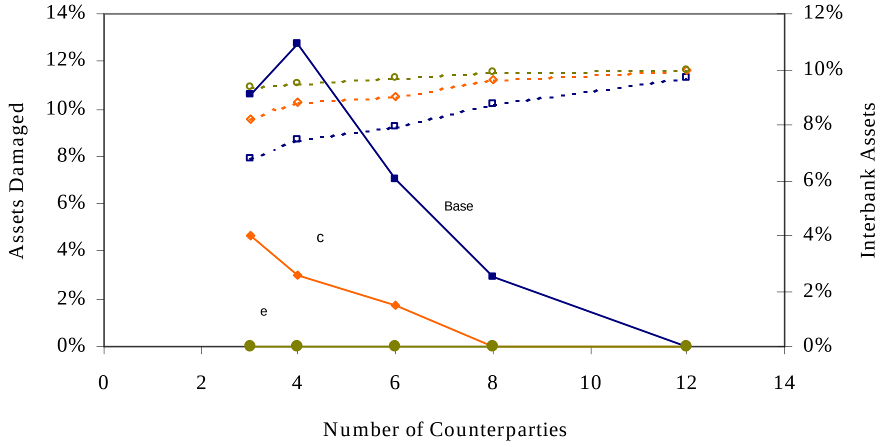

Figure 2

Assets damaged and Interbank Market size

Loss ratio = 30%

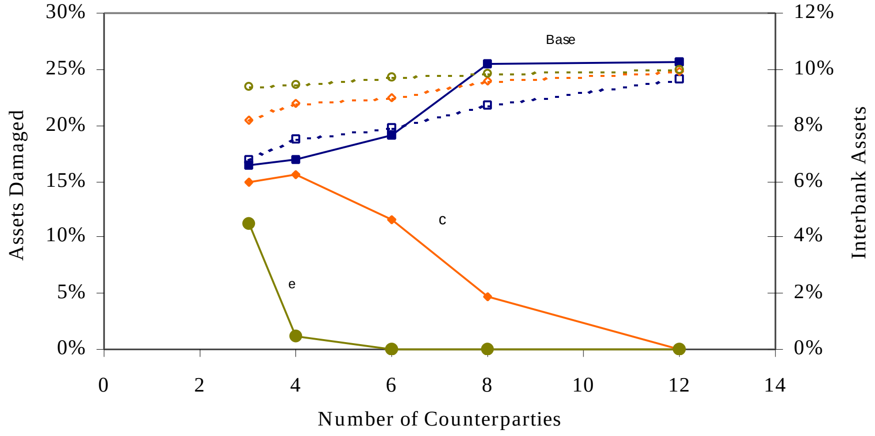

Figure 3

Assets of banks damaged and failed

Loss ratio = 40%

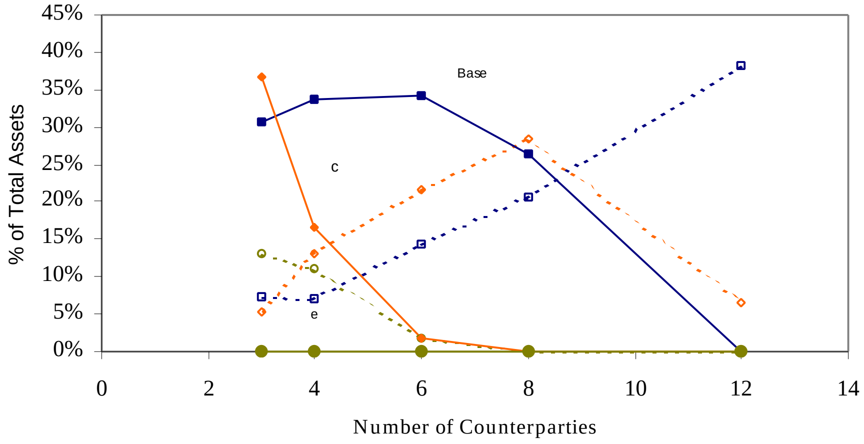

Figure 4

Assets of banks damaged and failed

Loss ratio = 50%

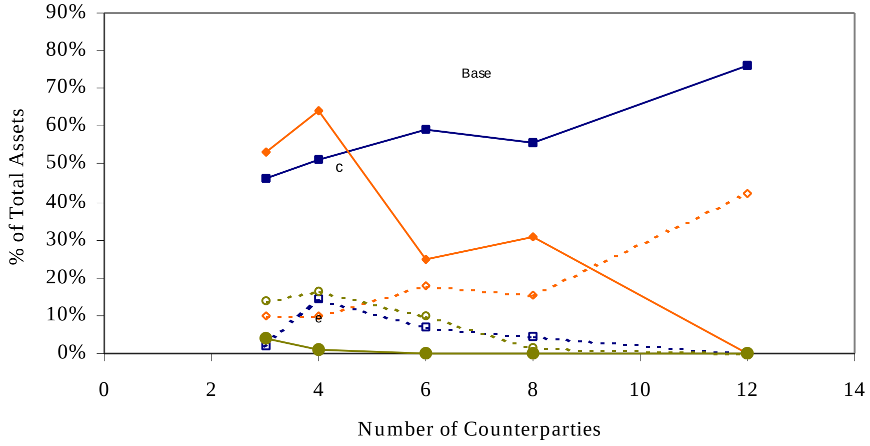

Figure 5

Maximum Interbank Liabilities

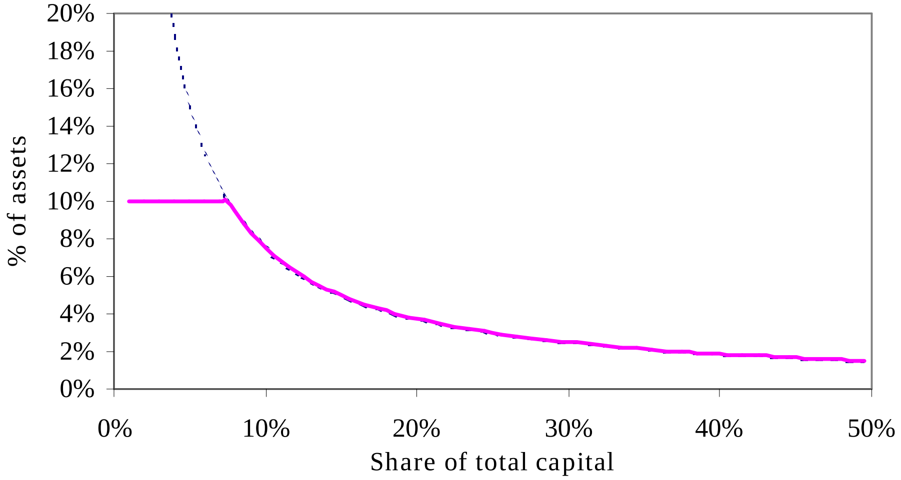

Figure 6

Assets of banks damaged

Loss ratio = 20%

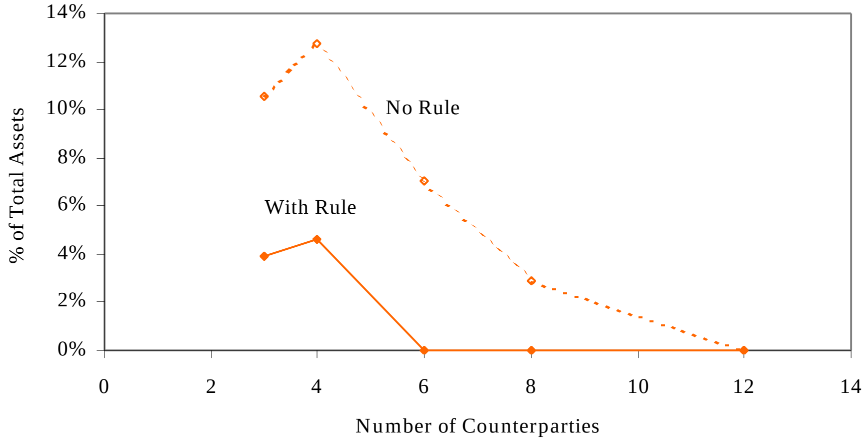

Figure 7

Assets of banks damaged

Loss ratio = 30%

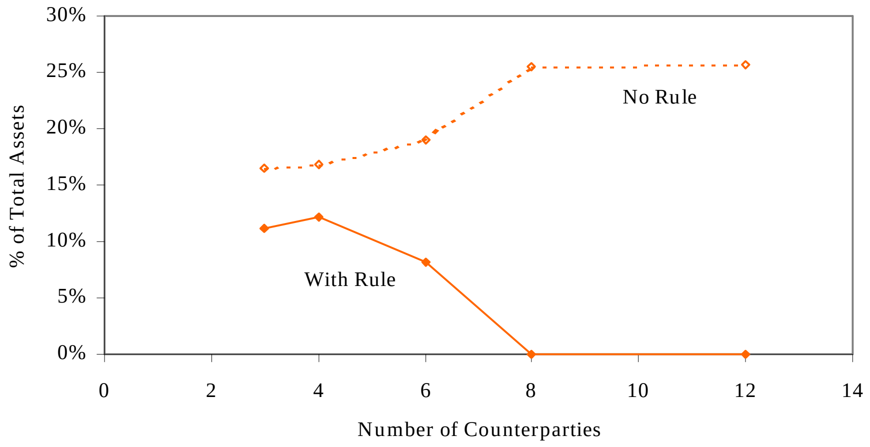

Figure 8

Assets of banks failed and damaged

Loss ratio = 40%

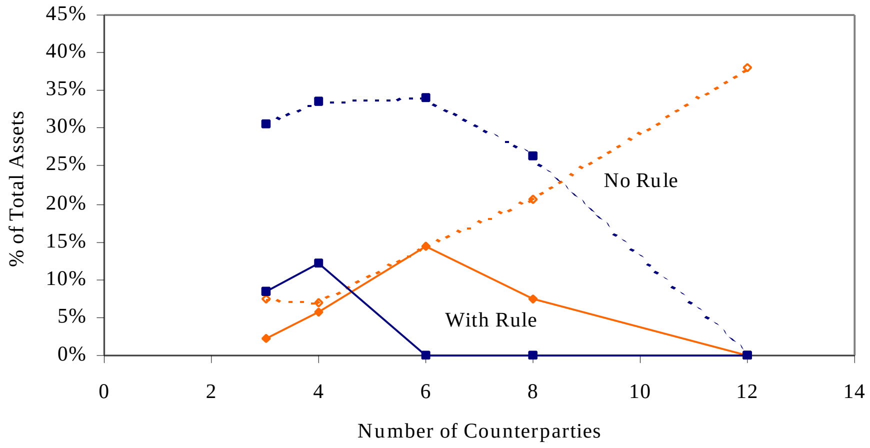

Figure 9

Assets of banks failed and damaged

Loss ratio = 50%