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WORKING PAPER

Liquidity matters:

Evidence from the Russian interbank market

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Liquidity matters: Evidence from the Russian interbank market

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Abstract

We suggest a new transmission channel of contagion on the interbank market, namely the liquidity channel. We apply this idea to the Russian banking sector and find that the liquidity channel contributes significantly to a better understanding and prediction of actual interbank market crises. Interbank market stability Granger causes the interbank market structure, while the opposite causality is rejected. This emboldens the case for viewing the interbank market structure as endogenous. The results corroborate the thesis that prudential regulation at individual bank level is insufficient to prevent systemic crises. We demonstrate that liquidity injections of a classical LOLR can effectively mitigate coordination failures on the interbank market not only in theory, but also in practice. In short: liquidity matters.

JEL: C8, G21

Keywords: interbank market stability, contagion, liquidity channel, lender of last resort, Russia

1 Introduction

There is broad discussion in the theoretical literature about the need for a lender of last resort (LOLR) to guarantee the stability of the banking sector. The classical Bagehot (1873) doctrine argues that the central banks should lend to illiquid but solvent banks at a penalty rate. This doctrine has been under attack from several sides. One strand of the literature mounts an attack on the LOLR by arguing that sophisticated interbank markets will provide liquidity to those who need it most. In this line of reasoning the task of guaranteeing financial stability comes down to the provision of adequate levels of aggregate liquidity by the monetary policy authorities, rendering the bank-specific liquidity provision by the LOLR redundant (see e.g. Goodfriend and King, 1988; Kaufman, 1991). On the other hand, the most striking stylized fact of the 2007-2008 sub-prime crisis is the persistent drought on the interbank market that sharply reduced interbank money flows from a flood to a trickle. The very relaxed monetary policy of the FED did not suffice to revamp market liquidity and even the massive LOLR injections ware barely enough to safe the system. Clearly the interbank market, no matter how sophisticated, is not immune to serious coordination failures, reinforcing the arguments of classic LOLR advocates like Rochet and Vives (2004) who demonstrate the theoretical possibility of a solvent bank turning illiquid as the result of a coordination failure on the interbank market and the positive role of a LOLR in correcting this market inefficiency.

There is a large literature that studies interbank market contagion through direct capital linkages, where banks fail when hit by a default in excess of their capital. In this literature, the structure of the interbank market is crucial for the ultimate effect of a financial shock on the banking system, as modelled in a deterministic manner by Allen and Gale (2000). Applications of this approach to national banking systems uncovered limited risk of contagion in Switzerland (Sheldon and Maurer, 1998), the U.S.(Furfine, 2003), Germany (Upper and Worms, 2004), the Netherlands (Lelyveld and Liedorp, 2006) and Belgium (Degryse and Nguyen, 2007). Contagion may however also run through indirect liquidity linkages, as modelled by Rochet and Vives (2004). Since individual interbank market participants are generally risk averse and have only asymmetric information, they may rationally overreact to any negative news about their counterparty and withdraw their assets as quickly as possible. Such a generalized liquidity crunch may push a solvent institution into illiquidity and bankruptcy. This liquidity driven approach has been applied in the empirical literature on contagion in payment systems (Angelini et al., 1996). Müller (2006) uses bilateral data on bilateral interbank exposures and assumes that a bank failure not only produces credit losses for its creditors, but also endangers its borrowers' liquidity through the termination of granted credit lines. Her simulations reveal substantial risk of contagion in Switzerland, contrasting the results of Sheldon and Maurer (1998) that are based on aggregate data.

In this paper we contribute to this discussion in several ways. We verify empirically whether liquidity matters for interbank market stability and whether an active LOLR can play a role in promoting this stability. In addition we verify whether the structure of the interbank market drives interbank market stability, as in Allen and Gale (2000), or is largely endogenous, as put forward by Castiglionesi and Navarro (2008). To this purpose we employ a dataset of Russian bilateral interbank exposures that covers two severe crises on the Russian interbank market prior to the sub-prime crisis, namely the crisis of 1998 and the crisis of 2004.

Similarly to Müller (2006) we exploit data on exact bilateral linkages, but in contrast to Müller (2006) we model the liquidity channel as the effect of a bank's default on its creditors' liquidity. The simulations reveal that there is only limited potential for contagion through the direct capital channel. The capital channel partially captures the 1998 interbank crisis, but completely misses the 2004 interbank meltdown. In contrast, we document substantial potential for contagion through indirect liquidity linkages. The liquidity channel not only captures the 1998 crisis but also the 2004 crisis very accurately. The results are robust to the definition of the initial financial shock (either the failure of a single bank or the correlated default of a number of banks). The simulations produce bank-specific failure frequencies that possess limited predictive power for real bank defaults beyond that contained in bank fundamentals. More importantly our approach reveals that the Central Bank of Russia's (CBR) liquidity injections were relatively effective in stabilizing the interbank market, lending support to the thesis that LOLR interventions can correct coordination failures on the interbank market. In addition our simulated measure of interbank market stability Granger causes the interbank market structure, while the opposite causality is rejected. This casts doubt over studies that use the interbank market structure as a determinant of financial stability and emboldens the case for viewing the interbank market structure as endogenous as in Castiglionesi and Navarro (2008).

The remainder of this paper is organized as follows. In the next section we describe our data and our simulation approach. The third section is devoted to the Russian interbank market and its crises to make the reader more familiar with this banking market. In the following sections we present the basic simulation results, our analysis of the LOLR's effectiveness in stabilizing the interbank market and our analysis of the endogeneity of the interbank market structure. The last section concludes.

2 Data and Methodology

Two established and highly respected private financial information agencies Banksrate.ru and Mobile provided us with monthly bank balances and monthly reports "On Interbank Loans and Deposits" (official form's code 0409501) for the period August 1998 - November 2004.[1] The latter report provides information on banks' gross interbank positions split by counterparty enabling us to reconstruct the exact matrix of interbank exposures at the beginning of each month. Balance sheets of foreign banks and off-balance-sheet positions are not available.

The following matrix summarizes the types of data used in our exercise:

$$L = \begin{pmatrix} 0 & y_{12} & y_{13} & y_{14} \\ y_{21} & 0 & y_{23} & y_{24} \\ y_{31} & y_{32} & 0 & y_{34} \\ y_{41} & y_{42} & y_{43} & 0 \end{pmatrix} \quad \begin{matrix} c_1 & l_1 \\ c_2 & l_2 \\ c_3 & l_3 \\ c_4 & l_4 \end{matrix}$$

where L is the matrix of interbank exposures with y_{ij} representing gross claims of bank i on bank j. Banks don't lend to themselves, hence $y_{ij} = 0$ if $i = j$. c_i and l_i are, respectively, capital and liquid assets of bank i. The net exposure (NE) on the interbank market can be computed for bank i as

[1] For more information on the data providers see their respective websites at www.banksrate.ru and www.mobile.ru. Karas and Schoors (2005) provide a detailed description of Mobile database.

$NE_i = \sum_{i=1}^{n} y_{ij} - \sum_{j=1}^{n} y_{ij}$. If $NE_i > 0$, bank i is a net borrower on the interbank market, otherwise it is a net creditor.

The anatomy of a crisis is determined by the initial shock and the propagation mechanism. In the baseline simulations we model the initial shock as a sudden single bank's default on its interbank obligations. Assume in the example above bank 4 defaults on its interbank obligations due to an exogenous shock. Banks 1 suffers a credit loss equal to its total gross claims on the defaulting institution, y_{14}.[2] Losses deplete bank capital. If losses exceed bank capital an institution turns insolvent and will, in turn, defaults on its own interbank obligations. Thus, in case of bank 1 if y_{14} exceeds c_1 the bank fails. A similar solvency test applies to other banks. If new defaults occur the associated credit losses further deplete the surviving banks' capital and possibly lead to new insolvencies. Formally, in each round of contagion the following rule determines defaulting institutions:

$$d_i = \begin{array}{l} 0 \text{ if } \sum_{j=1}^{N} y_{ij}^{f} \leq c_i \\ 1 \text{ if } \sum_{j=1}^{N} y_{ij}^{f} > c_i \end{array}$$

where y_{ij}^{f} are claims of bank i on failed bank j and d_i is a default indicator with $d_i = 1$ for failed banks. In this manner contagion propagates through the system until no more failures occur. We call simulations of this purely mechanical capital channel the 'passive banks' scenario.

In the 'active banks' scenario we also allow for contagion through the liquidity channel.When one bank experiences an adverse shock, uncertainty is created about other banks potentially subject to the same shock. Many of the market participants are risk averse and would rather be safe than sorry. In periods of uncertainty and mutual suspicion they might overreact to any negative news issued about their counterparty and try to withdraw their deposits as quickly as possible. In our simulations the role of the negative news triggering deposit runs is performed by credit losses. Market participants run on institutions that suffer credit losses by not prolonging outstanding credits and withdrawing funds on current accounts. We assume all banks behave homogeneously in this way. Banks that are exposed to credit losses therefore fail because of 1) the direct impact of the credit loss (the capital channel) and 2) the indirect impact on the exposed bank's liquidity driven by other banks' reactions on its credit loss.(the liquidity channel). In the simulations the additional liquidity channel boils down to deleting all banks suffering a direct credit loss (being touched by the shock) and being illiquid, (defined as a net interbank exposure in excess of liquid assets). Formally the defaulting institutions in each round of contagion are identified as follows:

$$d_i = \begin{array}{l} 0 \text{ if } \sum_{j=1}^{N} y_{ij}^{f} \leq c_i \text{ and } NE_i \leq l_i \\ 1 \text{ if } \sum_{j=1}^{N} y_{ij}^{f} > c_i \text{ or } NE_i > l_i \end{array}$$

[2]The assumption that a bank loses its total gross claims on the defaulting institution is consistent with the evidence on actual recovery rates. The CBR reports that only 3% of interbank claims on failed institutions were recovered in the process of bank liquidation in the period 2001-2003 (Vedomosti, 2003, N 121 (921)). In other words, loss given default on interbank claims was almost 100%.

and contagion propagates through the system until no more failures occur in a given round.

We also model a 'panic' scenario. This is an extreme case of the 'active banks' scenario in which the initial financial shock destroys all trust in the banking system, resulting in the immediate failure of all banks whose net exposure on the interbank market exceeds their liquidity, irrespective of whether the bank has given reason for suspicion by suffering a credit loss, or not. Boissay (2006) develops a theoretical model of financial contagion through trade credit in which an illiquid firm may cause a chain reaction that draws its suppliers (and hence creditors) down with it, even though these were sound in the first place. Boissay's framework corresponds to our panic scenario, in which following a shock all banks are treated as potentially fragile resulting in a panic-like settlement of all interbank positions.

When computing a bank's net interbank exposure we take into account claims on and debts to only non-failed banks. Here we assume, first, that defaulting institutions do not honour any of their obligations and, second, that all other banks will postpone paying their debts to these institutions. The latter assumption is plausible in the short run because troubled banks are not strong enough to collect these payments quickly. By the time the temporary administration, appointed by the judge, has built the list of creditors and borrowers and has started to clean up the mess, the banking crisis has already run its course. Note that this assumption of postponed debt repayment makes the remaining banks more liquid ceteris paribus. It is therefore a very conservative assumption that makes sure we do not overstate the severity of a crisis.

In the baseline simulations we let each bank fail once in each period (an idiosyncratic shock), track the resulting contagion effects as defined above and compute the share of failed assets in system-wide assets, excluding the initial failure. For each month for each initially failed bank we get 3 estimates of contagion corresponding to the three scenarios, 'passive banks', 'active banks' and 'panic'. For each month and scenario we then report the average across the 5% worst estimates of contagion of the three scenarios.

To test the robustness of our results to the choice of the initial bank failure, we adapt the idea of Elsinger et al. (2006) and expose banks to macroeconomic shocks using a one-factor version of the CreditRisk+ model (see Gordy (2002) for a general presentation of the CR+ model) in order to start the simulation with a number or correlated bank defaults (a systemic shock). Given that other credit risk models like KMV or CreditMetrics require banks to be listed or to have credit ratings, conditions not fulfilled for most Russian banks, CreditRisk+ is the best available alternative to simulate bank defaults. First, we derive unconditional default probabilities as fitted probabilities from a probit model as advocated by Hamerle and Rösch (2004) for parameterizing CR+. Using a panel of all Russian banks for the period August 1998 - November 2004 we regress the binary variable equal to one in the month of a bank's license withdrawal on a list of bank specific variables following notably Golovan et al. (2003) and Lanine and Vandervennet (2006). Results of these probability of default models are reported in the first column of table 1.[3] Most coefficients are significant with the expected signs. Higher profitability, capitalization, liquidity in the form of cash or investment into government securities, better loan quality and extensive use of cheap budget and deposit funding reduce the probability of default. Involvement into traditional banking activities such as granting loans signals less speculation and less risks. Money centre banks borrowing a lot on the interbank market and big banks represent a threat to the systemic stability and are unlikely to lose their license. We further assume that the actual default probabilities of Russian banks are driven by one systemic risk factor, the general state of the Russian economy.[4] For example, macroeconomic downturns might weaken financial institutions leading to more failures than in regular times. We model this idea by multiplying the estimated unconditional default probabilities by the random realizations of the systemic risk factor. The latter is a gamma distributed variable x with mean one and variance one as suggested for one-factor models in the CR+ manual, Section A7.3. When a bad outcome is realized ($x > 1$) all default probabilities scale up making individual failures more likely. When a good outcome is realized ($x < 1$) all default probabilities fall. For each month, we run 1000 random realizations of the systemic risk factor. In each simulation initially failing banks are determined by random Bernoulli draws with the success probability for each bank equal to its rescaled default probability (i.e. estimated unconditional default probability times the risk factor realization). As in the baseline simulations we track the contagion effects of the initial correlated defaults, compute the share of failed assets, and report the 5% expected shortfall for each month and each of the three scenarios.

Throughout the simulations we never allow foreign banks to fail, but we do allow foreign banks to run on domestic banks, i.e. claims on and debts to foreign banks enter the calculation of domestic banks' net interbank exposure. The two CBR-owned banks, Sberbank and Vneshtorgbank, known to have enjoyed the full and consistent backing of the CBR, are not allowed to fail. In each month we compute total assets of the banking sector by summing up assets of all banks having open interbank positions in that month excluding Sberbank and Vneshtorgbank.

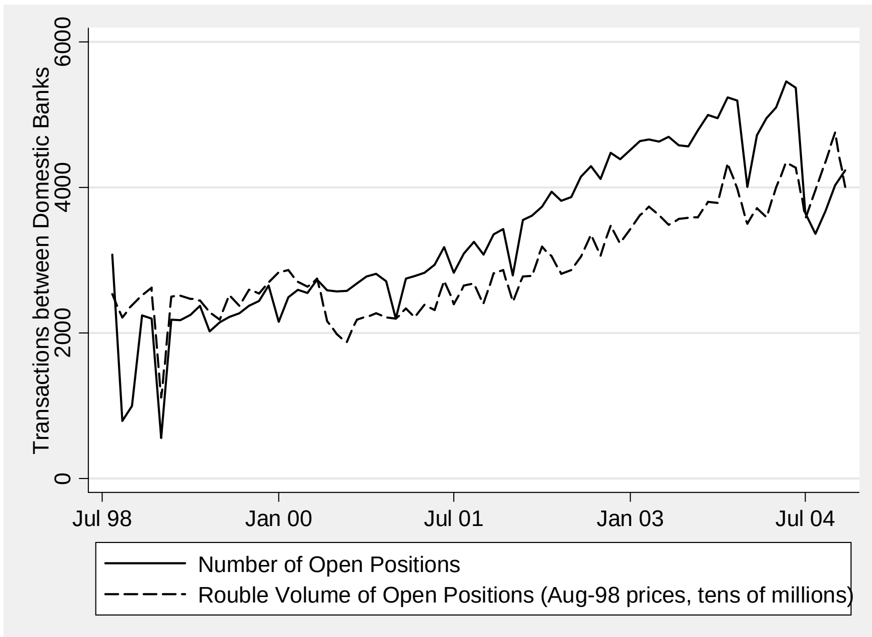
3 The Russian Interbank Market

Our simulations distinguish between two types of shocks, idiosyncratic and systemic, and two types of risk, solvency risk and liquidity risk. Such distinctions capture the differences between the two crises that hit the Russian banking sector in August 1998 and summer 2004, both resulting in the collapse of the

[3] Limiting bank failures to true bankrupties, thus discarding licence revokals due to mergers and compulsory/voluntary liquidation, does not produce substantially different failure predictions and is not considered in the paper. Introducing bank-specific effects into the probit model doesn't significantly alter the results either.

[4] Lesko et al. (2004) show that, though the single risk factor approach overestimates the portfolio risk, the overestimation error is small if it is applied to firms operating in one country.

Figure 1: Liquidity Drains on the Russian Interbank Market



interbank market. While the 2004 crisis was mainly triggered by rumors associated with a single bank failure, the 1998 turmoil resulted from a fundamental systemic shock having direct effects on banks' solvency. Figure 1 demonstrates the periods of low interbank market activity that followed both shocks together with a lesser-scale liquidity drain in the end of 2003. In all cases the volume of interbank lending decreases by less than the number of outstanding contracts providing evidence that the liquidity shocks hit primarily smaller banks.

The roots of the 1998 crisis go back to 1996 when the government's desperate need for money in the run-up to the presidential elections led to very high yields on treasury bills (GKOs). In the beginning of 1996 the average lending rate on loans to the real economy was 60% per annum, while the yield on GKOs was around 100% per annum. Moreover, incomes from GKO investment were tax deductible. In the second half of 1996 Russian banks began borrowing actively on foreign markets (currency loans from foreign banks and Eurobonds). The huge difference between domestic and foreign interest rates in combination with relatively stable rouble exchange rate, guaranteed by the ruble corridor policy (a crawling currency band), ensured huge profits. When the GKO market was opened to foreigners in 1997, the desire of foreign investors to hedge their ruble investments was met by Russian counterparties, who took short positions in forward contracts on foreign currency. The Russian banks, involved in this trade, carried a huge amount of fundamentally uncovered currency risk. In the beginning of 1998 the share of foreign currency denominated liabilities significantly exceeded rouble denominated liabilities. In a vain attempt to reduce the currency mismatch in their books, banks began extending foreign currency denominated loans to domestic borrowers. In fact, by shifting currency risk to their borrowers, banks substituted it by credit risk, because after the rouble devaluation most of the borrowers defaulted.

The Asian crisis and dwindling yields on GKOs made Russian government debt securities less attractive to foreigners and provoked capital outflow. Protecting the rouble from devaluation, the CBR lost a large share of its international reserves. At the same time the Russian government faced problems to roll over its GKO debt. In August 1998 the CBR's exchange rate policy became untenable. Although GKO yields soared to 100% per annum and more, banks were liquidating their positions. On 17 August 1998, Russia abandoned its exchange rate regime, defaulted on its domestic public debt and declared a moratorium on all private foreign liabilities, which was equivalent to an outright default. The Russian bank sector was hit severely by the uncovered forward contracts on foreign currency, the government default on GKOs and the subsequent bank runs (Perotti, 2002). The crisis completely paralyzed the interbank market. The recovery took more than one year.

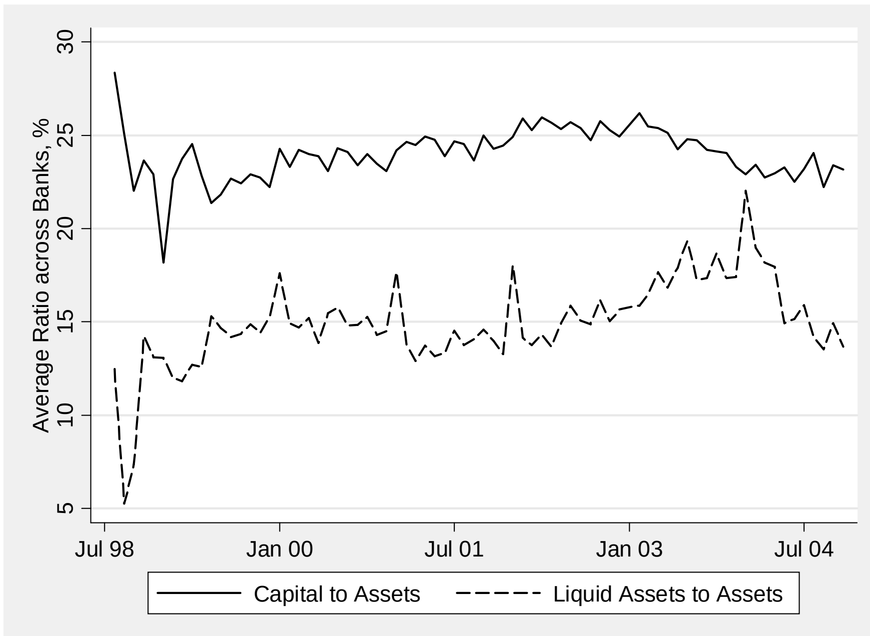
The 'mini-crisis' of 2004 was sparkled by unexpected regulatory action. In May 2004 the CBR closed a bank accused of money laundering while the head of the Federal Service for Financial Monitoring (FSFM) Mr. Zubkov announced that his Service suspected about a dozen banks in money laundering and sponsorship of terrorism, without naming the 'dirty dozen'. Several inconsistent 'black lists' began circulating the banking community as bankers tried to guess which banks were suspected by the FSFM. Mutual suspicion led to a drying up of liquidity on the interbank market, putting pressure on the hundreds of smaller banks that are highly dependent on it. The crisis of confidence provoked runs on several large banks among which were Guta Bank and Alfa Bank. Being severely hit by the liquidity shock and abrupt withdrawal of a number of large depositors, Guta Bank found itself on the edge of bankruptcy and was acquired by the state-owned Vneshtorgbank at a symbolic price.

Figure 2 confirms that the 2004 crisis mainly resulted in the drain of liquidity, while in 1998 the latter combined with serious solvency problems.

In between the two crises the interbank market has considerably grown and gained importance as a source of funding for Russian banks. Figure 1 shows that both the number and the inflation-adjusted volume of domestic transactions more than doubled since January 1999, the point when interbank market stability hindered by the 1998 turmoil was already largely restored. The number of market participants rose from about 650 in January 1999, a half of all existing banks at that time, to well above 900, representing three quarters of all banks in May 2004.

The average Russian bank has been a net borrower on the interbank market with a growing net liability position. While the average share of interbank claims in total assets remained relatively constant around 5-6%, the average share of interbank obligations rose from about 6% in 1999 to 8% in 2004. A rather

Figure 2: Financial Crises and Banks' Health

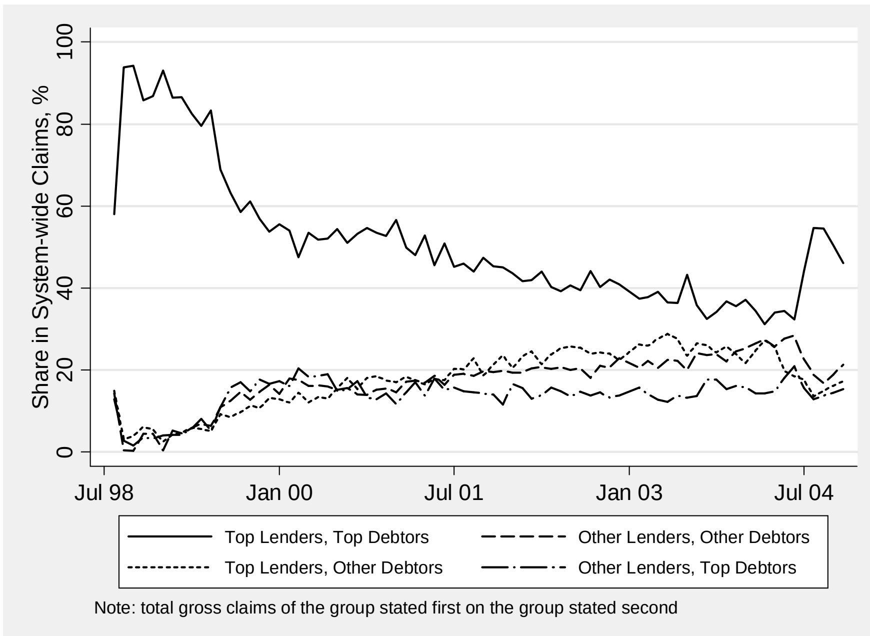


opposite trend of declining interbank market involvement took place for the 40 biggest banks. Their average share of interbank obligations in total assets fell from 25% in 1999 to 10% in 2001 and remained around that level till 2004. The corresponding share of interbank claims decreased from 10-12% in 1999-2001 to 7-9% in 2002-2004. Thus, while big banks on average reduced their reliance on the interbank market as a net source of funding, small banks enhanced it.

The growing number of market participants and the easier access of small banks to the interbank market show up in a decreasing market concentration as demonstrated by Figure 3. The volume of transactions between the top 40 lenders and the top 40 borrowers accounted for more than 80% of system-wide interbank claims in 1999 but diminished to less than 40% by May 2004. The other three lines representing total gross claims of top lenders on non-top borrowers and of non-top lenders on both groups of borrowers display the opposite increasing trend. Figure 3 provides further evidence that in periods of turmoil primarily small banks are left aside. The resulting rise in market concentration is evident for both the post-1998 crisis period and the turbulent summer of 2004.

Top lenders and top debtors are likely to contribute most to contagion. Defaulting top debtors deliver major credit losses and infect many other banks while top lenders are potentially the most dangerous panic makers having claims, and hence the ability to run, on numerous counterparties. We arbitrarily look

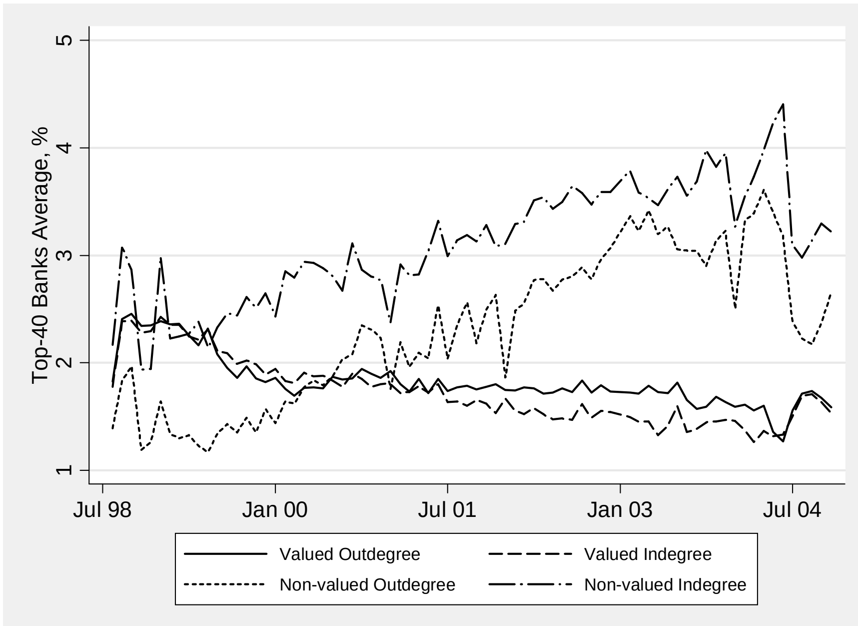
Figure 3: Global Domestic Exposures



at the top 40 of both categories. Figure 4 focuses on the top debtors and top lenders' ability to spread contagion to the rest of the system. In each month we sort banks by one of the four indicators: their share in system-wide interbank claims, their share in system-wide interbank liabilities, the percentage of market participants they have as counterparties on their asset side and similarly for the liability side. The respective names for those indicators in the social network terminology are valued outdegree, valued indegree, non-valued outdegree and non-valued indegree, all four being examples of the so called centrality indices. Each measure considers transactions between domestic banks only. We keep the forty biggest values of each indicator and take the average across them. We finally plot those averages over time.

Two opposite trends are evident from Figure 4. While the valued indices decreased over time, the non-valued ones noticeably rose. Banks with the biggest interbank obligations (valued indegree) could in case of default on average deliver a credit loss of 2-2,5% of the total interbank market volume in 1998-1999 but only 1-1,5% in 2004. Similarly banks with the biggest interbank claims (valued outdegree) could on average withdraw 2-2,5% of the total interbank market volume from their counterparties in 1998-1999 but only 1-1,5% in 2004. On the other hand, banks with the biggest number of counterparties on their liability side (non-valued indegree) could in case of default on average spread contagion to 2-3% of all the market participants in 1998-1999 but to almost double so

Figure 4: Market Concentration and Contagion

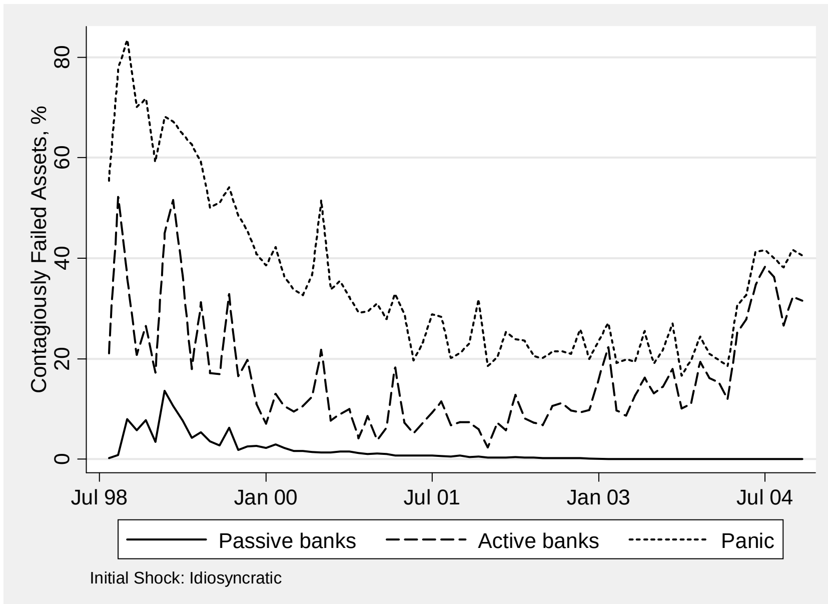


much in 2004. Banks with the biggest number of counterparties on their asset side (non-valued outdegree) could run on 1-2% of the market participants in 1998-1999 and again on almost double so much in 2004. Overall these figures suggest that while the magnitude of potential shocks has diminished over time, the risk of being hit by a shock has grown. This observation is in line with the decreasing market concentration detected in Figure 3. More links between banks imply that losses are absorbed by a larger number of counterparties but also that more banks get infected.

A few of the biggest Russian banks have ensured that the volume of transactions with foreign counterparties has always exceeded the volume of domestic transactions, both in terms of borrowing and lending, although only by a small margin during the second half of our sample period. For an average bank, however, less than 20% of interbank activities involve a foreign counterparty. Thus, the major contribution of foreign banks to our contagion exercise relates to their powerful ability to run on big domestic banks.

Few Russian banks have permanent relationships with other banks. Considering only the bilateral links that show activity in at least one period, only a quarter of the bilateral links are active in more than one third of the observed periods, while only 12% of the bilateral links are active in more than half of the observed periods. Such an unstable market structure no doubt adds to the variability of contagion risk over time.

Figure 5: Contagion in Alternative Scenarios

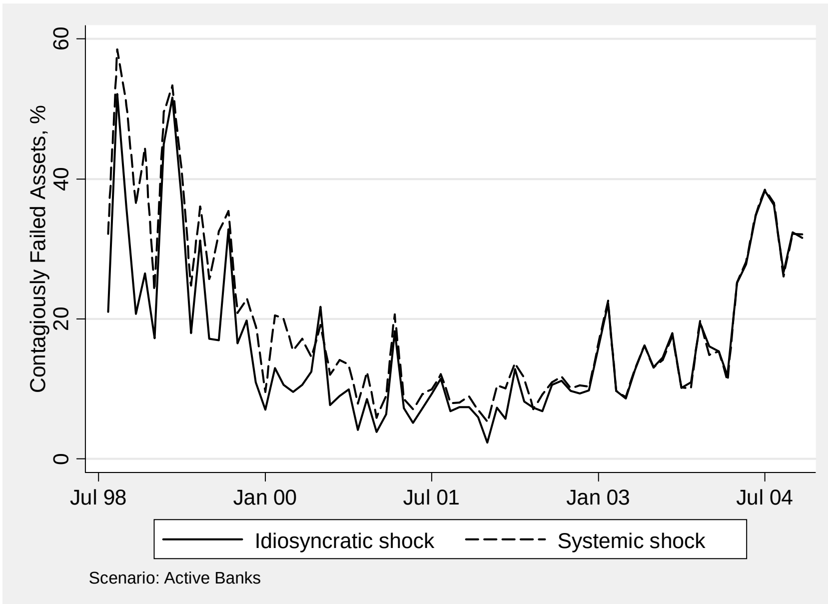


4 Results

Figure 5 plots our estimates of contagion for each of the three scenarios of the baseline idiosyncratic shock. In the 'passive banks' scenario market participants don't run on each other and only solvency matters for survival. In the 'active banks' scenario banks run on illiquid counterparties directly suffering credit losses while in the 'panic' scenario they run on all illiquid counterparties.

Using the single solvency condition for tracking bank failures proves sufficient to capture the post-1998 crisis period when solvency problems were indeed a major issue for many banks. We find that across the 5% worst-case scenarios the average share of system-wide bank assets failed due to contagion fluctuates around 10% following the crisis of August 1998 and gradually declines to negligible levels by 2000. This share remains virtually zero from then onwards, showing no signs of trouble even around the summer of 2004. Allowing banks to run on each other not only increases the size of contagion but, importantly, also points out the system's intrinsic instability in both 1998 and 2004. Indeed the estimate of contagion, provided by the simulations of the 'active banks' scenario, declines from 50% in September 1998 to about 10% by 2000, stays at low levels till end 2003 and then rises again to a peak of 40% in July 2004. The simulations of the 'panic' scenario exhibit similar dynamics, but larger levels of contagion in every period. Given the estimated system's intrinsic instability in 2004 it is, with hindsight, not so surprising that the license withdrawal from a

Figure 6: Contagion with Alternative Shocks



medium-sized bank and rumors that more banks would follow sufficed to trigger a systemic crisis. Clearly the liquidity channel of contagion, incorporated in the active banks scenario and the panic scenario, contributes to our understanding of real life systemic crises on the interbank market. Liquidity matters.

A bank is illiquid if its remaining *net* liabilities on the interbank market exceed its highly liquid assets. The simulated bank defaults due to liquidity problems are, therefore, invariant to whether we explicitly allow for the bilateral setoff - netting - of interbank positions or not. Given that those defaults drive our main results, the latter turn out to be intrinsically robust to the possibility of netting. Our estimates of contagion are also robust to the definition of the shock as shown in Figure 6.

Next to correctly identifying periods of intrinsic instability on a systemic level, our simulations produce bank-specific failure frequencies that possess predictive power for real bank defaults. We define a bank's exposure to contagion risk as the percentage of simulations in which a bank fails due to domino-effects. For each bank in each month we compute four versions of this risk measure and sequentially add them to the standard failure prediction model. Table 1 reports the results. The second column reports a standard model for the sample of banks active on the interbank market. The four versions of the contagion risk measure correspond to the different combinations of the initial shock and the propagation mechanism assumed in the simulations: the 'active banks' scenario with the idiosyncratic shock (column 3) and the systemic shock (column 4) and

Table 1: Failure Prediction Model

Net Income	-0.93***	-1.25**	-1.26**	-1.17**	-1.25**	-1.28**
Capital	-0.77***	-0.92***	-0.93***	-0.92***	-0.72***	-0.69***
Reserves	-2.26***	-2.10***	-2.06***	-2.06***	-1.41***	-1.39***
Treasury Bonds	-1.85***	-3.81***	-3.89***	-4.04***	-3.85***	-4.06***
Total Loans	-0.95***	-1.18***	-1.19***	-1.19***	-1.17***	-1.16***
Bad Loans	0.88***	1.56***	1.56***	1.55***	1.34***	1.22***
Non-bank Deposits	-0.90***	-0.74**	-0.74**	-0.73**	-0.52*	-0.48
Size	-0.09***	-0.08***	-0.08***	-0.09***	-0.07***	-0.06***
State Deposits	-0.40	-0.76	-0.74	-0.74	-0.66	-0.74
Bank Deposits	-0.43**	-0.78**	-0.87**	-0.88***	-1.42***	-1.43***
Contagion Risk			1.70*	1.80***	0.50***	0.85***
Observations	100086	52457	52457	52457	52457	52457
Pseudo R2	0.25	0.24	0.24	0.24	0.25	0.26

Note: The table reports probit regressions of the binary variable equal to one in the month of a bank's licence revokal on a list of bank-specific variables. Data is monthly for August 1998 - November 2004. Column 1 reports results for the panel of all Russian banks. Columns 2-6 report results for the panel of banks active on the interbank market. Size is the log of assets. Contagion risk is the percentage of simulations, in which a bank fails due to domino-effects. Other explanatory variables are rescaled by total assets. Constants are not reported. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

the 'panic' scenario with the two shocks (columns 5 and 6).

Bank fundamentals show up consistently with expected signs. Remarkably, our measure of contagion risk is always positive and significant. Banks, which often fail in our simulations, do fail in reality.

5 The Role of the LOLR

For the remainder of the paper we focus on the 'active banks' scenario. In this section we study the effect of the Central Bank's LOLR liquidity injections on systemic stability, by constructing counterfactuals. In the construction of these counterfactuals we treat Sberbank and Vneshtorgbank as integral parts of the broad CBR. The CBR has extensively used both its daughters as a policy instrument, in particular encouraging them to provide liquidity to smaller banks during the turbulent summer of 2004. Both banks have in turn enjoyed the full and consistent backing of their parent.

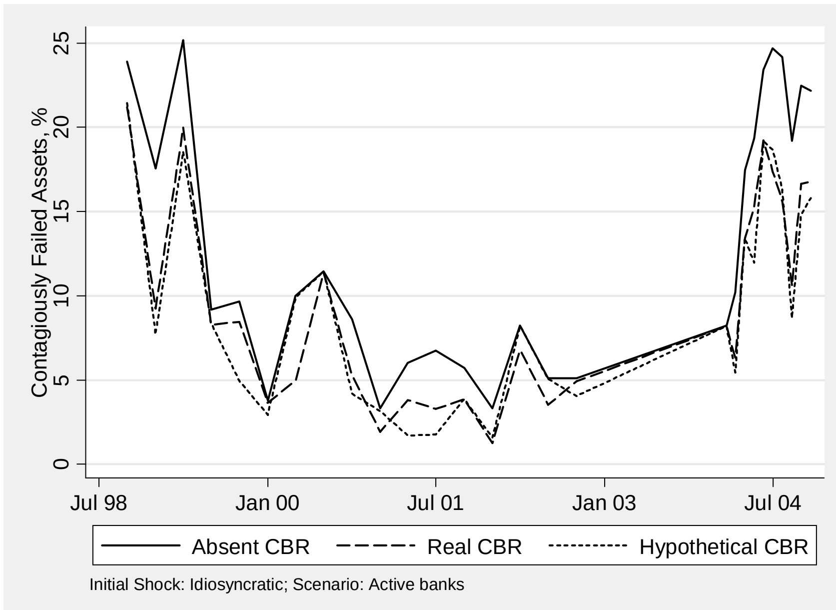
We start by modelling what would have happened in terms of contagion risk if the broad CBR (including its daughters) would not have injected liquidity in the market as a LOLR. This 'absent CBR' counterfactual is constructed by lowering all banks' liquidity holdings with their amount of borrowing from the broad CBR and rerun the baseline simulations. Like all other banks Sberbank and Vneshtorgbank are allowed to fail and to run on other banks in these simulations.

We model a second 'real CBR' counterfactual by not allowing Sberbank and Vneshtorgbank to fail or run on other banks. This counterfactual simulation essentially interprets all interbank loans of the two CBR-owned banks as emergency liquidity injections. This differs from our baseline simulations in previous sections, where both banks were also not allowed to fail, but did run on other banks.

In a third counterfactual we assess whether a 'hypothetical CBR' could have increased the system's intrinsic stability by optimally redistributing the available liquidity among banks. Technically we lower all banks' monthly liquidity positions by their borrowing from the broad CBR, essentially treating those borrowings as LOLR liquidity injections. We compute the total monthly amount of these injections and redistribute them towards banks with the biggest partial contributions to contagion. These are computed as follows: For each bank in each period we measure its partial contribution to systemic risk as an average reduction of contagion caused by the exogenously imposed survival of this bank. Specifically, in each simulation we sequentially impose the survival of each contagiously failing bank, rerun the simulation, and compute by how much the share of contagiously failed assets drops relative to original simulation. This partial contribution to contagion of a given bank in a given month is averaged across simulations Then we sort banks in a descending order by their average partial contribution to contagion and redistribute liquidity. We increase the liquidity holdings of the bank ranked first to the amount sufficient to cover its all interbank obligations. In this manner we ensure that the bank with the largest average contribution to contagion never fails because of insufficient liquidity. We do the same for banks ranked second, third etc. until the cumulative counterfactual liquidity injection equals the total amount of broad CBR liquidity injections in the respective period. We then rerun the simulations with these adjusted liquidity positions. This procedure basically amounts to optimizing the stability effect of the broad CBR's liquidity injections by redistributing them to the banks of our choice, without manipulating the magnitude of liquidity injection itself.

Limited data on CBR lending allows us to run the experiment for 27 out of total 75 periods: quarterly for October 1998-October 2002 and monthly for February-November 2004. As Sberbank and Vneshtorgbank are allowed to fail in the absent CBR experiment we compute total assets of the banking sector including those two banks, in order to make our measure of contagion always bounded between zero and one. Figure 7 reports the results for the simulations with an idiosyncratic shock. We report what would have happened without the CBR's intervention (absent CBR), what really happened (real CBR), and what would have happened if the CBR would have redistributed liquidity according to our methodology (hypothetical CBR). The results reveal that the CBR's liquidity injections contributed considerably to the mitigation of systemic risk, specifically in times of crisis. Our 'optimal' redistribution of liquidity could at best have lead to a marginal improvement in the system's stability. Provided that we can inject the same amount of liquidity as the broad CBR, we conclude the Russian LOLR system seems to have performed relatively well in distributing

Figure 7: Liquidity Redistribution Experiment



it to the banks whose stability was most beneficial to the stability of the system. This lends support to the thesis that the liquidity injections of a LOLR can effectively mitigate coordination failures on the interbank market not only in theory, but also in practice

6 Contagion and Market Structure

Theory suggests that market structure may play an important role in determining contagion risk in interbank markets (see e.g. Allen and Gale (2000) or Freixas, Parigi and Rochet (2000)). To our knowledge, Degryse and Nguyen (2007) are the first to empirically investigate the impact of interbank market structure on contagion risk. Assuming exogeneity of the market structure they find the latter to be one of the main drivers of contagion risk on the Belgian interbank market. Castiglionesi and Navarro (2008) however model how the interbank market structure evolves endogenously from first principles. In their model, two banks have to agree to establish a link (this is the notion of pairwaise stability). The rationale of the model is that, when the probability of default is too high, the safe banks do not want to be linked with the risky ones and accordingly severe their links, while the risky banks find it almost always convenient to be linked. We found indications for this 'flight to quality' in times of high default probability already in figure 3 Therefore we verify empirically whether the interbank market structure drives contagion risk, as in most of the literature, or vice versa, as suggested by Castiglionesi and Navarro (2008) and the anecdotal evidence given above. We implement this by running Granger causality tests. Our measure of market structure is the volume of transactions between the top 40 lenders and the top 40 borrowers depicted in Figure 3. Our measure of contagion is depicted in Figure 5 under the 'active banks' scenario. Granger causality regressions include two lags and a time trend. We leave the first six months following the 1998 crisis out of our sample. In those months only few banks were active on the interbank market and the data series exhibit excessive volatility. We find that our measure of contagion risk Granger causes market concentration at the 1% level but not vice versa (results available on request). This result is robust to using different measures of contagion ('active banks' scenario versus 'panic' scenario). It is also robust to the addition of aggregate measures of bank health to the Granger causality regressions., like average capitalization and average liquidity shown in Figure 2. When the risk of failure rises, Castiglionesi and Navarro (2008) predict that the periphery will be disconnected to the core, but this can be inefficient for very high probabilities of default. in the sense that a social planner would not severe the links. In this sense the endogenous interbank market structure may aggravate the effect of financial shocks on systemic instability, rather then cause the systemic instability.

7 Conclusions

In this paper we suggest a new approach to modeling systemic risk in the interbank market. Specifically we enrich the literature with a new transmission channel of contagion on the interbank market, namely the liquidity channel. We apply this idea to the Russian banking sector and find that the liquidity channel contributes significantly to a better understanding and prediction of actual interbank market crises, that the bank-specific failure frequencies produced by our simulations possess some limited predictive power for real bank defaults beyond that contained in bank fundamentals and that our simulated measure of interbank market stability Granger causes the interbank market structure, while the opposite causality is rejected. This casts doubt over studies that use the interbank market structure as a determinant of financial stability and emboldens the case for viewing the interbank market structure as endogenous as in Castiglionesi and Navarro (2008). The results corroborate the thesis that prudential regulation at individual bank level is insufficient to prevent systemic crises, because this approach neglects the potential effect of severing interbank links on financial stability. Especially bank-specific capital rules, no matter how sophisticated, will never suffice to prevent coordination failures on the interbank market, simply because capital is not a very important variable in assessing the risk of contagion and systemic meltdown. This is an important lesson in the aftermath of the subprime crises, that appears to have been essentially a worldwide liquidity 'panic' scenario kick-started by the initial correlated default of some banks. Regulators would be well advised to conduct stress tests on the stability of the interbank market in the line of this paper, if they are serious about preventing the next interbank market crisis. In addition, our results clearly suggest that the liquidity injections of a classical LOLR can effectively mitigate coordination failures on the interbank market not only in theory, but also in practice. In short: liquidity matters.

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