BOFIT Discussion Papers
19 • 2008

Alexei Karas, Koen Schoors and Gleb Lanine

Liquidity matters: Evidence from the Russian interbank market

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BOFIT Discussion Papers
Editor-in-Chief Iikka Korhonen

BOFIT Discussion Papers 19/2008
12.11.2008

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ISBN 978-952-462-929-4
ISSN 1456-5889
(online)

Suomen Pankki
Helsinki 2008

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Tiivistelmä

Tässä tutkimuksessa tarkastellaan uutta interbankmarkkinoiden häiriöiden tartuntaväylää, likviditeettikanavaa. Venäjän pankkijärjestelmää koskevan tilastoaineiston avulla työssä osoitetaan, että likviditeettikanavan huomioonotto auttaa ymmärtämään ja ennustamaan interbankmarkkinoiden kriisejä. "Interbankmarkkinoiden vakaudella on Granger-kausaalisuus interbankmarkkinoiden rakenteeseen nähden, mutta päinvastaisesta kausaliteetista ei ole todisteita. Näin ollen markkinoiden rakenne olisi endogeeninen. Tulosten mukaan pankkivalvonnan toteuttaminen yksittäisten pankkien tasolla ei ole riittävää järjestelmäkriisien ehkäisemiseksi. Keskuspankin likviditeetin lisääminen voi tehokkaasti korjata pankkien välisten markkinoiden koordinaatio-ongelmat sekä teoriassa että käytännössä. Likviditeetillä on väliä.

Asiasanat: interbankmarkkinoiden vakaus, tartunta, likviditeettikanava, keskuspankin lainananto, Venäjä

Liquidity matters: Evidence from the Russian interbank market

Alexei Karas
Ghent University

Koen Schoors
Ghent University

Gleb Lanine
Dexia Bank

September 16, 2008

Abstract

We suggest an additional transmission channel of contagion on the interbank market – the liquidity channel. Examining the Russian banking sector, we find that the liquidity channel contributes significantly to understanding and predicting interbank market crises. Interbank market stability Granger causes the interbank market structure, while the opposite causality is rejected. This bolsters the view that the interbank market structure is endogenous. The results corroborate the thesis that prudential regulation at the individual bank level is insufficient to prevent systemic crises. We demonstrate that liquidity injections of a classical lender of last resort can effectively mitigate coordination failures on the interbank market both in theory and practice. Apparently, liquidity does matter.

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 says central banks should lend to illiquid, but solvent, banks at a penalty rate. A modern line of criticism dismisses the supposed need for an LOLR with the observation that sophisticated interbank markets are capable of providing liquidity to those who need it. Under this view, monetary authorities can assure financial stability through the provision of adequate levels of aggregate liquidity, and thereby obviate the need for bank-specific liquidity provision by an LOLR (e.g. Goodfriend and King, 1988; Kaufman, 1991). Unfortunately, this reasoning reconciles poorly with what we have seen in the current liquidity drought of the 2007-2008 sub-prime crisis in which interbank money flows have been effectively reduced from a flood to a trickle. Even the US Federal Reserve's extremely relaxed monetary stance and massive LOLR injections have failed to assure adequate market liquidity.

No matter how sophisticated we regard our interbank markets, they do not appear to be immune to serious coordination failures. The current crisis has revived interest in the work of LOLR advocates such as 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 an LOLR in correcting this market inefficiency.

There is also a large body of literature on interbank market contagion through direct capital linkages. In studying the failure of banks hit by a default in excess of their capital, the structure of the interbank market is crucial for the ultimate effect of a financial shock on the banking system. Allen and Gale (2000) model this in a deterministic manner. Applications of this approach to national banking systems have been useful in detecting limited risk of contagion for Switzerland (Sheldon and Maurer, 1998), the US (Furfine, 2003), Germany (Upper and Worms, 2004), the Netherlands (Lelyveld and Liedorp, 2006) and Belgium (Degryse and Nguyen, 2007). Rochet and Vives (2004), however, also have modeled contagion through indirect liquidity linkages. They argue that since individual interbank market participants are generally risk averse and subject to asymmetric information, they may rationally overreact to negative news about a counterparty and attempt to withdraw their assets from the troubled counterparty as quickly as possible. Such a generalized liquidity crunch, in turn, may push solvent institutions 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 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. In contrast to the results of Sheldon and Maurer (1998), which are based on aggregate data, Müller's simulations reveal a substantial risk of contagion in Switzerland.

This paper has several goals. We verify empirically whether liquidity matters for interbank market stability and whether an active LOLR can play a role in promoting such stability. We then consider whether the structure of the interbank market drives interbank market stability as in Allen and Gale (2000) or is largely endogenous as suggested by Castiglionesi and Navarro (2008). For this purpose, we employ a dataset of Russian bilateral interbank exposures that spans two severe crises (1998 and 2004) on the Russian interbank market.

Like 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. Our simulations suggest 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 captures both the 1998 crisis and the 2004 crisis very accurately. Our results are robust to the definition of the initial financial shock (the failure of a single bank or the correlated default of a number of banks). The simulations produce bank-specific failure frequencies that possess 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, which supports 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. Sections 4 and 5 present the basic simulation results, our analysis of the LOLR's effectiveness in stabilizing the interbank market, as well as an analysis of the endogeneity of the interbank market structure. The last section concludes.

2 Data and Methodology

Two established private financial information agencies, Banksrate.ru and Mobile, provided us with monthly bank balances and monthly reports "On Interbank Loans and Deposits" (official form code 0409501) for the period August 1998 to November 2004.[1] The latter report provides information on the gross interbank positions of banks broken down by counterparty, which allows 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, however.

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

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

where L is the matrix of interbank exposures with y_{ij} representing gross claims of bank i on bank j. Banks do not lend to themselves, so $y_{ij} = 0$ 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 $NE_i = \sum_{j=1}^{n} y_{ji} - \sum_{j=1}^{n} y_{ij}$. 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 above

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

example that Bank 4 defaults on its interbank obligations due to an exogenous shock. As a result Bank 1 suffers a credit loss equal to its total gross claims on the defaulting institution, y_{14}.[2] These losses deplete bank capital. If losses exceed bank capital, the institution turns insolvent and defaults on its 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. As new defaults occur, the associated credit losses further deplete the surviving banks' capital and possibly lead to new insolvencies. Formally, the following rule determines defaulting institutions in each round of contagion:

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

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 that could potentially also be subject to the same shock. Many market participants are risk averse (better safe than sorry), so in periods of uncertainty and mutual suspicion, skittish banks may overreact to negative news about a counterparty and attempt 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 calling in outstanding credits and withdrawing funds on current accounts. Here, we assume all banks behave consistently in this respect. As a result, banks exposed to credit losses fail due to 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 our simulations, the additional liquidity channel boils down to deleting all banks suffering a direct credit loss (touched by the shock) and being illiquid (i.e. having net interbank exposure in excess of liquid assets). Formally, the defaulting institutions in each round of contagion are identified as follows:

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

Contagion propagates through the system until no more failures occur.

We next model a "Panic" Scenario, an extreme form of the Active Banks Scenario in which the initial financial shock destroys all trust in the banking system. The result is an immediate failure of all banks with net exposures on the interbank market exceeding their liquidity, irrespective of whether the

[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, losses from default on interbank claims were nearly 100%.

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 those that were initially sound. Boissay's framework corresponds to our Panic Scenario, in which all banks are treated as potentially fragile in the wake of a shock and there is a frenzy to settle all interbank positions.

When computing a bank's net interbank exposure, we only take into account claims on and debts to non-failed banks. Here we assume, first, that defaulting institutions will not honor 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 court has installed a temporary administrator, compiled a list of creditors and borrowers and started cleaning up the mess, the banking crisis has run its course. Note that this assumption of postponed debt repayment makes the remaining banks ceteris paribus more liquid, making sure we do not overstate the severity of a crisis.

In our baseline simulations, we let each bank fail once in each period (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 make three estimates of contagion corresponding to our 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.

To test the robustness of our results to the choice of the initial bank failure, we adapt an idea of Elsinger et al. (2006) and expose banks to macroeconomic shocks using a one-factor version of the CreditRisk+ model in order to start the simulation with a number or correlated bank defaults (a systemic shock).[3] As other credit risk models such as KMV or CreditMetrics require banks to be listed or 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 along the lines of Golovan et al. (2003) and Lanine and Vander Vennet (2006). Results of these default probability models are reported in the first column of table 1.[4] 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

[3] See Gordy (2002) for a general presentation of the CR+ model.

[4] Limiting bank failures to true bankrupties and discarding licence revocations due to mergers and compulsory/voluntary liquidation, does not produce substantially different failure predictions, so they are not considered in the paper. The introduction of bank-specific effects into the probit model was also found to have no significant inpact on the results.

default. Involvement into traditional banking activities such as granting loans signals less speculation and less risks. Money center banks that borrow extensively on the interbank market and big banks represent a threat to 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.[5] For example, macroeconomic downturns might weaken financial institutions leading to more failures than in good economic 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 to make individual failures more likely. When a good outcome is realized, ($x < 1$), all default probabilities decline. For each month, we run 1,000 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 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, which enjoy 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 shock (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 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 bank solvency. Figure 2 highlights 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.

[5] Lesko et al. (2004) show that, although the single-risk-factor approach overestimates portfolio risk, the overestimation error is small for firms operating in just one country.

Figure 1: Liquidity Drains on the Russian Interbank Market

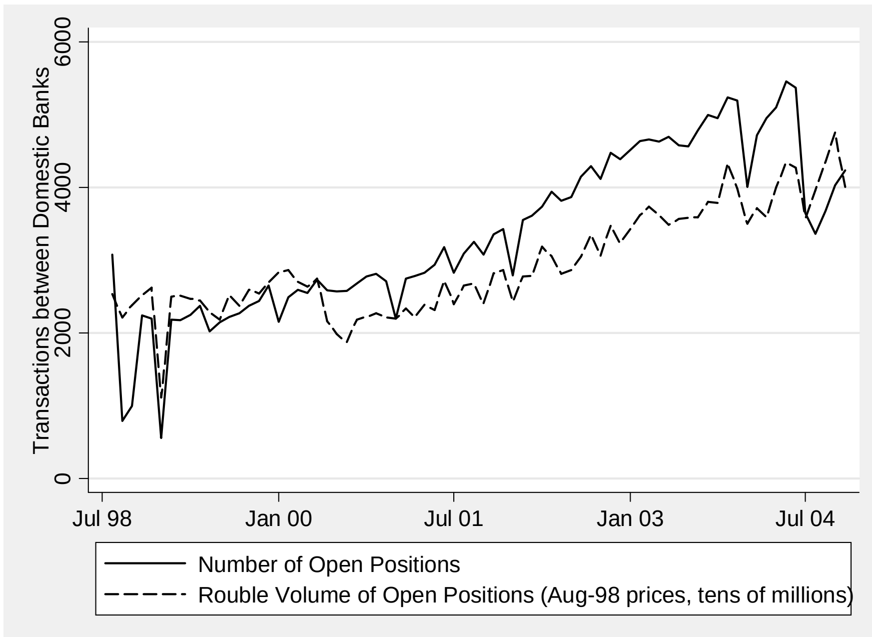


Figure 2:

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 a rob-Peter-to-pay-Paul strategy of government finance based on perversely high yields on government treasury bills (GKOs). At 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, income from GKO investments was tax deductible. In the second half of 1996, Russian banks began borrowing actively on foreign markets (currency loans from foreign banks and Eurobonds). Huge profits were ensured by the huge difference between domestic and foreign interest rates in combination with a relatively stable rouble exchange rate under the CBR's rouble corridor policy (crawling peg). When the GKO market was opened to foreigners in 1997, the desire of foreign investors to hedge their rouble investments was met by Russian counterparties that 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 on their books, banks began extending foreign-currency loans to domestic borrowers. By shifting currency risk to their borrowers, banks substituted currency risk with credit risk because after the rouble's devaluation most borrowers defaulted.

The Asian crisis and dwindling yields on GKOs made Russian government debt securities less attractive to foreigners and provoked capital outflow. In its struggle to stave off a rouble devaluation, the CBR burned through most of its foreign currency reserves. At the same time, the Russian government found it increasingly difficult to roll over its GKO debt. In August 1998, the CBR's exchange rate policy became untenable. Although GKO yields had reached 100% per annum and more, banks started liquidating their positions. On August 17,1998, Russia abandoned its exchange rate regime, defaulted on its domestic public debt and declared a moratorium on all private foreign liabilities, which was tantamount 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 subsequent bank runs (Perotti, 2002). It took over a year to recover from a crisis that completely paralyzed the interbank market.

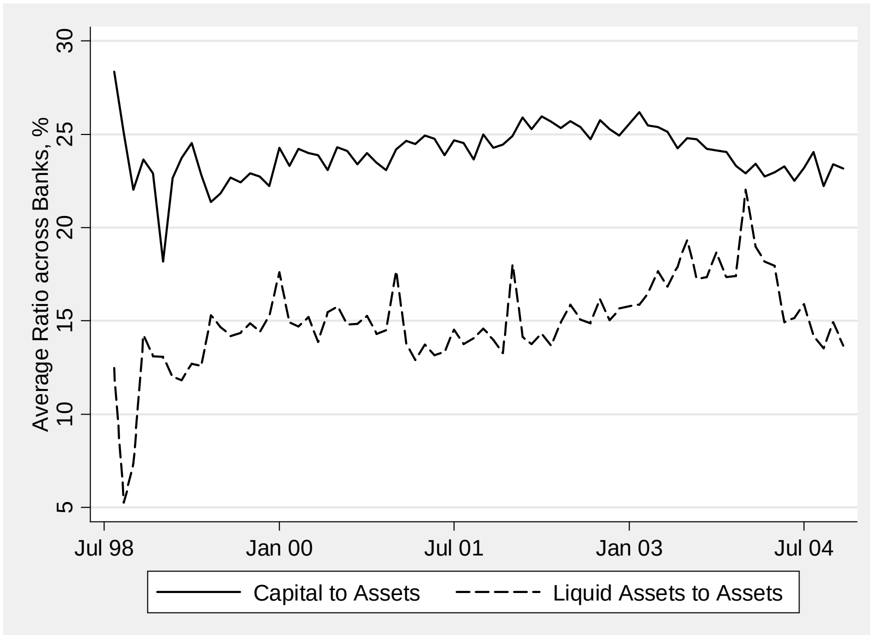
The mini-crisis of 2004, in contrast, was sparked by unexpected regulatory action. In May 2004, the CBR closed a bank accused of money laundering and the head of the Federal Service for Financial Monitoring (FSFM), Victor Zubkov, announced his service was investigating an unspecified "dirty dozen" banks suspect of being engaged in money laundering and sponsorship of terrorism. Several inconsistent versions of the FSFM's black list began circulating among nervous bankers trying to figure out who had been targeted. Mutual suspicion led to a drying up of liquidity on the interbank market, which put pressure on the hundreds of smaller banks dependent on it. The crisis of confidence then provoked runs on several large banks, including Guta Bank and Alfa Bank. The double whammy of a liquidity shock and abrupt withdrawals by many of its large depositors pushed Guta Bank to the verge of bankruptcy, at which point it was acquired by state-owned Vneshtorgbank for a token price.

Figure 3 confirms that the 2004 crisis mainly resulted in the drain of liquidity, while in 1998 the latter combined with serious solvency problems.

Between the two crises, the interbank market expanded considerably and gained importance as a source of funding for Russian banks. Figure 2 shows that the number and the inflation-adjusted volume of domestic transactions more than doubled between January 1999 (the point when interbank market stability hindered by the 1998 turmoil was already largely restored) and May 2004. The number of market participants rose from about 650 in January 1999 (half of all existing banks) to well above 900 (three-quarters of all banks) in May 2004.

The average Russian bank had 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 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 until 2004. The corresponding share of interbank claims decreased from 10-12%

Figure 3: Financial Crises and Banks' Health

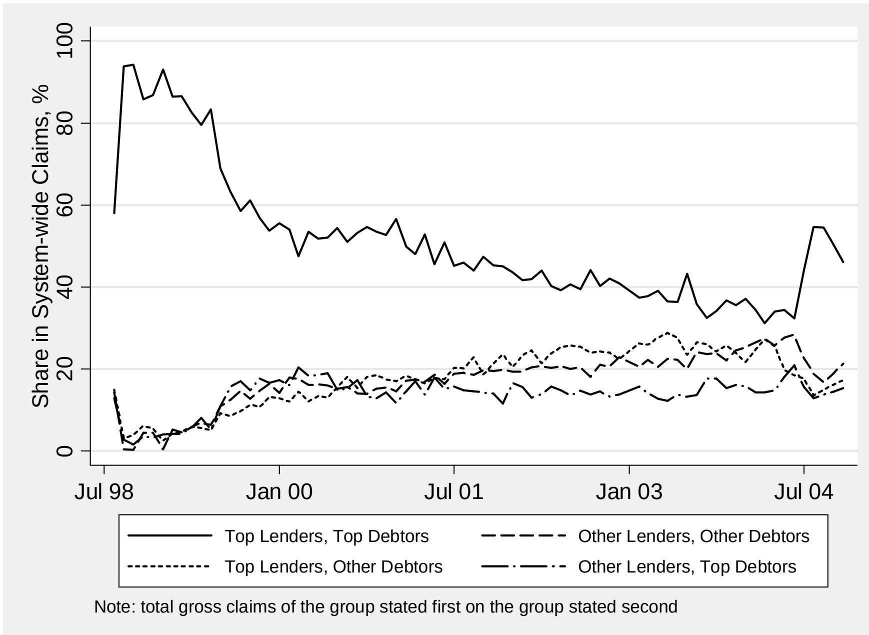


in 1999-2001 to 7-9% in 2002-2004. Thus, while big banks on average reduced their reliance on the interbank market as a net source of funding, small banks became increasingly dependent on it.

The growing number of market participants and the easier access of small banks to the interbank market shows up in a decreasing market concentration as shown in Figure 4. 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; this diminishes to less than 40% by May 2004. The other three lines (total gross claims of top lenders on non-top borrowers, and claims of non-top lenders on both groups of borrowers) display the opposite increasing trend. Figure 4 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. Top lenders, in turn, are potentially the most dangerous panic makers as they have claims, and hence the ability to run, on numerous counterparties. We arbitrarily look at the top 40 of both categories. Figure 5 focuses on the ability of top debtors and top lenders to spread contagion throughout 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,

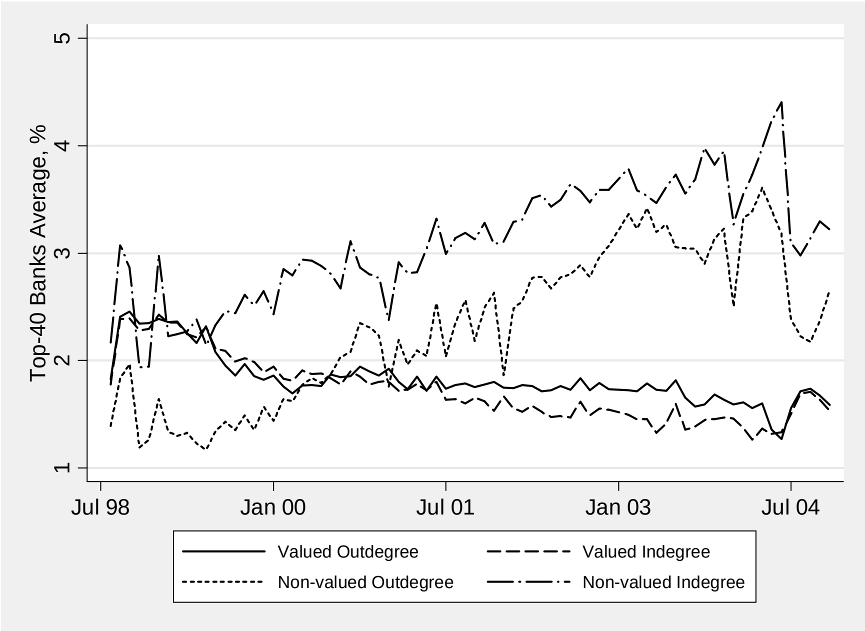
Figure 4: Global Domestic Exposures



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 of these centrality indices only consider transactions between domestic banks. We keep the forty biggest values of each indicator and take the average across them. We then plot the averages over time.

Two opposite trends are evident from Figure 5. While the valued indices decrease over time, the non-valued indices rise. 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 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,

Figure 5: Market Concentration and Contagion

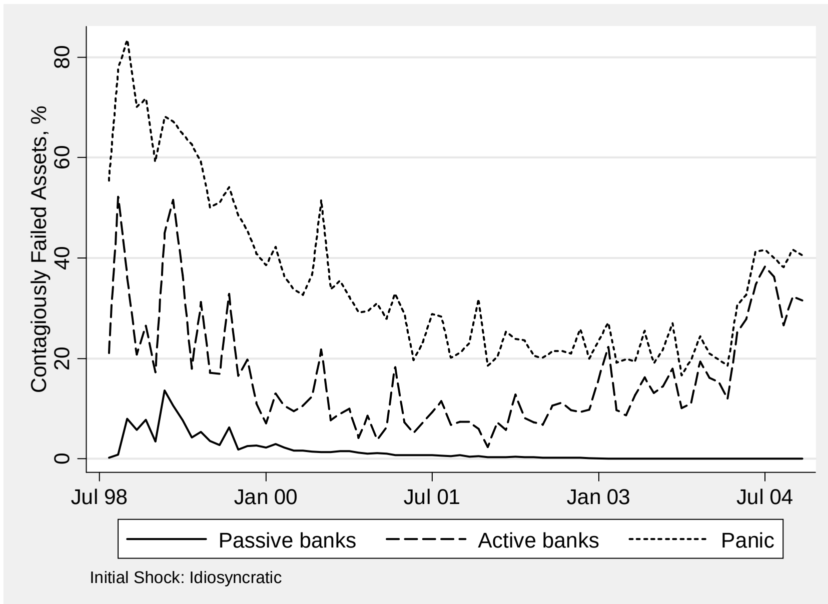


the risk of being hit by a shock has grown. This observation is in line with the decreasing market concentration detected in Figure 4. More links between banks imply both that losses are absorbed by a larger number of counterparties and that more banks get infected.

A few of the biggest Russian banks ensured that the volume of transactions with foreign counterparties 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, 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 undoubtedly adds to the variability of contagion risk over time.

Figure 6: Contagion in Alternative Scenarios

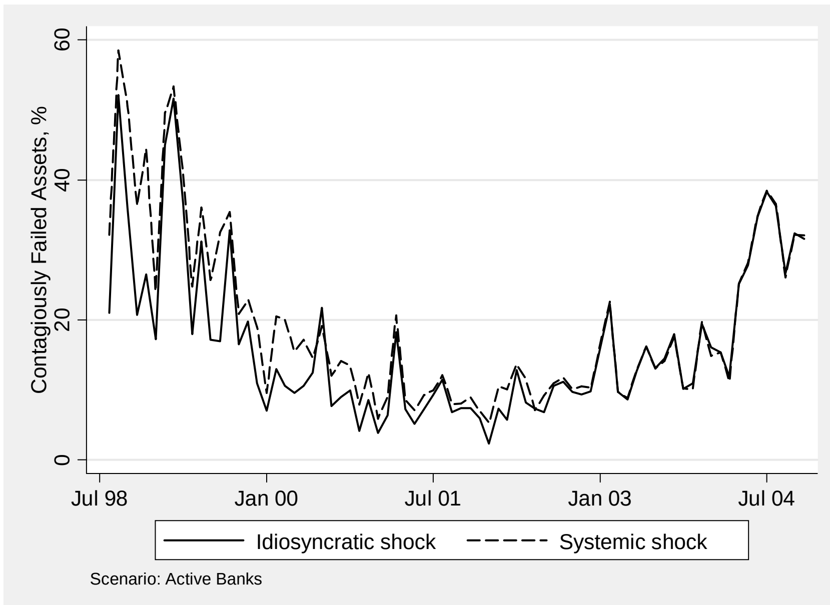


4 Results

Figure 6 plots our estimates of contagion for each of the three scenarios of the baseline idiosyncratic shock. In the Passive Banks Scenario, market participants do not run on each other and only solvency matters for survival. In the Active Banks Scenario, banks run on illiquid counterparties suffering credit losses. 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 the major issue for many banks. We find that, across the 5% worst-case scenarios, the average share of system-wide bank assets failing 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 on and shows no sign of approaching trouble even at the start of the summer of 2004. Allowing banks to run on each other not only increases the size of contagion; it highlights the system's intrinsic instability in both 1998 and 2004. Indeed, the estimate of contagion under the Active Banks Scenario declines from 50% in September 1998 to about 10% in 2000, then hovers at low levels until end-2003, when it begins the climb to a peak of 40% in July 2004. Our Panic Scenario simulations exhibit similar dynamics, but with higher levels of contagion in every period. In hindsight, given the estimated intrinsic instability of the system in 2004, it is hardly surprising that a license withdrawal from a medium-sized bank and

Figure 7: Contagion with Alternative Shocks



rumors that more banks would follow triggerred 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 the same whether or not we explicitly allow for the bilateral setoff (netting) of interbank positions. Given that these 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 7.

Besides 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: Active Banks Scenario with the idiosyncratic shock (column 3) and the systemic shock (column 4), and Panic

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. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

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 that failed in our simulations also tended to fail in reality.

5 The Role of the LOLR

For the remainder of the paper, we focus on our Active Banks Scenario. In this section, we examine the effect of central bank LOLR liquidity injections on systemic stability by constructing counterfactuals. We treat Sberbank and Vneshtorgbank as integral parts of the CBR. The CBR has extensively used both these subsidiaries as agents of policy implementation. In the turbulent summer of 2004, they played a key role in providing liquidity to smaller banks. Both state banks enjoy the full and consistent backing of the CBR.

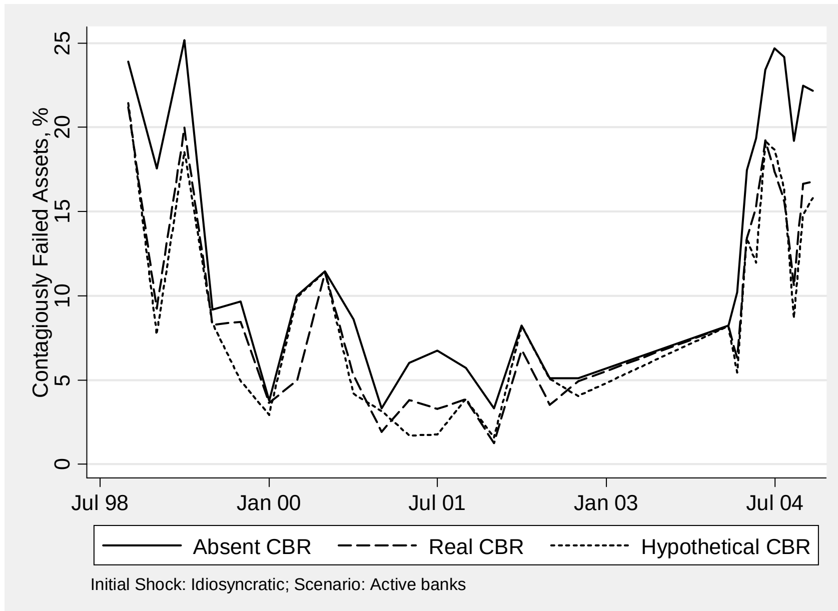
We start by modeling what would have happened in terms of contagion risk if the CBR and its subsidiaries did not act as an LOLR and inject liquidity into the market. This "absent CBR" counterfactual is constructed by lowering all banks' liquidity holdings with their amount of borrowing from the broad CBR and rerun the baseline simulations. Like other banks, Sberbank and Vneshtorgbank are allowed to fail and to run on other banks in these simulations.

We next model a "real CBR" counterfactual in which the CBR prevents Sberbank and Vneshtorgbank from failing or running 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, while not allowed to fail, could run on other banks.

In a third counterfactual, we assess whether a "hypothetical CBR" might have increased the system's intrinsic stability by optimally redistributing 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. 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 the original simulation. This partial contribution to contagion of a given bank in a given month is averaged across simulations We then 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. Finally, we rerun the simulations with these adjusted liquidity positions. This procedure 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 restricted the experiment to 27 of the 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 Sberbank and Vneshtorgbank to keep our measure of contagion always bounded between zero and one. Figure 8 reports the results for the simulations with an idiosyncratic shock. We report what would have happened without the CBR's intervention ("absent CBR"), with the actual CBR's liquidity injections ("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 performed relatively well in delivering liquidity to the banks whose stability was most critical 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.

Figure 8: Liquidity Redistribution Experiment



6 Contagion and Market Structure

Theory suggests that market structure may play an important role in determining contagion risk in interbank markets (e.g. Allen and Gale, 2000; 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 a main driver 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 agree to establish a link (the notion of pairwise stability). The rationale of the Castiglionesi-Navarro model is that, when the probability of default is too high, safe banks will refuse to be linked with the risky banks and accordingly sever their links. Risky banks, on the other hand, find it almost always to their advantage to be linked. Indications of a flight to quality in times of high default probability are already evident in Figure 4. We run Granger causality tests to verify empirically whether the interbank market structure drives contagion risk, as most authors suggest, or whether the opposite applies as suggested by Castiglionesi and Navarro (2008) and the anecdotal evidence mentioned above. Our measure of market structure is the volume of transactions between the top 40 lenders and the top 40 borrowers depicted in Figure 4. Our measure of contagion is depicted in Figure 6 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.[6] This result is robust to using different measures of contagion (Active Banks Scenario and Panic Scenario). It is also robust to the addition of aggregate measures of bank health such as average capitalization and average liquidity (shown in Figure 3) to the Granger causality regressions. When the risk of failure rises, Castiglionesi and Navarro (2008) predict that the periphery will be disconnected from the core. This can be inefficient for very high probabilities of default, however, in the sense that a social planner would not sever the links. Thus, the endogenous interbank market structure may aggravate the effect of financial shocks on systemic instability rather than cause systemic instability.

7 Conclusions

In this paper, we suggested a new approach to modeling systemic risk in the interbank market based on a new transmission channel of contagion on the interbank market – the liquidity channel. We applied this idea to the Russian banking sector and found it helpful in understanding and predicting interbank market crises. Moreover, the bank-specific failure frequencies produced by our simulations possess some predictive power for real bank defaults beyond that contained in bank fundamentals and our simulated measure of interbank market stability Granger-causes the interbank market structure, while the opposite causality is rejected. This casts doubt on studies that use the interbank market structure as a determinant of financial stability and bolsters the case for viewing the interbank market structure as endogenous as proposed by Castiglionesi and Navarro (2008).

Our results corroborate the thesis that prudential regulation at the individual bank level is insufficient to prevent systemic crises. It neglects the potential effects on financial stability resulting from the severing of interbank links. In particular, bank-specific capital rules, no matter how sophisticated, can never in themselves prevent coordination failures on the interbank market – capital is not an important variable in assessing the risk of contagion and systemic meltdown. This is an important lesson to heed in the current sub-prime crisis, which appears to have been a worldwide liquidity panic kick-started by the initial correlated default of a few 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, or at least mitigating, the next interbank market crisis. Our results clearly suggest that liquidity injections of a classical LOLR can effectively mitigate coordination failures on the interbank market. As it turns out, liquidity does matter.

[6] Results available on request.

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Bank of Finland
BOFIT – Institute for Economies in Transition
PO Box 160
FIN-00101 Helsinki

☎ + 358 10 831 2268
bofit@bof.fi
http://www.bof.fi/bofit