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The views expressed in this paper are not necessarily the views of the Croatian National Bank.

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Contagion Risk in the Croatian Banking System

Marko Krznar

Abstract

This paper explores systemic risk in the Croatian interbank market, focusing on interbank credit risk. In theory, bank contagion depends on the size and structure of the interbank market. It is found that the dimension of the Croatian interbank market is small and that it can be described as a multiple money centre structure, with bilateral exposures concentrated on a few big banks. In order to assess contagion risk in the banking system, simulations of idiosyncratic bank failures and macroeconomic shocks were performed. Because of the shallow domestic interbank market, the first order requirement for bank contagion due to an idiosyncratic failure is not fulfilled. This requirement is also not satisfied in the case of the exposures to foreign banks, although they five times exceed the level of the domestic interbank market. Bank contagion stemming from macroeconomic shocks, although theoretically possible, could only materialise in highly improbable scenarios.

JEL: G21, G28

Keywords: interbank exposures, bank contagion, idiosyncratic bank failure, macroeconomic shock

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Contents

1 Introduction

From a financial stability point of view, the interbank market is a double-edged sword. On the one hand, it plays an important role in ensuring bank liquidity and efficient monetary policy implementation. On the other hand, the interbank market may serve as a channel for contagion, through which solvency and liquidity problems are spread, in a domino effect, from one bank to the rest of the banking system, thus creating the risk of a banking crisis. Despite the predominance of positive interbank market effects most of the time, and the disciplinary role of the interbank market in relation to banks (Dinger and von Hagen, 2008), bank contagion still presents a potential threat. Therefore, researchers try to assess potential losses arising from such *direct*[1] contagion, focusing on interbank credit risk. An important finding of these studies is that the proportion and direction of bank contagion heavily depend on interbank market features, such as the structure and size of interbank exposures.

This paper follows a similar route, trying to answer the question: *What would be the financial stability effects of defaults by certain banks on the interbank market?* The contribution of this work is threefold. First, it defines the structure of the Croatian interbank market and the structure of the domestic banking system's exposure to foreign banks. Second, in line with the current empirical literature from other countries, it explores the possibility of the occurrence of direct bank contagion in Croatia, and estimates the risk of bank contagion due to both idiosyncratic failures and macroeconomic shocks. Third, it monitors changes in the banking system's resilience to these risks over time.

The paper is organised as follows: Chapter 2 briefly presents the theory of bank contagion, whereas Chapter 3 gives an overview of the methodology and the main results of direct bank contagion studies in other countries. The characteristics of the data used are explained in Chapter 4, which also provides an insight into the domestic interbank market structure, as well as in the structure of the domestic banking system's exposure to foreign banks. Chapter 5 sets out the main results of the study. Chapter 6 examines other potential bank contagion channels in Croatia which are not investigated in this paper, and is followed by a conclusion.

2 Theory of Bank Contagion

A systemic risk arising from the failure of banking institutions has always been in the focus of economic policy discussions. This is due to the correlation between the condition of a banking system and economic growth (Klingebiel et al., 2006). Such a risk can easily materialise in the banking system, owing to this sector's particular characteristics (De Bandt and Hartman, 2000), such as:

1 The difference between direct and indirect contagion is explained in the following chapter.

1) the banks' balance sheet structure, which implies the transformation of short-term liabilities (deposits) into long-term placements, making the stability of the banking system heavily dependent on depositor confidence;
2) a complex network of exposures among financial institutions through the money market, the large value payment system and the settlement system;[2]
3) the intertemporal character of financial agreements and the credibility problem arising therefrom (asymmetry of information results in asset price volatility).

Up to now, theory has mainly distinguished between two types of bank contagion systemic risk, related to the channels through which it occurs and spreads. In their comprehensive overview of systemic risk, De Bandt and Hartmann (2000) distinguish between *direct contagion,* resulting from direct interbank linkages, through their mutual credit exposures, and *indirect contagion,* arising from the widespread existence of asymmetric information in the financial system, so that the contagion is caused by a run of depositors on account of expectations related to bank soundness and the resilience of the financial sector.

However, recent failures and nationalisations of US investment banks and some Western European banks showed the significance of an insufficiently considered contagion channel – *the fire sale contagion channel*, which was a consequence of a heavy dependence on short-term financing sources, and low capitalisation levels of banks, in a period of weak liquidity in which the global interbank market failed to function. One more contagion channel which is seldom considered in the literature and is especially relevant for CEE and Baltic countries, which have a considerable number of foreign-owned banks, is the *cross-border contagion channel*. This channel reflects the possibility that parent banks may reduce the inflow of or completely withdraw credit lines extended to their daughter banks and thus cause difficulties for these banks.

Although the presented contagion channels are considered separately in the literature, they do not exclude each other in practice, and can even be mutually stimulating. One of the few theoretical works attempting to incorporate various contagion channels is that by Iyer and Peydró-Alcalde (2005), which models a link between an interbank market default and deposit withdrawal; they also test their model using the example of the banking system of India (Iyer and Peydró-Alcalde, 2006). Cifuentes et al. (2005) use a theoretical model to explain the connection between an interbank market default and the fire sale contagion channel.

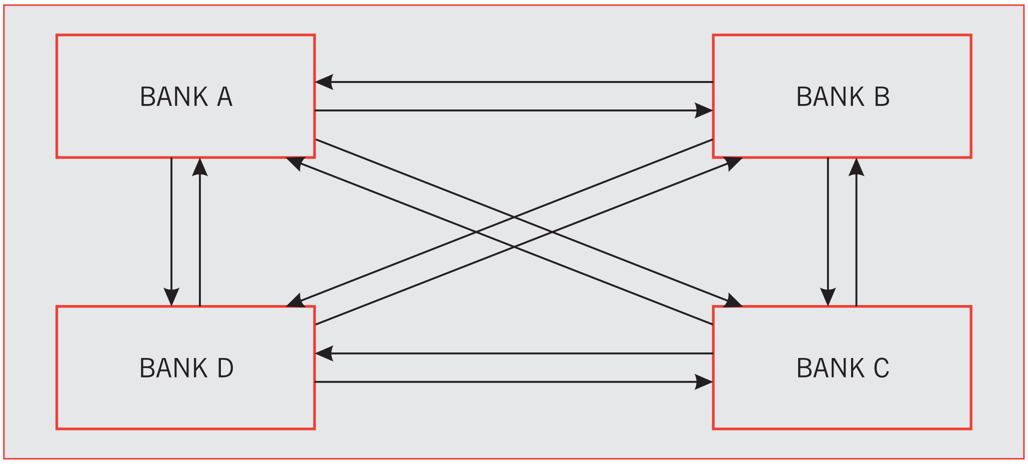
The growing interest among researchers in bank contagion issues observed in recent years coincides with placing financial stability among the main goals of central banks. The emphasis is put on direct contagion, while other contagion channels are neglected due to a lack of or insufficient development of research methods.

The possibility of the occurrence and spread of direct contagion depends primarily on the structure and size of the interbank market. Theoretically, there are three major types of interbank market structure. According to Allen and Gale

2 And, recently, also through derivative financial instruments, as shown by the mid-2007 secondary mortgage loan market crisis that spilled over from the USA to Europe.

(2000), the structure can be *complete* or *incomplete,* with contagion being less likely in the case of a *complete* structure, i.e. if the bank has symmetric linkages with all other banks in the banking system. While in such a case the contagion is less likely to occur initially, it spreads faster through the system. The complete structure is shown in Figure 1.

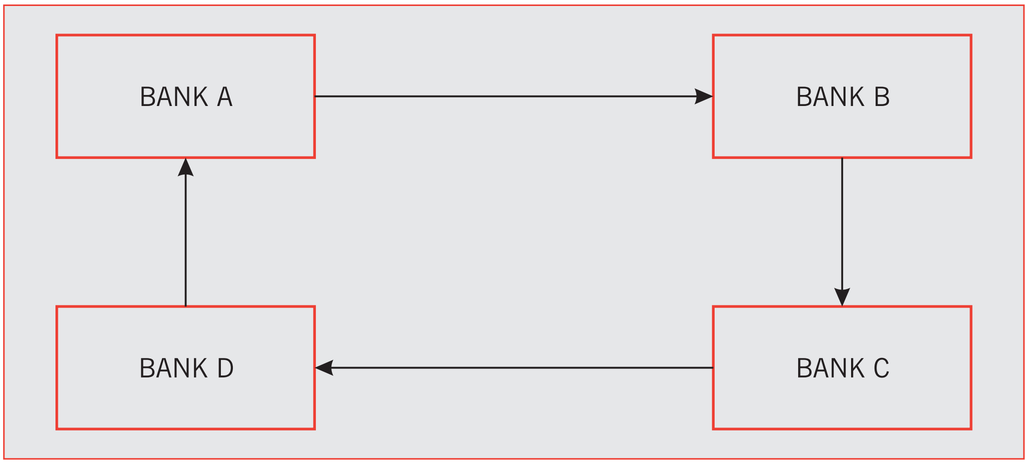
Figure 1 Complete Interbank Market Structure



Source: Upper and Worms (2004).

By contrast, *incomplete* interbank market structures, where banks have linkages with a smaller number of banks, are more prone to interbank contagion. Figure 2 shows an extreme example of an incomplete structure, where a bank is the creditor to only one bank, which is not its debtor.

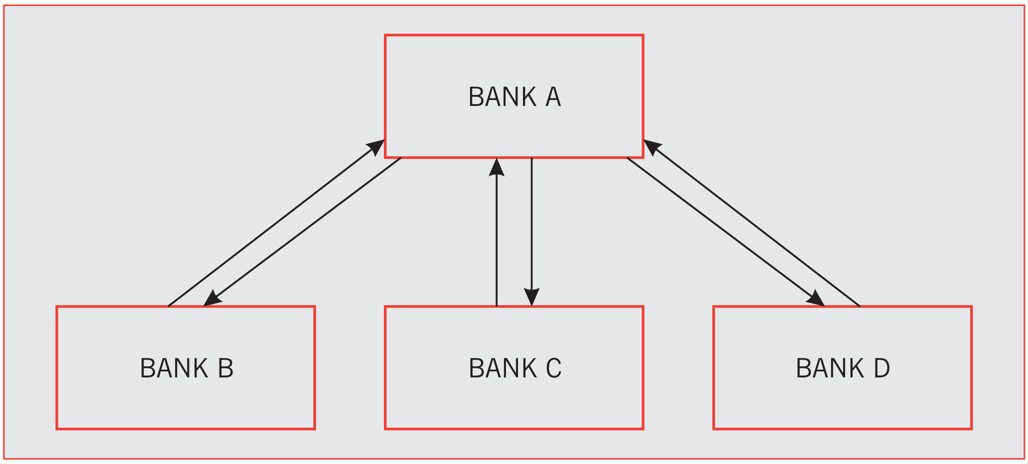
Figure 2 Incomplete Interbank Market Structure



Source: Upper and Worms (2004).

The third type of interbank market structure, *the money centre*, has been developed by Freixas et al. (2000). This structure implies the symmetrical linkage of a "money centre" bank to other banks, but without any mutual links among other (peripheral) banks. Consequently, the failure of a money centre bank can cause bank contagion, whereas the failure of a peripheral bank would only have a minor impact on the banking system. The "money centre" structure is shown in Figure 3.

Figure 3 "Money Centre" Structure



Source: Upper and Worms (2004).

Direct bank contagion can take the form of an *idiosyncratic failure*, where the initial bank failure results from a bank-specific shock, e.g. due to internal omissions or fraud. Another source of the direct bank contagion is *macroeconomic shocks*, to which all banks are exposed. Both types of direct bank contagion are tested in this paper.

3 Empirical Models of Direct Bank Contagion

3.1 A Model of Bank Contagion due to an Idiosyncratic Failure

Most of the empirical literature on interbank contagion issues explores the effects of the failure of a single bank on the rest of the banking system. Such an initial failure results from a shock to which only this bank is exposed. It is generally examined whether the failure of this single bank would lead to subsequent collapses of other banks.

The simplifying assumptions underlying these simulations are as follows:

1) contagion is isolated from all kinds of macroeconomic shocks;
2) no interaction between banks' defaults and deposit withdrawal is observed;
3) portfolio holdings and prices remain constant over time;
4) no seniority rule in the collection of claims is observed;
5) the collateralisation of claims is not observed;
6) bank failures are unexpected;
7) the central bank does not come to the aid of failing banks, acting as the "lender of last resort";
8) interbank claims are not backed by government guarantees;
9) troubled banks cannot be recapitalised.

Some of these assumptions contribute to the underestimation of contagion effects (1 –3), in some of them it is unclear in which direction they move the simulation (4), whereas others (5 – 9) can safely be claimed to overestimate contagion effects. These assumptions can be very restrictive.

For example, as regards the first assumption, the objection is that in reality bank failures are not self-inflicted, but mostly associated with the worsening of general macroeconomic indicators.

Simultaneous bank failures and deposit withdrawals that are not observed in the second assumption could be expected in reality.

The third and sixth assumptions neglect the optimising behaviour of banks. Although this is not immediately evident, the third assumption thus implies a status quo in liquidity and counterparty risk in the interbank market and, in turn, neglects the effect of fire sale as a consequence of deleverage. And exactly this contagion channel contributed the most to the spreading of the financial crisis in the US and Western Europe since 2007.

The sixth assumption in turn contributes to the overestimation of the effects of contagion simulations as the exposed banks do not react to protect themselves from potential losses that cannot be anticipated.

The fourth and fifth assumptions unrealistically imply that all creditors will be faced with the same loss rates.

Quite contrary to the seventh and eight assumptions involving the passivity of central banks and governments, we have learned from experiences with previous banking crises and the recent financial crisis that central banks take a part in bank rescues by supplying liquidity. In the event that central bank measures fail to achieve the desired effect, and a bank comes to the brink of bankruptcy, the ultimate solution is the nationalisation of systemically important banks.

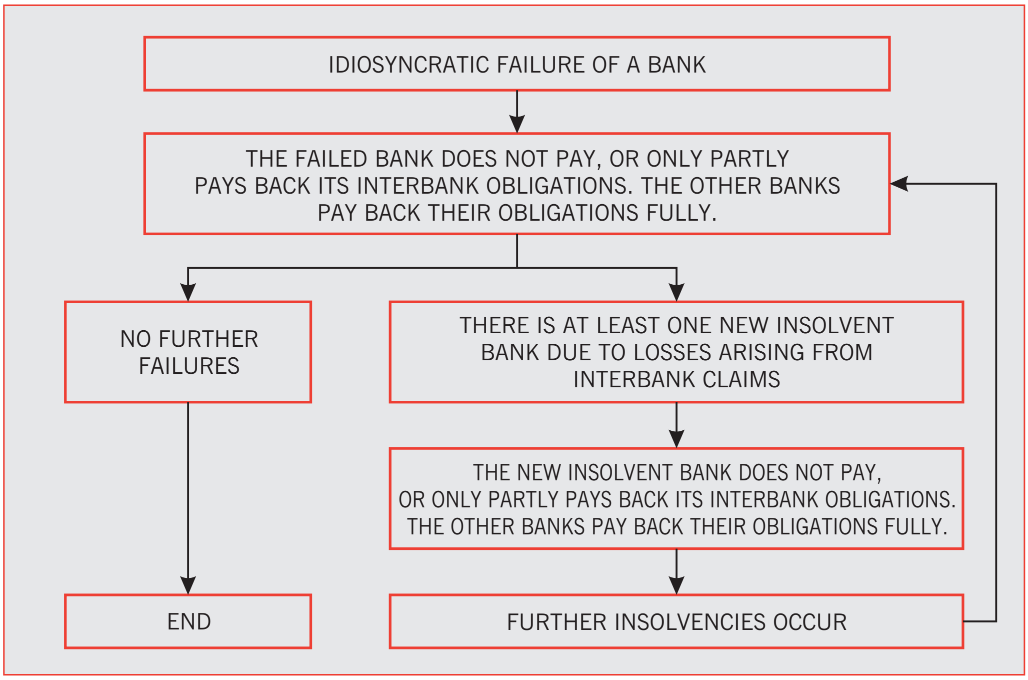
A solution used very often for the saving of troubled banks is recapitalisation, which is an indication that the ninth assumption is unrealistic.

Although he provides a detailed critical review of these assumptions, Upper (2007) also emphasises the usefulness of such simulations. In his view, bank contagion simulations enable the identification of systemically important institutions and those that would be the worst affected by the observed failure. These simulations also indicate in which way the interbank market structure affects the scope of contagion and specify possible costs and benefits of crisis management within the central bank.

As idiosyncratic failure simulations are carried out in the form of a stress testing technique (Čihák, 2007), they are aimed at assessing the proportion of potential losses. However, given the characteristics of idiosyncratic failures, it is impossible to determine the probability of such scenarios.

The simulation is carried out by assuming the failure of each bank, completely or partially defaulting on its liabilities. If the initial failure of a bank does not cause the collapse of another bank, there is no contagion. In the opposite situation, contagion occurs and the simulation is continued by examining the effects of the failure of "contaminated" bank(s) on other banks. The simulation is carried out until the contagion is completely eliminated. The simulation procedure is demonstrated in Figure 4.

Figure 4 Simulation of Bank Contagion due to an Idiosyncratic Failure



Source: Lublóy (2005).

The first step in the simulation process is to define a matrix of interbank exposures, capturing bilateral interbank liabilities and claims. The matrix is shown in expression (1). If the banking system consists of N banks, the matrix X will be of the order $N \ x \ N$, where x_{ij} represents the claims of bank i in a row against bank j in a column:

$$X = \begin{array}{c|c} \begin{bmatrix} X_{11} & \cdots & X_{1j} & \cdots & X_{1N} \\ \vdots & \ddots & \vdots & ⋰ & \vdots \\ X_{i1} & \cdots & X_{ij} & \cdots & X_{iN} \\ \vdots & ⋰ & \vdots & \ddots & \vdots \\ X_{n1} & \cdots & X_{nj} & \cdots & X_{NN} \end{bmatrix} & \begin{matrix} \Sigma_j \\ a_1 \\ \vdots \\ a_i \\ \vdots \\ a_N \end{matrix} \\ \hline \Sigma_i \quad l_1 \ \cdots \ l_j \ \cdots \ l_N & \end{array} \tag{1}$$

The values of x_{ii} on the diagonal are equal to zero, as a bank cannot be exposed to itself. a_i represents the total interbank claims of bank i against all other banks, and l_j represents total interbank liabilities of bank j:

$$a_i = \sum_j x_{ij} \, , l_j = \sum_i x_{ij} \tag{2}$$

As data on bilateral interbank exposures are unavailable in most countries where simulations on bank contagion were conducted, and the only available data are the banks' balance sheet data on total claims against and liabilities to other banks (expression (2)), the entropy maximisation method has often been used. This method assumes an equal dispersal of exposures and liabilities among banks, taking account of the consistency with the sums of rows and columns in the matrix, i.e. assuming a structure of interbank exposures similar to the Allen and Gale (2000) complete interbank market structure.[3]

Once the matrix of interbank exposures is defined, the simulation is started, i.e. the failure of each of N banks is assumed. The necessary condition to be satisfied for contagion to occur is that the losses arising from the interbank exposures of at least one bank exceed this bank's capital.[4]

$$\Theta x_{ij} > c_i \tag{3}$$

In other words, contagion occurs if, due to the failure of bank j, there is at least one bank i whose losses exceed its capital c_i. Consequently, the loss of bank i equals the product of its exposure to bank j x_{ij} and the rate of loss Θ due to default of bank j. This definition of insolvency can be considered hard. Some authors also use a soft definition of insolvency in their simulations. According to the definition of the Basel Committee on Banking Supervision, insolvency occurs if a bank's capital adequacy ratio drops below 4%.

A serious dilemma facing researchers in this phase is the choice of a loss rate. It is not clear which rate to use, the main problem being the seniority of claims (so that the loss rate will vary from creditor to creditor). According to an empirical study by James (1991), in the mid-1980s, the average loss rate due to a bank failure was 30% of the book value of the collapsed bank, plus an additional 10% to cover administrative costs. Kaufman (1994) estimated the loss of the Continental Illinois Bank due to failure at 5% of its book value.[5] According to the Basel II Guidelines; banks applying the IRB (Internal Ratings Based) Approach are required to apply a 45% loss rate for senior claims not secured by broadly recognised collateral. For subordinated claims a loss rate of 75% is prescribed. In the case of claims secured by broadly recognised collateral the above rates can be modified.[6]

Due to these objective problems, in order to assess the loss rates, Furfine (2003), Wells (2004), Blåvarg and Nimander (2002), Upper and Worms (2004), Degryse and Nguyen (2007), Van Lelyveld and Liedorp (2006), and Mistrulli (2007) carried out simulations with different loss rates in the range of $0\% < \Theta \leq 100\%$. Lublóy (2005), gave only minor contagion effects in Hungary, and Sheldon and Maurer (1998) (for Switzerland), assumed a maximum loss rate of 100%.

3 The cross-entropy minimisation method is sometimes also used, by applying the already known large exposure structure to aggregate exposures from banks' balance sheets.
4 The capital usually means the *Tier 1* capital whose definition is additionally modified by some authors.
5 Taken from Upper and Worms (2004).
6 Taken from Lublóy (2005).

3.1.1 Overview of the Literature on Bank Contagion due to an Idiosyncratic Failure

Most researchers find that the occurrence of bank contagion due to an idiosyncratic failure is a possible but highly improbable scenario.[7] Given certain differences in the definition of input data, the results obtained in these research works are not fully comparable. The strongest contagion effects have been observed by Degryse and Nguyen (2007): In the case of the most severe idiosyncratic failure the losses of Belgian banks would amount to about 20% of the banking system's assets. Upper and Worms (2004) in Germany, Wells (2004) in Great Britain, Van Lelyveld and Liedorp (2006) in the Netherlands, and Mistrulli (2007) in Italy estimate the maximum losses at 15% of the banking system's assets. Despite the large amounts of losses, it is emphasized that such scenarios are highly improbable.

In contrast to this, Blåvarg and Nimander (2002) in Sweden, Lublóy (2005) in Hungary and Sheldon and Maurer (1998) in Switzerland find that the possibilities of contagion are very limited. Furfine (2003) in the USA and Amundsen and Arnt (2005) in Denmark also argue that the possibilities of interbank contagion are limited, but a drawback of their simulations is that they only use the overnight transaction data, which do not provide a full picture of the interbank market. Table 1 summarises the research results on bank contagion due to an idiosyncratic failure in the above mentioned countries.

7 As previously mentioned, in the case of idiosyncratic bank failures it is impossible to determine the probability of such events. However, analysts tend to use the term *unlikely* in their evaluations, which is close to the meaning of the word *improbable*.

Table 1 Overview of Research Results on Bank Contagion due to an Idiosyncratic Failure

Author(s)	Country	Institutions	Type of data	Period	Note	Results
Sheldon and Maurer (1998)	Switzerland	Domestic banks	Entropy maximization	1987-1999	Maximum loss rate	Minor contagion effects, accounted for by a domestic interbank market that is small when compared with exposures to foreign banks
Blåvarg and Nimander (2002)	Sweden	4 largest domestic banks	15 largest bilateral interbank exposures	September 1999 -September 2001	Different loss rates; assumption that all interbank claims are uncollateralized. "Soft"definition of a bank's insolvency if its CAR < 4%	Contagion is rarely spread to the largest banks. The interbank contagion risk imported from abroad mainly stems from exchange rate exposures.
Furfine (2003)	USA	Domestic banks, Fedwire participants (719 commercial banks)	Federal Reserve's large-value payment system, daily data on bilateral interbank exposures	February 1998 -March 1999	Different loss rates; only uncollateralized interbank borrowings accounting for as little as 14% of total interbank exposures; simulated failures of the most significant bank, second most significant bank, two most significant banks and the tenth most significant bank	Contagion risk very low
Wells (2004)	Great Britain	Domestic banks	Entropy maximization and cross-entropy minimization by using the data on the structure of interbank exposures based on 24 largest bilateral interbank exposures	December 2000	Different loss rates Model 1: Maximum dispersion of exposures Model 2: Concentration structure arising from the data on large exposures Model 3: "Money centre" structure	The possibility of contagion depends significantly on the chosen loss rate. Model 2 implies a stronger possibility of contagion, but a lower loss of assets. The heaviest losses occur in Model 3.
Upper and Worms (2004)	Germany	Domestic banks and branches of foreign banks	Entropy maximization	December 1998	Different loss rates: with or without government guarantees (safety net)	Heavy losses in the case of contagion. The losses increase sharply if the loss rate exceeds 40%. Government guarantees (safety net) considerably reduces the contagion effects.
Lublóy (2005)	Hungary	Domestic banks	Uncollateralized bilateral exposures	6 periods, totalling 50 days in 2003	Maximum loss rate. "Soft" definition of a bank's insolvency if its CAR < 4%	Contagion can only result from the default of a subsidiary due to the failure of a head bank in a bank group. Second-round contagion never occurs. The simulation is modified and the bank's default is defined as a fall in its capital adequacy ratio below 4%. However, even in this case the contagion occurrence is limited.
Amundsen and Arnt (2005)	Denmark	Domestic banks	Kronos large-value payment system, daily data on overnight bilateral exposures	2004	Different loss rates	Low probability of contagion. Should it occur, it would affect banks accounting for less than 5% of the banking sector's total assets.
Van Lelyveld and Liedorp (2006)	Netherlands	Domestic banks and branches of foreign banks	Entropy maximization and cross-entropy minimization based on the data on large bilateral interbank exposures	December 2002	Different loss rates	The threat of contagion is more likely to come from abroad than from the domestic inter-bank market. Contagion through the domestic market is only possible in the case of a large bank's failure. No failure of a large bank results in the failure of another large bank.
Mistrulli (2007)	Italy	Domestic banks	Entropy maximization and bilateral exposures	1990-2003	Different loss rates	The contagion risk through the domestic interbank market is higher than through exposures to foreign banks, but it is still very low. Changing from a total structure to a multiple money centre structure aggravates the contagion effects.
Degryse and Nguyen (2007)	Belgium	Domestic banks	Entropy maximization	1993-2002	Different loss rates	The failure of a domestic bank cannot lead to the failure of another domestic bank. Belgian banks are much more exposed to German, French, British and Dutch banks. In the worst-case scenario, the loss caused by a foreign bank's failure would amount to about 20% of the banking system's total assets. The contagion effects can be reduced by changing from a complete interbank market structure to a money centre structure.

Sources: Van Lelyveld and Liedorp (2006), Mistrulli (2007) and the author.

3.2 A Model of Bank Contagion due to a Macroeconomic Shock

Besides the bank contagion simulations dealing with the initial failures of banks due to bank-specific shocks, there is also a simulation assuming the initial failure of a bank (banks) due to macroeconomic shocks to which the banking system is exposed. This assumption is much more realistic, as, according to the available historical data, most bank failures are caused by shocks to which several banks are exposed concurrently (Upper, 2007). Such shocks reduce the resilience of "surviving" banks, thus enhancing contagion risk. However, even if the assumption of isolation from macroeconomic shocks is rejected, the simulations of bank contagion due to macroeconomic shocks still suffer from other simplifying assumptions specified in the model of bank contagion due to an idiosyncratic failure.

A model of bank contagion due to a macroeconomic shock was developed by Elsinger, Lehar and Summer (2006). The model explores the impact of different scenarios of macroeconomic shocks like the exchange rate and interest rate shocks, as well as shocks related to securities prices and the business cycle. As a consequence of these shocks, banks face losses[8] due to the market risk and credit risk, which affects their "value" and the ability to settle their liabilities to other banks. An advantage of this model is the possibility of using Monte Carlo simulation to create a large sample of scenarios for macroeconomic shocks and, consequently, determining the probability of contagion. A model by Elsinger et al. (2006) is based on that by Eisenberg and Noe (2001), which examines a static clearing mechanism for a financial system with exogenous income positions of institutions and a given structure of bilateral nominal liabilities. The model is extended to include a random variable (for testing various macroeconomic scenarios). A detailed elaboration of the model is given below.

The banking system consists of $\boldsymbol{N} = \{1,...,N\}$ banks. Each bank $i \in \boldsymbol{N}$ is characterised by a given value e_i net of claims a_{ij} against and liabilities l_{ij} to other banks $j \in \boldsymbol{N}$ in the system. Therefore, the banking system is defined by the previously described matrix of interbank exposures X consisting of $N \times N$ elements and a vector $e \in \Re^N$. If for a given pair (X,e), the net value of a bank becomes negative, i.e. the bank is in default, its creditor banks are paid off proportionally,[9] without observing the seniority rule. The proportional payoff can be formalised as follows: vector $d \in \Re^N_+$, denotes total liabilities of banks to the rest of the banking system, i.e. we have $d_i = \sum_{j \in N} x_j$. The proportional sharing of losses requires the definition of a new matrix $\Pi \in [0,1]^{N*N}$ by the elements of matrix X being divided by the total liabilities of the banks in the columns of the matrix.

$$\pi_{ij} = \frac{x_{ij}}{d_i}, \text{ if } d_i > 0; \text{ if } d_i = 0, \pi_{ij} = 0 \tag{4}$$

8 Or gains, e.g. if a bank has large net foreign currency claims and the domestic currency depreciates.
9 I.e. the losses are shared proportionally by banks.

When the new matrix is defined, the so-called "clearing payment vector" p^{*}[10] can be also determined. This vector has the following form for any $i \in \boldsymbol{N}$:

$$p_i^* = \min\left[d_i, \max\left(\sum_{i=1}^{N} \pi_{ij} p_j^* + e_i, 0\right)\right] \tag{5}$$

By defining the clearing payment vector for a given structure of interbank liabilities and the values of banks (Π, e, d) it is possible to establish two important things: 1) which bank in the banking system is insolvent, i.e. defaulting ($p_i^* < d_i$) and 2) the recovery rate[11] for each defaulting bank $\left(\dfrac{p_i^*}{d_i}\right)$.

The clearing payment vector also provides important information on the character of a bank's default, i.e. the default is *fundamental* if bank i is unable to honour its obligations, assuming that all other banks honour their obligations:

$$\sum_{j=1}^{N} \pi_{ji} d_j + e_i - d_i < 0 \tag{6}$$

Contagious default occurs in the situation when bank i is unable to honour its obligations only because other banks are unable to honour their obligations:

$$\sum_{j=1}^{N} \pi_{ji} d_j + e_i - d_i \geq 0, \text{ but } \sum_{j=1}^{N} \pi_{ji} p_j^* + e_i - d_i < 0 \tag{7}$$

The contribution of the study by Elsinger et al. (2006) consists in the assumption that e_i is a random variable, which enables this model to be used for the simulation. Each draw (i.e. a change in the value of) e_i represents a new scenario.

The values of banks e_i are determined as follows. Assume that there are two periods: $t=0$, which is the observation period and $t=1$, which is the hypothetical clearing period, when bank claims are settled in accordance with the clearing mechanism. In period $t=0$, the portfolio holdings of each bank are observed, both interbank exposures and debts from matrix X, and the remaining portfolio holdings, such as loans, stocks and bonds on the assets side, as well as liabilities to non-banks on the liabilities side.[12] These "non-bank portfolio" holdings are exposed to credit and market risks. It is assumed that the portfolio holdings remain constant over time. The value of the portfolio at $t=1$ depends on the realisation of the previously mentioned risks, so that we get the value of a "non-bank portfolio" e at $t=1$. Now, we can also determine the clearing payment vector $p_i^*(e)$.

These authors test the model in Austria using Monte Carlo simulation, enabling them to create a large sample of scenarios and thus determine the probability

10 The clearing payment vector includes a bank's obligations to other banks, and it respects the proportionality principle in the recovery of debt from a failed bank.

11 The recovery rate is the percentage of an insolvent bank's obligations to its clients that can be honoured.

12 It is the difference between the values of assets and liabilities of the remaining portfolio holdings (related to non-banks) that makes the value of bank e_i.

of a macroeconomic shock resulting in bank contagion. Fundamental defaults are much more frequent than contagious defaults, so that the average contagious default probability is only 0.006%, whereas the probability of any type of default is 0.8%. They also find that the recovery rates in the case of bank defaults are relatively high, so that the median recovery rate amounts to 66%. Despite the scarcity of contagious defaults, there are scenarios in which such defaults would occur in as many as 75% of all default cases. Therefore, the authors conclude that although the probability of bank contagion is slight, its impact on the soundness of banking systems would be considerable.

4 Data

The analysis is based on the CNB data from the report on banks' exposures by activity, which makes it possible directly to establish the amounts of bilateral exposures to both domestic and foreign banks, and, at the same time, provides an insight into the structure of the interbank market. This helps us to avoid many difficulties facing researchers in this area in other countries who, owing to the unavailability of data on direct bilateral exposures, base their estimations on the data on aggregate exposures and aggregate debts to other banks, using the entropy maximisation or entropy cross-minimisation methods.[13] A minor data-related problem is the fact that in the reports used lower-value loans are classified into the small-loan portfolio, so that these data probably indicate all exposures of small banks to large ones. On the other hand, some minor exposures of large banks to small ones may be classified into the small-loan portfolio, so they cannot be seen. However, these are negligible amounts and have no impact on the main conclusions of this paper.

The reports on banks' exposures by activity include all data on placements relating to granted loans, time deposits or off-balance exposures. Moreover, these data relate to all exposures, irrespective of their maturity, but, based on the data on deposits received and loans granted to financial institutions (not only banks), it can be indirectly established that a large share of these exposures (over 95% of the deposits received by and over 92% of the loans granted to a financial institution as at 31 December 2007) have maturities up to one year, and can be considered as relating to the money market. The interbank exposures contain both collateralized and uncollateralized claims. The data relate to year-ends in the period 2005-2007. In this period, the number of banks in the Croatian banking system was stable.[14]

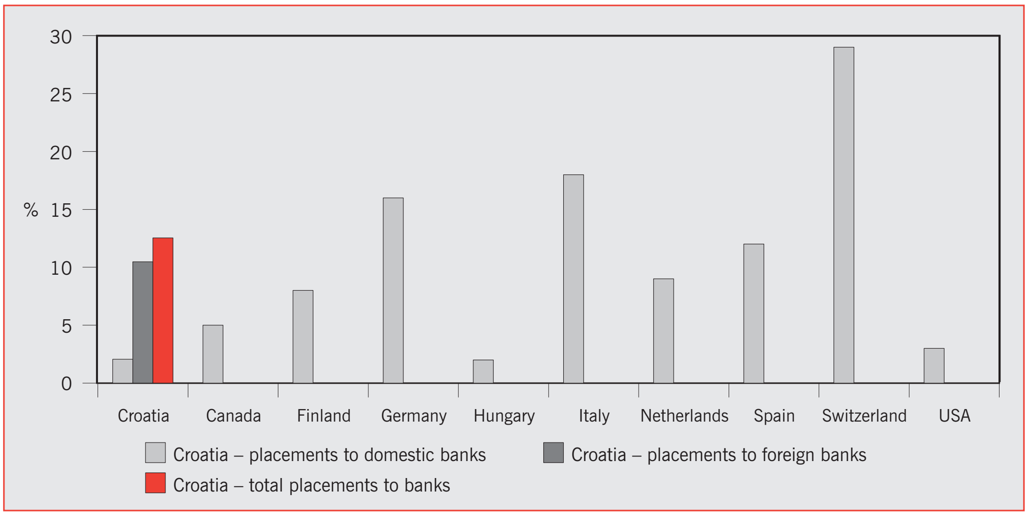
The Croatian interbank market was worth HRK 7,151m at the end of December 2007, representing as little as 2% of the banking system's assets. This share was even smaller in the previous years. The small significance of the domestic in-

13 Such approximation of the structure of interbank exposures may deviate significantly from actual data.

14 There were only three changes: First, on 30 June 2006, Podravska banka d.d. took over Požeška banka d.d. However, in order to simplify the simulation, it was assumed that Požeška banka was part of Podravska banka at the end of 2005. Second, on 6 April 2007, Gospodarsko-kreditna banka d.d. changed its name to Veneto banka d.d. and third, on 23 April 2007, Banka Sonic d.d. changed its name to Banco Popolare Croatia d.d. The new names of these banks were used for the previous periods.

terbank market becomes apparent when compared with interbank exposures in the Western European countries. Thus, as shown in Figure 5, the German interbank market accounts for about 16% of the total banking system's assets.[15] In the observed period, the exposure of Croatian banks to foreign banks was five times higher (HRK 36,112m, as at 31 December 2007) than that to domestic banks, which leads to the logical conclusion that the threat of idiosyncratic contagion is more likely to come from foreign than from domestic banks. The considerable exposure to foreign banks is a direct consequence of the CNB's *Decision on the minimum required amount of foreign currency claims*, which provides that these claims should amount to 20% of a bank's liabilities.[16] By including these exposures this ratio increases to 13% of the banking system's assets.

Figure 5 Interbank Lending as a Percentage of Total Banking System Assets



Note: The data relate to June 2005, with the exception of the data on Finland, Italy and Croatia which relate to March 2005, December 2003 and December 2007. The figures for all countries except Hungary (for which only the data on collateralised interbank placements are presented) comprise both collateralized and uncollateralized placements, whereas the data for the USA only relate to commercial banks. The data for Switzerland also include interbank exposures to foreign banks. For all other countries, the data relate to domestic interbank exposures only.
Sources: Upper (2007), Mistrulli (2007) and author's calculation.

The characteristics of exposures in the domestic interbank market and to foreign banks for the entire observed period by bank group, broken down by size and ownership, are summarised in Table 2. At the end of 2007, the Croatian banking system comprised 23 small, 4 medium-sized and 6 large banks. Small banks account for less than 1% of banking system assets, medium-sized banks for between 1% and 5% and large banks for more than 5%. Of these 33 banks, 15 were in domestic private ownership, 2 were in domestic government ownership and 16

15 In this connection, it is noteworthy that the data presented in the figure are not completely comparable owing to differences in the interbank exposure definition across the countries.

16 While a CNB decision regulating foreign currency liquidity of banks, the so-called "decision on the 53%", existed even before 2003, it prescribed the obligation of banks to maintain their foreign currency claims only as a percentage of their short-term foreign currency liabilities. According to a decision initially adopted in 2003, the calculation base for the minimum required foreign currency claims was broadened to include long-term foreign currency liabilities of banks as well (OG 10/2003). The decision was subsequently amended, and a decision adopted in 2009 (OG 23/2009) is currently in effect.

were in foreign ownership. All bank groups show stronger exposures to foreign than to domestic banks, with few exceptions when viewed individually. In addition, substantial differences exist in the ratio of domestic vs. foreign bank exposures, depending on the bank group. Accordingly, the highest ratio is observed in large banks and foreign-owned banks (these bank groups' exposures to foreign banks were six times larger than their exposures to domestic banks at the end of 2007). Concurrently, the exposures of small domestic-owned banks to foreign banks were double their exposures to domestic banks.

Table 2 Banks' Exposures, 31 December 2007

	Bank groups	Exposure to domestic banks (in million HRK)	Exposure to foreign banks (in million HRK)	Total exposure to banks (in million HRK)	Structure of exposure to domestic banks	Structure of exposure to foreign banks	Ratio of exposure to foreign banks to exposure to domestic banks
2005	Small	885.3	2,411.7	3,297.0	22.9%	9.5%	2.7
	Medium-sized	346.4	2,608.1	2,954.5	8.9%	10.2%	7.5
	Large	2,640.8	20,493.7	23,134.5	68.2%	80.3%	7.8
	Domestic private ownership	485.2	1,501.0	1,986.2	12.5%	5.9%	3.1
	Domestic government ownership	188.1	629.0	817.1	4.9%	2.5%	3.3
	Foreign ownership	3,199.2	23,383.5	26,582.7	82.6%	91.7%	7.3
	Total	3,872.5	25,513.5	29,386.0	100.0%	100.0%	6.6
2006	Small	1,161.5	2,614.5	3,776.1	24.9%	8.9%	2.3
	Medium-sized	846.3	3,956.6	4,802.9	18.2%	13.5%	4.7
	Large	2,650.7	22,655.5	25,306.2	56.9%	77.5%	8.5
	Domestic private ownership	499.0	1,559.5	2,058.5	10.7%	5.3%	3.1
	Domestic government ownership	381.7	1,018.2	1,399.9	8.2%	3.5%	2.7
	Foreign ownership	3,777.8	26,648.9	30,426.8	81.1%	91.2%	7.1
	Total	4,658.5	29,226.6	33,885.1	100.0%	100.0%	6.3
2007	Small	1,739.2	2,903.1	4,642.3	24.3%	8.0%	1.7
	Medium-sized	1,628.4	4,642.1	6,270.4	22.8%	12.9%	2.9
	Large	3,783.4	28,566.4	32,349.8	52.9%	79.1%	7.6
	Domestic private ownership	1,039.5	1,655.0	2,694.5	14.5%	4.6%	1.6
	Domestic government ownership	826.7	1,552.5	2,379.2	11.6%	4.3%	1.9
	Foreign ownership	5,284.7	32,904.1	38,188.8	73.9%	91.1%	6.2
	Total	7,151.0	36,111.5	43,262.5	100.0%	100.0%	5.0

Sources: CNB and author's calculation.

The structure of the Croatian interbank market at the end of 2007 is shown in a matrix of interbank exposures in Figure A in the Appendix, while Table 3 displays the characteristics of these bilateral exposures, broken down by bank groups, for the whole observed period. Bilateral exposures rarely exceed HRK 100m. Interbank claims and liabilities are concentrated on six large banks that represent some kind of money centres. Specifically, at the end of 2007 large banks participated in slightly less than 50% of possible bilateral relationships as at least one partner (either as a creditor or debtor).[17] By contrast, small banks participated as debtors or creditors in just 14% of possible bilateral relationships, and medium-sized banks in 26%.[18] The importance of large banks is also indicated by the fact that they accounted for 53% of claims and 79% of liabilities in the interbank market. Small banks and medium-sized banks, which are less often mutually exposed, are oriented towards large banks and surprisingly more often figure as creditors than as debtors. This finding probably reflects the fact that for these banks, which have neither sufficient funds for diversification nor expert staff for quality asset management, the easiest solution is to place excess funds with large banks. The Croatian interbank market is hence close to the theoretical definition of the interbank market structure provided by Freixas et al. (2000), but comprises more money centres to which peripheral banks are linked. Accordingly, failures of money centre banks would have more significant impacts than failures of peripheral banks.

Table 3 Domestic Interbank Market

	Bank groups	Creditor or debtor		Creditor		Debtor		Claims and liabilities (in million HRK)		
		Number[a]	Percentage[b]	Number[a]	Percentage[b]	Number[a]	Percentage[b]	Claims	Liabilities	Net position
2005	Small	136	9.2%	98	13.3%	38	5.2%	885.3	494.3	391.0
	Medium-sized	41	16.0%	20	15.6%	21	16.4%	346.4	539.6	–193.3
	Large	173	45.1%	57	29.7%	116	60.4%	2,640.8	2,838.5	–197.7
2006	Small	187	12.7%	121	16.4%	66	9.0%	1,161.1	724.2	436.9
	Medium-sized	187	24.2%	27	21.1%	35	27.3%	846.3	842.5	3.8
	Large	62	48.7%	70	36.5%	117	60.9%	2,625.3	3,065.9	–440.6
2007	Small	202	13.7%	139	18.9%	63	8.6%	1,739.2	721.6	1,017.6
	Medium-sized	67	26.2%	30	23.4%	37	28.9%	1,628.4	1,241.0	387.4
	Large	191	49.7%	61	31.8%	130	67.7%	3,783.4	5,188.4	–1,405.0

[a] The number of bilateral relationships in which banks from a bank group participate as creditors, debtors or as both creditors and debtors to banks from other bank groups or to other banks from their own groups.
[b] Bilateral relationships in which banks from a bank group participate as creditors, debtors or both creditors and debtors to banks from other bank groups or other banks from their groups, shown as a percentage of the maximum theoretical number of such bilateral relationships.
Sources: CNB and author's calculation.

The structure of exposures to thirty-three major foreign banks is shown in a matrix in Figure B in the Appendix.[19] Large foreign-owned banks have the largest

17 At the end of 2007, large banks participated in 191 bilateral relationship as creditors or debtors. The maximum theoretical number of bilateral relationships was [(6*33)*2-6*2]=384.

18 The maximum theoretical number of bilateral relationships in which they participate as least as one partner is [(23*33)*2-23*2]=1472 for small banks, and [(4*33)*2-4*2]=256 for medium sized banks.

19 The choice of these thirty-three major foreign banks is intended to facilitate the comparison of the results of simulations of idiosyncratic failures of domestic and foreign banks. At the end of 2007, the Croatian banking system was exposed to 165 foreign banks. As the exposures to a large number of these banks were small (e.g. bilateral exposures in thousands HRK), the inclusion of such data would diminish the median effects of idiosyncratic failures of foreign banks, which is unrealistic. The exposures to thirty-three major foreign banks accounted for 80% of domestic banking system exposures to foreign banks at the end of 2005, for 76% at the end of 2006 and for 79% in December 2007. The amounts of Croatian banking system exposures to thirty-three major foreign banks at the end of 2005, 2006 and 2007 are shown in Table A in the Appendix.

exposures to major foreign banks. At the end of 2007, their exposures accounted for 79% of exposures to major foreign banks and for 64% of theoretically possible bilateral exposures to major foreign banks.[20] This percentage is 17% and 37% for small and medium-sized banks respectively.[21] None of the small banks had a bilateral exposure exceeding HRK 100m. It can also be noticed that exposures are not oriented to several foreign banks, but that their distribution is quite dispersed.

However, as already noted, when assessing the possibility of bank contagion due to an idiosyncratic failure one should not consider the absolute amounts of exposures but their ratio to banks' regulatory capital. As shown in Table 4, at the end of 2007, the bilateral exposures, either to domestic or foreign banks, in none of the bank groups exceeded the amount of their regulatory capital.[22] This means that a necessary condition for bank contagion due to an idiosyncratic failure according to the hard definition of insolvency is not fulfilled.

Table 4 Exposures-to-Regulatory-Capital Ratio, 31 December 2007

Bank groups	Ratio of exposures to domestic banks to regulatory capital	Ratio of exposures to foreign banks to regulatory capital	Ratio of total exposures to banks to regulatory capital	Ratio of maximum bilateral exposures to domestic banks to regulatory capital	Ratio of maximum bilateral exposures to foreign banks to regulatory capital
Small	50.67%	84.58%	135.24%	17.10%	14.64%
Medium-sized	28.12%	80.16%	108.28%	12.68%	12.60%
Large	12.44%	93.91%	106.35%	4.34%	11.50%
Domestic private ownership	48.05%	76.50%	124.55%	18.11%	13.81%
Domestic government ownership	70.52%	132.43%	202.95%	22.93%	19.73%
Foreign ownership	14.56%	90.63%	105.18%	9.53%	13.09%
Total	18.04%	91.09%	109.13%	14.24%	13.82%

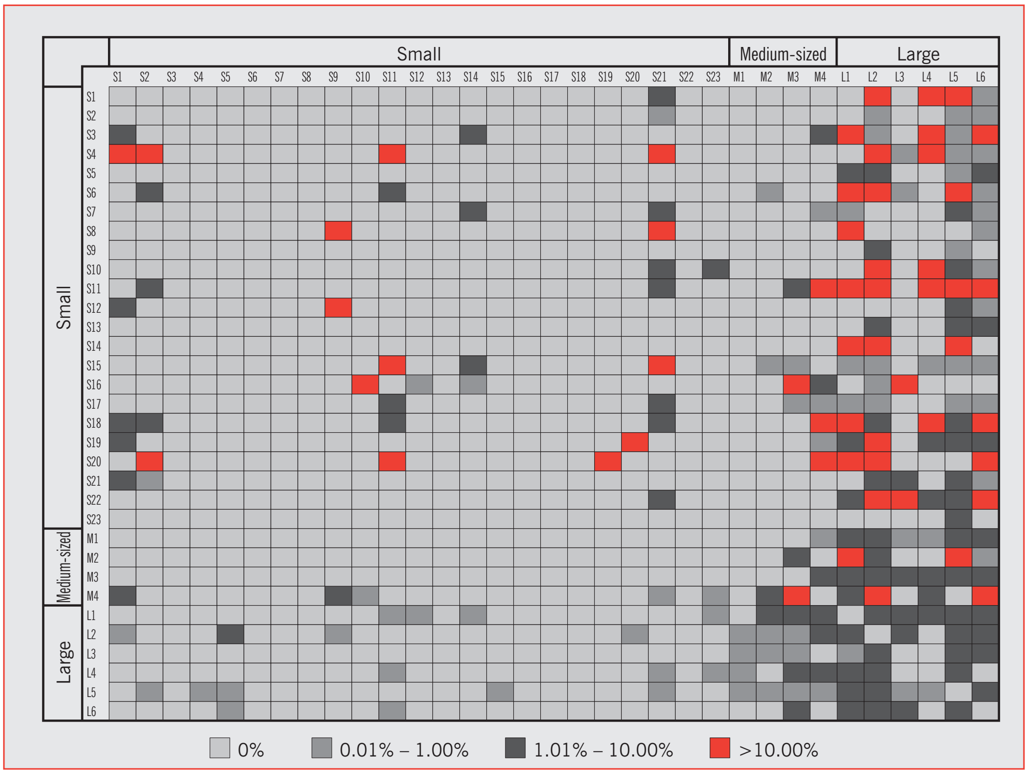
Note: The maximum-bilateral-exposure-to-regulatory capital ratio was based on the simple arithmetic mean.
Sources: CNB and author's calculation.

20 At the end of 2007, there were 127 bilateral exposures of large banks to major foreign banks, whereas the maximum theoretical number of bilateral exposures was 6*33=198.

21 The maximum theoretical number of bilateral exposures to major foreign banks was 23*33=759 for small banks and 4*33=132 for medium-sized banks.

22 In the previous years this indicator recorded similar values.

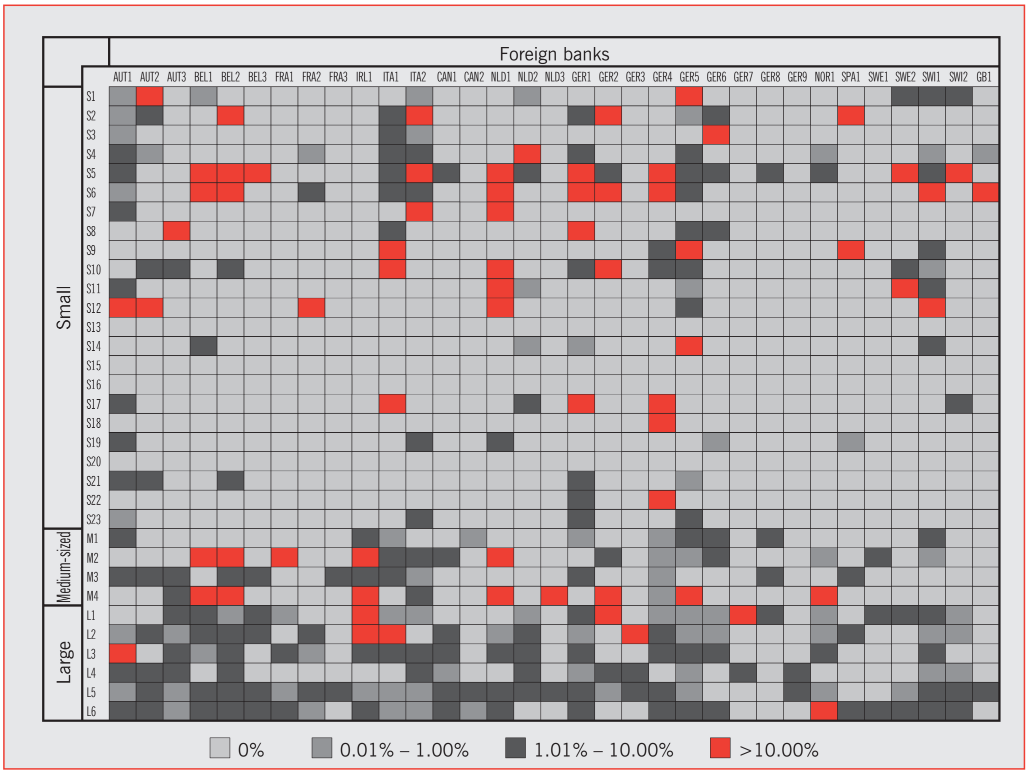
Figure 6 Matrix of the Ratios of Exposures in the Domestic Interbank Market to Regulatory Capital, 31 December 2007



Note: The elements of the matrix represent the claims of a bank in a row against a bank in a column shown as the percentage of the regulatory capital of the bank in a row. Due to the obligation to maintain banking secrecy, the banks are represented by code names and not by their actual names. The sequence of banks is random.
Sources: CNB and author's calculation.

The ratio of bilateral exposures to regulatory capital at the end of 2007 is also shown graphically in Figures 6 and 7. The dominant colours are grey and dark grey, which is an indication that most bilateral exposures are lower than 10% of regulatory capital (76% of domestic interbank market bilateral exposures and 77% of bilateral exposures to major foreign banks). Red appears more often in relation to the exposures of small banks, which is also one of the reasons why the results of the idiosyncratic contagion simulation (presented later in the paper) show that capital adequacy ratios decrease below 10% mainly in the case of small banks.

Figure 7 Matrix of the Ratios between Exposures to Thirty-Three Major Foreign Banks and Regulatory Capital, 31 December 2007



Note: The elements of the matrix represent the claims of a bank in a row (domestic) against a bank in a column (foreign) shown as the percentage of the regulatory capital of the bank in a row. Due to the obligation to maintain banking secrecy, the banks are represented by code names and not by their actual names. The sequence of banks is random.
Sources: CNB and author's calculation.

Despite the fact that banking system exposures to foreign banks considerably exceed the size of the domestic interbank market, the ratios of bilateral exposures to regulatory capital are not significantly different. This is because exposures to foreign banks are more dispersed than exposures to domestic banks, as shown in Table 5.

Table 5 Dispersion of Banks' Exposures and Debt to Domestic and Foreign Banks

Date	31 December 2005		31 December 2006		31 December 2007	
Dispersion indicators	Domestic	Foreign	Domestic	Foreign	Domestic	Foreign
Maximum bilateral exposure (in million HRK)	429.8	479.4	379.3	1,914.7	285.7	1,471.7
Number of bilateral exposures > 100 million HRK	9	71	10	76	22	99
Median debt (in million HRK)	22.0	510.3	33.6	469.7	32.9	679.9
Maximum debt (in million HRK)	869.1	1,363.9	1,089.9	2,684.3	1,569.2	1,920.0
Share of maximum debt in total banking system exposure	22.4%	5.3%	23.4%	9.2%	21.9%	5.3%
Total debts > 500 million HRK	3	17	2	16	6	25
Gini coefficient of banking system exposure	0.75	0.26	0.72	0.35	0.75	0.28

Note: The dispersion of exposures to foreign banks is analysed on the basis of thirty-three major foreign banks.
Sources: CNB and author's calculation.

5 Results

5.1 Idiosyncratic Failures

As mentioned in the previous section, the Croatian banking system does not satisfy a necessary theoretical condition for the possible materialisation of bank contagion due to an idiosyncratic failure according to the hard definition of insolvency. This is not the case with either exposures to domestic banks or exposures to foreign banks. Therefore the simulation of contagion carried out in this paper examines the impact of each bank's failure on the losses of the banking system as a whole and the losses of exposed banks through their capital adequacy ratios (hereinafter: CAR). The simulations show that not even the condition for bank contagion according to the soft definition of insolvency is satisfied, i.e., that in none of the exposed banks does the CAR drop below 4%. It was therefore decided to present the results in such a manner as to observe in which cases the CAR drops below the prescribed minimum level of 10%.

Since there are such cases when a bank is at the same time both the creditor and debtor to another bank, such mutual claims were not netted,[23] that is, the simulation was carried out using gross exposures. This is because an interbank claim against a failed bank is entered in a "waiting list" together with all the other claims collected according to seniority. Also, such collection of claims against the failed bank may last several years. If netting had been performed, the results showing the impact of idiosyncratic failures would have been even more insignificant.

The impact of an idiosyncratic failure on the CAR of the exposed bank *i* can be defined by the following formula:

$$CAR^{1} = \frac{C_i - \Theta x_{ij}}{RWA - \Theta x_{ij}} \tag{8}$$

where CAR^1 is the CAR after failure, C_i regulatory capital, RWA risk weighted assets, Θ the rate of loss, while x_{ij} is the exposure of bank *i* to failed bank *j*.

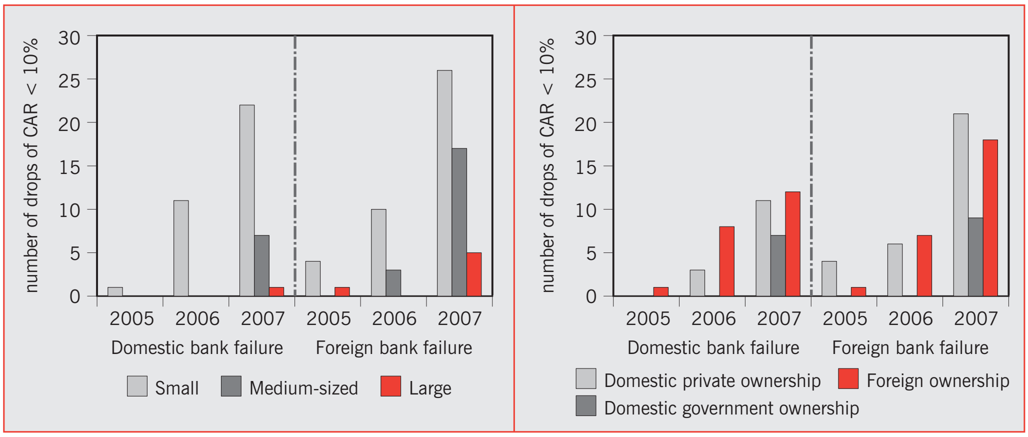
Due to the previously noted difficulties with estimating an acceptable rate of loss per exposure due to default, the impact of idiosyncratic failures was observed using various rates ($0\% < \Theta \leq 100\%$), while the focus was on the most pessimistic scenario with the maximum loss rate of 100%.

The results show that banks' losses would be well amortised by regulatory capital so that the capital adequacy ratio would drop below 10% in only few banks. Figure 8 shows the cases where the CAR drops below 10%, as broken down by bank groups. The CAR more often drops below 10% in the case of idiosyncratic failures of foreign banks than in the case of domestic bank idiosyncratic failures, but the difference is not significant. This is due to the already mentioned considerably dis-

23 In most empirical articles dealing with idiosyncratic contagion netting of mutual claims is not performed.

persed distribution of bilateral exposures to foreign banks, whose ratios to banks' regulatory capital[24] do not differ from the same ratios in the domestic interbank market. The CAR decreases below 10% in small and medium-sized banks, and less often in large banks.

Figure 8 Cases when the Capital Adequacy Ratio Drops below 10% as a Result of Idiosyncratic Failures, as Broken Down by Bank Groups, Θ=100%



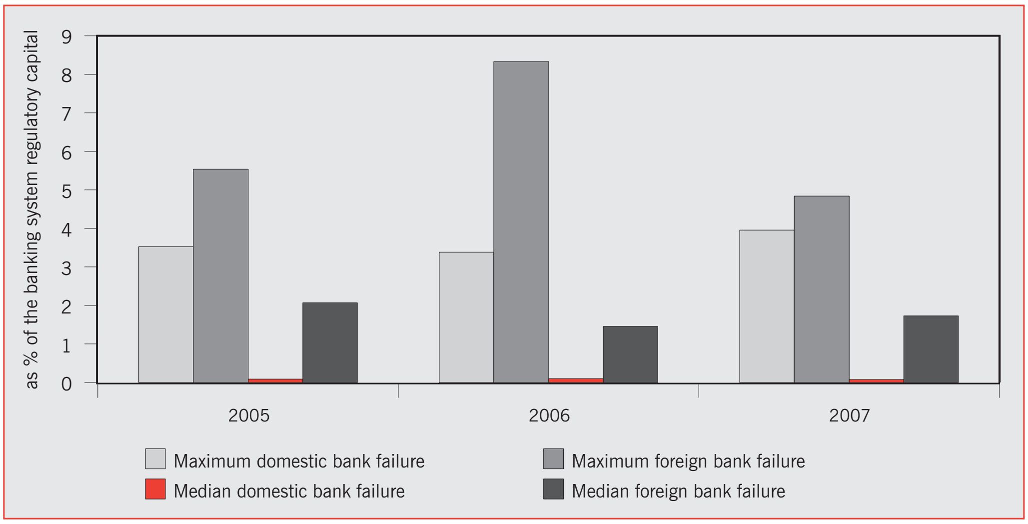
Note: The results presented summarise the cases where the CAR drops below 10% after 33 independent simulations of bank failure. In the case of a domestic bank idiosyncratic failure, the impact of the failure of one bank on the remaining thirty-two banks is observed, so that, assuming that all the banks are exposed to other banks, the maximum theoretical number of possible cases of the capital adequacy ratio dropping below 10% is 32*33=1056, whereas in the case of idiosyncratic failures of major foreign banks the maximum theoretical number is 33*33=1089.
Sources: CNB and author's calculation.

Although this figure might seem to suggest that the materialisation of idiosyncratic failures has an increasingly strong impact on the decrease in the CAR of banks, the situation is quite the opposite. The CARs decrease below 10% only in banks where they initially slightly exceed 10%, and there were more such banks at the end of 2007 than in the previous years (as seen in Tables B, C and D in the Appendix). The banking system was generally better capitalised at the end of 2007 than in the previous years and thus more shock-resilient. While the CNB's *Decision on amendments to the decision on the capital adequacy of banks*,[25] which took effect in June 2006, had an immediate effect on decreasing the CAR of banks due to the increase in risk weights for assets exposed to currency risk, it also led to a wave of bank recapitalisations and a consequent rise in the banking system CAR to 15.4% at the end of 2007, compared with 14.7% at the end of 2005.[26] The increased resilience of the banking system is indicated by the simulation results: median losses[27] as a percentage of regulatory capital would in the case of idiosyn-

24 Predominantly regarding large foreign-owned banks.
25 OG 149/2005.
26 The increase in the CAR was also due to changes in its denominator. In order to offset the increase in risk-weighted assets brought by the CNB's decision, banks changed the currency structure of their balance sheets, increasing their reliance on kuna sources of funds and kuna borrowing. This restructuring contributed to the decrease in the banking system's exposure to currency-induced credit risk (CICR), which was the intention of the said decision.
27 A median loss is a loss due to the failure of a bank to which the banking system has a median exposure.

cratic failures of domestic banks be slightly lower at the end of 2007 (0.08% of the banking system regulatory capital) than at the end of 2005 (0.09% of the banking system regulatory capital). This can be observed in Figure 9, which also shows that the maximum losses in the event of failures of the systemically most important domestic and foreign banks would be approximately comparable.[28] In contrast, median losses in the case of idiosyncratic failures of major foreign banks would far exceed median losses caused by idiosyncratic failures of domestic banks (i.e. they would respectively account for 1.73% and 0.08% of the banking system regulatory capital at the end of 2007). This leads to the conclusion that idiosyncratic failures of foreign banks would have stronger effects on banking system losses. However, as these losses would to a great extent be incurred by large banks, they would be well amortised by regulatory capital and would not exert significant influence on the CARs of these banks (as measured by their dropping below 10%).

Figure 9 Comparison of Losses due to Idiosyncratic Failures, Θ=100%



Sources: CNB and author's calculations.

Tables B, C and D in the Appendix show that, in the event of a failure of small domestic bank S19 at the end of 2007, the lowest capital adequacy ratio of 6% would be recorded by small bank S20.[29] In the same year, the CAR would decrease below 10% in eight more banks, of which only two initially had a CAR higher than 11%. These banks' CARs were lower at the end of 2007 than in the previous years, so the result indicating that at the end of 2007 the CAR would decrease below 10% in the event of a larger number of idiosyncratic failures is not surprising.

Although the simulation results indicate that the Croatian banking system would well withstand idiosyncratic failures, this does not mean that the operational stability of exposed banks would remain intact if such failures actually occurred. The reason for this is the already mentioned simplifying assumptions applied in

28 The "systemically most important bank" is the bank to which the Croatian banking system has the largest exposure.

29 Assuming the loss rate of 100%.

the simulations, which do not take into account circumstances that might further increase the effects of the initial bank failure (e.g. a possible macro shock, deposit withdrawal, the effect of fire sale on the reduction in asset prices, a change in liquidity conditions in the interbank market, etc.). This paper also does not analyse the feasibility of the recapitalisation of banks whose CARs would decrease below 10% in the event of idiosyncratic failures, and this might prove a difficult task in the case of a wider financial crisis. It should also be stated that the simulations of the idiosyncratic failures of foreign parent banks were done based on the assumption that domestic daughter banks, as well as all other banks, would suffer only the losses arising from their exposures to the failed bank.

5.2 Bank Contagion due to a Macroeconomic Shock

This paper also tests the possibility of contagion in the Croatian banking system due to macroeconomic shocks. It aims to establish whether a bank's default resulting from a macroeconomic shock can lead to the insolvency of the banks that have exposures to it and were previously also affected by a macroeconomic shock. This simulation was compiled according to the previously presented model by Elsinger et al. (2006), with some modifications. As opposed to the said model, this one does not use Monte Carlo simulation but a stress testing technique developed at the CNB, which treats both market and credit risks as a "single" credit risk. The macroeconomic model of credit risk that provides a basis for the stress testing technique was estimated by the OLS regression. The annual rate of change in the ratio of non-performing loans to total loans is the dependent variable, while the independent variables are the annual rate of change in GDP and the nominal exchange rate of the kuna against the euro. The results of the regressions mostly confirmed the earlier assumptions: the coefficients with GDP and the exchange rate are statistically significant and of expected directions, that is, the domestic currency depreciation and economic slowdown are positively correlated with the increase in non-performing loans.[30] Macroeconomic shock scenarios (e.g. a drop in the GDP growth rate, depreciation of the kuna exchange rate) are thus reflected in the quality of bank loans.[31] Also slightly modified is the definition of the value of a bank (e_i), which is, in a significant departure from the original model, equalled to the value of regulatory capital. While the simulations are conducted, various macroeconomic scenarios are established by changing the NPLR growth rates. These scenarios generate losses for banks, which leads to a reduction in their regulatory capital (e_i); and efforts are made to determine the thresholds[32] at which a bank defaults on its commitments as a direct result of a macroeconomic shock (*fundamental default*) or as a consequence of bank contagion (*contagious default*). As it

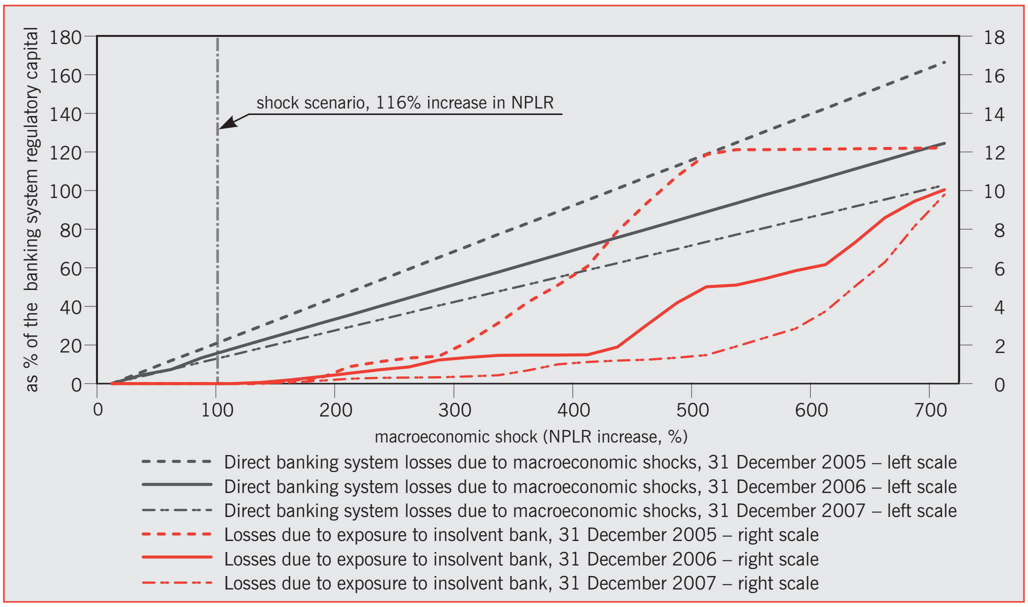
30 For a more detailed explanation of the credit risk model see *Financial Stability* (2008), No. 1.
31 The loan quality indicator used is the ratio of non-performing loans to total loans (hereinafter: NPLR).
32 In countries with a large number of banks, (Elsinger et al. (2006) conducted a simulation with 881 banks) establishing thresholds would be purposeless and Monte Carlo simulation should be carried out instead.

is the case with Elsinger et al. (2006), default is defined by the negative clearing value of a bank. However, Elsinger et al. (2006) define the negative clearing value as a situation when a bank's interbank liabilities exceed its collectible interbank claims and its value as defined by its assets and liabilities structure, whereby in this model the value of a bank is equalled to its regulatory capital.

Taking into account the limiting assumptions which provide a basis for the simulations of bank contagion due to a macroeconomic shock, carried out in this paper, the results show that bank insolvencies defined in this way are possible in highly improbable scenarios and that the "contagions" occurring in such scenarios would primarily result from the macroeconomic shock itself, rather than from the exposure to an insolvent bank, which can also be ascribed to the small interbank exposures of domestic banks.

The relevance of the simulation results with regard to the macroeconomic shocks affecting the Croatian economy in the past was assessed by means of the macroeconomic scenario used in Financial Stability (2008). This scenario is based on the movements of macroeconomic variables in the late nineties, when the economy was faced with a slowdown in foreign capital inflows and a banking crisis. In this period, the GDP growth rate decreased by 6.5 percentage points and the kuna exchange rate depreciated by 10% against the German mark. In the model of credit risk used in this paper, this combination of macroeconomic variable trends equals a NPLR increase of 116%. If a macroeconomic shock of such a scale occurred, minor losses owing to exposures to insolvent banks would be incurred in late 2006 and 2007, with interbank liabilities of one of the banks slightly exceeding the value of its regulatory capital and interbank claims.

Figure 10 Losses due to Macroeconomic Shocks

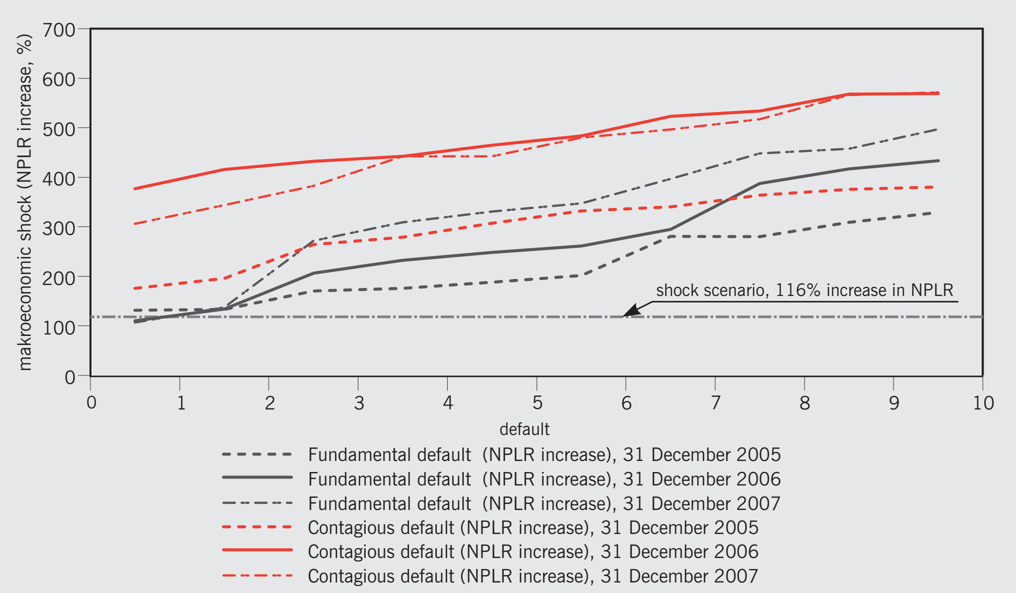


Note: The ratio between the scales is 10:1.
Sources: CNB and author's calculation.

As shown in Figure 10, banking system losses due to a macroeconomic shock (left scale) far exceed the losses arising from exposures to defaulting banks (right scale). The losses arising from exposures to defaulting banks materialise only after macroeconomic shocks involving a NPLR increase of 132% in December 2005, 110% in December 2006 and 107% in December 2007. These losses increase slowly at "lower" levels of NPLR growth and accelerate with the previous insolvency of a large number of banks. It is shown that the banking system grows more resilient to macroeconomic shocks, since the losses due to macroeconomic shocks and the consequences of banks' default are considerably lower in relation to regulatory capital at the end of 2007 than they were in the previous years. Furthermore, the losses due to bank default grow faster at the end of 2005, reaching 2% of regulatory capital in the event of a NPLR increase of 300%, than at the end of 2007, when this level of losses would be reached with the macroeconomic shock involving a NPLR increase of about 500%.

An indication of the banking system's high resilience to macroeconomic shocks and the small probability of default[33] due to contagion is also provided in Figure 11. The first fundamental defaults would occur in the event of macroeconomic shocks involving a NPLR increase of slightly over 100%, while the first contagious defaults would occur after the shocks involving a NPLR increase of over 300%. The only exception is the end of 2005, when such defaults would occur a bit earlier, which is due more to a slightly weakened banking system resilience to macroeconomic shocks in that year than to losses due to exposures to previously insolvent banks.

Figure 11 Sequence of the First Ten Bank Defaults Resulting Directly from Macroeconomic Shocks and as a Consequence of Contagion



Sources: CNB and author's calculation.

33 The possibility of default due to contagion in this paper is assessed by comparing the simulation results with the initial scenario involving a NPLR increase of 116%, which can be considered "relatively moderate". Specifically, as shown by the experiences of some Asian countries during the Asian crisis in the late nineties, it is not impossible for the NPLR in the banking sector to increase more than ten times. Under such scenario, massive bank failures and a strong effect of bank contagion could definitely be expected.

However, these results should be viewed with some caution, since both the original credit risk model and the simplified bank contagion model represent rough approximations of the impact of macroeconomic shocks on banks' balance sheets and their consequent insolvency. The initial assumptions of the simulations should also be taken into account. For example, the simulations also neglect a highly probable interaction of macroeconomic shocks and deposit withdrawal, a combination of events far worse than the shocks observed in this paper.

6 An Analysis of Other Contagion Channels in Croatia

As already mentioned, this paper investigates only direct bank contagion, that is, it focuses on the assessment of interbank credits risk; this is due to the non-existence of advanced research methods capable of providing a comprehensive overview of systemic risk in the banking system. The non-existence of research methods to assess other contagion channels could be attributed to the following facts: (i) some of these channels are strongly dominated by behavioural factors (the deposit withdrawal channel), (ii) some have turned out to be destructive only recently (the fire sale channel), and (iii) some of them have been discussed only hypothetically (the cross-border contagion channel).

Despite all this, an attempt will be made to intuitively assess the threat posed by each of these channels. In the empirical literature, a general argument for the lack of interest in the contagious bank run is that households have confidence in the deposit insurance scheme since most household deposits are lower than the maximum deposit insurance amount, Upper and Worms (2004). However, as proved during the peak of the financial crisis in October 2008, manifested by the failures and nationalisations of a large number of banks in the US and Western Europe, the contagious bank run, contrary to the previously mentioned claims, did not disappear from the financial systems of developed countries. Many countries reacted promptly, increasing the deposit guarantee coverage in order to send a signal to households that their money in banks is safe. Croatia also increased the deposit guarantee coverage from 100,000 kuna to 400,000 kuna. This received a positive response from the media and the Croatian public received additional information on the basic features of the deposit insurance scheme.

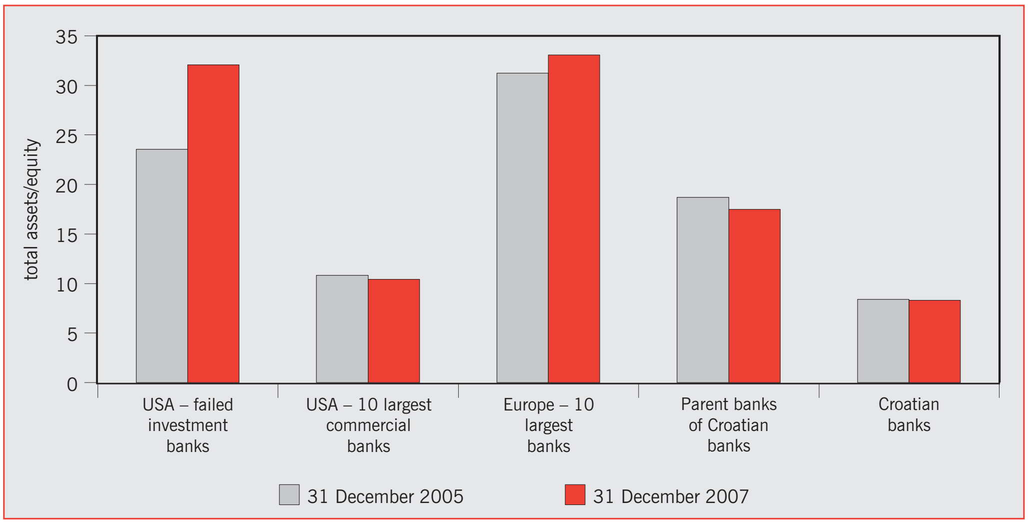
Nevertheless, the question remains as to how households would react in the event of a failure of a domestic bank or its foreign parent bank. To what extent would their behaviour derive from past experiences with bank failures in the late nineties? What would be the fate of single banks? For example, a failure of a bank or rumours about its possible failure might lead to deposit withdrawal from other banks or undermine the confidence in the entire banking system and lead to keeping money "under the mattress". On the other hand, households can put withdrawn deposits in another bank which enjoys their trust so that the banks perceived as reliable might experience deposit inflows and thus not only avoid the exposure to contagion, but even profit from other banks' failures. The third (and the least probable) case is that depositors fail to react to the failures of other banks.

There are several available ways to tackle the unpredictable behavioural factors, including the examination of historical bank failures in order to establish the impact of such events on the deposits in the rest of the banking system, and surveys of depositors. From a technical point of view, a simulation of the contagious bank run represents a simple modification of liquidity risk stress testing, that is, the observation of a bank's capability to compensate for a certain percentage of withdrawn deposits by its liquid assets. It is established that the coverage of deposits by liquid assets was higher than 35% at the end of 2007 in all banks in Croatia which means that these banks would be able to compensate for a relatively high percentage of withdrawn deposits.[34]

The materialisation of the fire sale risk is conditioned upon a high dependence of banks on the sources from the interbank market and, accordingly, upon the liquidity and the state of confidence (counterparty risk) in that market. The dependence on external funds for growth financing is typical of US investment banks and of large European banks. This is also presented in Figure 12, which shows the high financial leverage of the mentioned bank groups prior to the financial crisis, which more than four times exceeds the financial leverage of Croatian banks. The low financial leverage contributes to a reduced probability of the activation of the fire sale channel in the Croatian banking system. In addition, as a consequence of the *Decision on the minimum required amount of foreign currency claims*, Croatian banks either hold substantial portions of their assets in the accounts of banks abroad or have them invested in the treasury bills of countries with high credit ratings. Therefore, judging by the considerable share of foreign liquid assets, even if this channel was activated, it would not produce significant effects on the reduction of bank asset prices.

34 The high coverage of deposits by liquid assets is due to the CNB's *Decision on the minimum required amount of foreign currency claims*, whose initial aim was to increase banks' resilience to a potential deposit withdrawal. Specifically, due to the high euroisation of the Croatian financial system, which is reflected in the dominance of euro deposits, CNB explicitly regulates banks' foreign currency liquidity. It could also be expected that a bank run would be related to a drop in confidence in the domestic currency and that household kuna time deposits would be released and converted from the kuna into the euro.

Figure 12 Comparison of the Financial Leverage in Selected Banking Systems



Note: Data represent a simple arithmetic mean. The ratio for failed American investment banks includes Bearn Stearns, Lehman Brothers Holdings Inc. and Merrill Lynch & Co. Inc. The sample for Croatian parent banks consists of Erste Group Bank AG, Hypo Alpe Adria Bank International AG, Intesa Sanpaolo, OTP Bank Plc, Raiffeisen International Bank-Holding AG, Société Générale and Unicredit SPA.
Sources: BankScope, CNB and author's calculation.

A contagion channel which poses a potentially larger threat to the Croatian banks is the cross-border contagion channel. Specifically, there is a risk that foreign-owned domestic banks may be faced with the reduction or even cancellation of credit lines by their parent banks if they should encounter difficulties. It is hard to assess correctly the amount of threat posed by the possible activation of this channel. The literature offers two approaches to cross-border contagion.

The first approach is to conduct a descriptive analysis of the data on credit inflows into emerging economies from the banking systems of developed countries that submit data to the Bank for International Settlements. Some authors, e.g. Geršl (2007), calculate common lender indices, assessing which countries have the closest structure of common lenders, which then reveals the location of the risk of spillover of negative effects from one country to another through the common lender.

The second approach represents an assessment of the sensitivity of credit growth in a daughter bank to its specific indicators, specific indicators of its parent bank and some macroeconomic variables. This type of assessment is done by using panel regressions on financial statement indicators from the BankScope database. This approach is used by Derviz and Podpiera (2006), and Aydin (2008) follows in the similar vein, although the main purpose of his study is to define the main determinants of credit growth of banks in CEE countries. These research findings enable the establishment of indicators which to some degree might assess the threat posed by a possible reduction of credit inflows from parent banks to daughter banks. One of the shortcomings of this approach is that the dependent variable – the growth rate of credit in the daughter bank – does not necessarily provide a good approximation of trends in the inflows from the parent bank.

7 Conclusion

Building on the theoretical literature, which shows that the occurrence and spreading of bank contagion through the interbank market primarily depends on the structure and size of interbank exposures, this paper establishes that this structure most closely relates to the “money centre” structure, with six large banks representing these centres. In terms of size, the Croatian interbank market, as measured by the ratio of total exposures to banking system assets, is considerably smaller than those in West European countries. Due to small bilateral interbank exposures, which in none of the banks exceed the value of regulatory capital in the observed period (end of 2005-2007), the necessary condition for the materialisation of bank contagion due to an idiosyncratic failure according to the hard definition of insolvency is not fulfilled. This result differs from the findings of empirical studies in the West European countries, suggesting that such bank contagion is a possible, but highly improbable event.

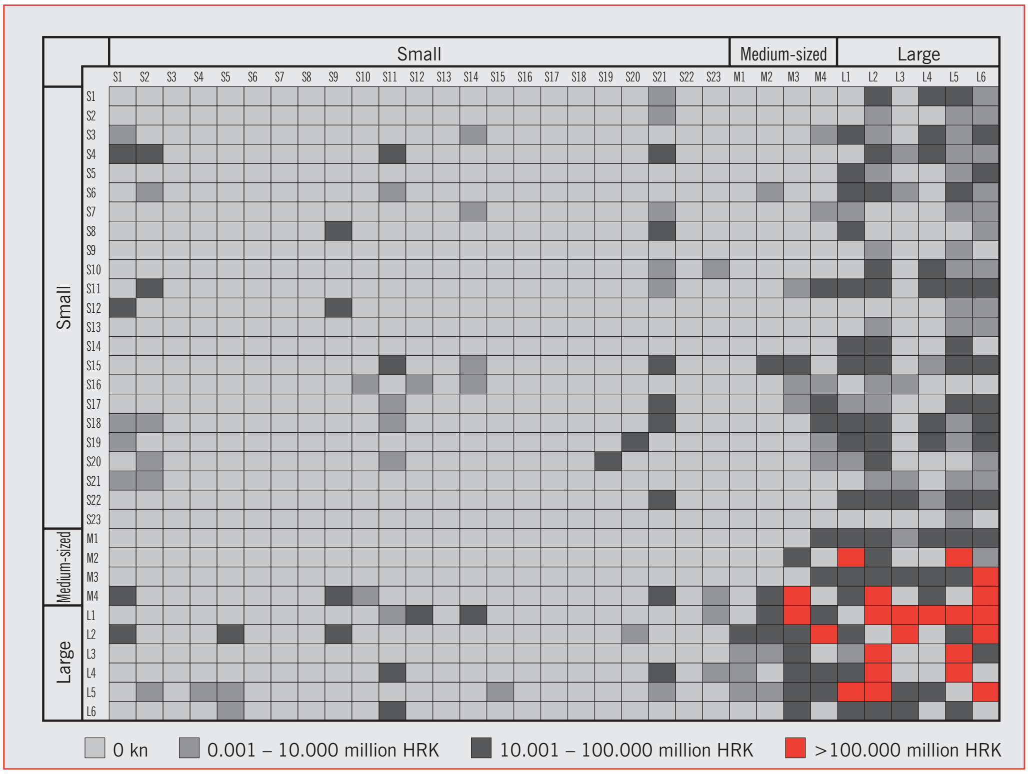
The same conclusion on the unlikelihood of the occurrence of bank contagion due to an idiosyncratic failure according to the hard definition of insolvency is reached when we observe Croatian banking system exposures to foreign banks, which five times exceed the size of the domestic interbank market. Even when the simulation is modified, the effect of idiosyncratic failures on the capital adequacy ratios observed and maximum loss rate assumed, the impacts of these failures appear relatively small. The lowest recorded CAR would at the end of 2007 amount to 6%, which means that not even the necessary condition for bank contagion under the soft definition of insolvency is satisfied, that is, in none of the exposed banks does the CAR drop below 4%. In addition, if an idiosyncratic failure materialised, the CAR would drop below the prescribed 10% in just a few banks, and mostly in those banks whose initial CARs were low. As regards the losses arising from interbank exposures, the loss generated by the worst idiosyncratic failure would amount to slightly below one percent of banking sector assets, which is considerably less than the losses that would be recorded in case of the most severe failures in Western European countries (up to 20% of banking sector assets).

It is shown that, although banking system exposures to foreign banks are considerably larger than those to domestic banks, which means that median losses in the cases of foreign bank failures would be much greater than in the cases of domestic bank failures, due to the comparability of the ratios of bilateral exposures to regulatory capital, these shocks would, on average, have only a slightly greater impact on banks’ capital adequacy ratios. The simulation of bank contagion due to a macroeconomic shock establishes the possibility of its materialisation, but only in highly improbable scenarios.

While it may be objected that the simulations used in this paper are based on non-realistic assumptions, especially with regard to neglect of the optimising behaviour of banks, so far they have been the most developed method for the assessment of the potential occurrence of banking system contagion. However, advances have been made in this area with sophisticated theoretical models which observe the interdependence of interbank market losses and deposit withdrawal (Iyer and Peydró-Alcalde, 2005) as well as the impact of such losses on fire sale (Cifuentes et al., 2005), which additionally contributes to losses through reduced asset prices. Extending simulations for these channels is very challenging and a success of this fusion would contribute to including the simulations of bank contagion into the standard toolkit of the institutions responsible for financial stability. Accordingly, in order to gain a better insight in the development of systemic risk, future research in this field in Croatia should also employ these new techniques.

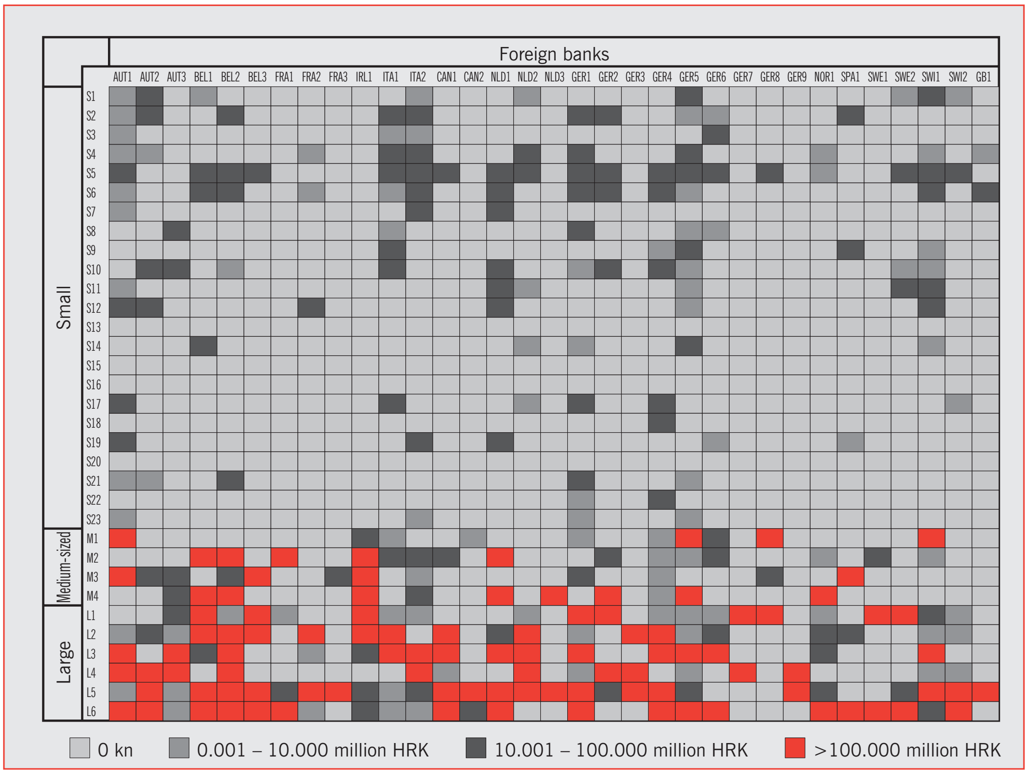
Appendix

Figure A Matrix of the Domestic Interbank Market, 31 December 2007



Note: The elements of the matrix represent the claims of a bank in a row against a bank in a column shown as the percentage of the regulatory capital of the bank in a row. Due to the obligation to maintain banking secrecy, the banks are represented by code names and not by their actual names. The sequence of banks is random.
Sources: CNB and author's calculation.

Figure B Matrix of Domestic Banks Exposures to Thirty-Three Major Foreign Banks, 31 December 2007



Note: The elements of the matrix represent the claims of a bank in a row (domestic) against a bank in a column (foreign). Due to the obligation to maintain banking secrecy, the banks are represented by code names and not by their actual names. The sequence of banks is random.
Izvori: HNB, izračun autora

Table A Croatian Banking System Exposures to Thirty-Three Major Foreign Banks (in million HRK)

RANK	31 December 2005		31 December 2006		31 December 2007	
1	Belgium 2	1,363.9	Italy 1	2,684.3	Ireland 1	1,920.0
2	Germany 1	1,252.2	Netherlands 1	1,470.4	Italy 1	1,865.4
3	Netherlands 1	1,232.8	Germany 1	1,467.1	Belgium 1	1,719.1
4	Ireland 1	1,177.2	Belgium 2	1,318.1	Belgium 2	1,631.1
5	Austria 1	1,022.7	Belgium 1	1,234.7	Belgium 3	1,357.9
6	Belgium 1	944.0	Canada 1	1,116.2	Netherlands 1	1,298.5
7	France 1	811.5	Ireland 1	1,073.7	Germany 1	1,253.7
8	Great Britain 3	791.4	France 1	815.5	Germany 2	1,164.7
9	Italy 1	717.1	Austria 2	776.4	Canada 1	1,156.8
10	Germany 4	648.4	Switzerland 1	653.0	Germany 3	1,149.3
11	Germany 2	640.1	Great Britain 1	644.2	Germany 4	1,120.6
12	United States 3	617.7	Germany 2	635.6	Netherlands 2	976.0
13	Switzerland 2	607.6	Netherlands 2	611.0	Austria 1	929.2
14	Belgium 3	588.0	Spain 1	559.1	Austria 2	804.8
15	Germany 5	540.1	Germany 3	552.3	Germany 5	699.0
16	Germany 12	516.3	United States 1	501.1	Sweden 1	685.0
17	Norway 1	510.3	Canada 2	469.7	Switzerland 1	679.9
18	United States 1	493.9	France 2	458.1	Austria 3	668.1
19	Germany 6	489.4	Denmark 1	454.7	France 1	655.8
20	Canada 1	485.8	United States 2	444.1	Norway 1	655.2
21	Sweden 1	466.2	Germany 5	423.0	Germany 6	639.5
22	Netherlands 3	453.7	Switzerland 3	382.4	Switzerland 2	629.4
23	Sweden 2	427.5	Switzerland 2	370.8	Italy 2	609.2
24	Italy 2	412.4	Germany 9	336.4	Netherlands 3	550.0
25	Switzerland 1	398.1	Netherlands 3	330.8	Sweden 2	539.2
26	Great Britain 2	392.5	Spain 2	330.6	Spain 1	491.9
27	France 2	389.2	Austria 1	328.2	Germany 7	479.5
28	Austria 2	385.5	United States 3	327.4	France 2	442.1
29	Austria 4	336.1	Germany 4	327.4	Canada 2	393.9
30	Switzerland 3	318.4	Great Britain 2	317.5	France 3	393.1
31	Denmark 1	296.2	Germany 10	294.3	Germany 8	384.9
32	Austria 5	296.0	Germany 11	292.6	Germany 9	376.3
33	Spain 1	262.7	Sweden 1	283.1	Great Britain 1	371.0
	Total	20,285.0	Total	22,283.9	Total	28,690.2

Note: At the end of 2005, the thirty-three major foreign banks accounted for 80% exposures to foreign banks, 76% at the end of 2006 and 79% at the end of 2007. Due to the obligation of banking secrecy, the banks are represented by code names and not by their actual names.
Sources: CNB and author's calculation.

Table B Impact of Domestic and Foreign Bank Idiosyncratic Failures on the CAR, 31 December 2005, $\Theta=100\%$

	Bank	Initial CAR	Domestic bank idiosyncratic failure				Foreign bank idiosyncratic failure			
			Minimum CAR	Median CAR	Average CAR	Number of CAR < 10%	Minimum CAR	Median CAR	Average CAR	Number of CAR < 10%
Small	S1	24.2	20.1	22.9	22.6	0	21.6	24.0	23.6	0
	S2	14.2	13.3	14.0	13.9	0	11.5	12.8	13.0	0
	S3	22.9	21.2	22.4	22.2	0	21.2	21.8	21.9	0
	S4	16.9	16.6	16.7	16.7	0	14.5	16.4	15.9	0
	S5	17.4	15.6	16.9	16.6	0	15.5	16.8	16.6	0
	S6	17.4	15.5	16.3	16.5	0	13.9	14.2	14.8	0
	S7	16.8	16.2	16.6	16.5	0	14.4	14.6	14.6	0
	S8	15.9	15.8	15.8	15.8	0	14.3	15.4	15.1	0
	S9	15.7	13.0	13.9	14.0	0	9.2	14.5	13.5	2
	S10	17.6	17.4	17.5	17.5	0	14.2	16.5	16.5	0
	S11	12.0	9.9	10.7	10.6	1	10.5	11.0	11.1	0
	S12	11.4	11.3	11.3	11.3	0	9.3	10.9	10.5	2
	S13	51.7	50.9	51.2	51.2	0	51.7	51.7	51.7	0
	S14	16.2	14.8	14.9	15.1	0	13.7	15.0	14.9	0
	S15	37.9	31.8	32.2	33.5	0	37.9	37.9	37.9	0
	S16	36.8	34.3	35.2	35.2	0	36.8	36.8	36.8	0
	S17	21.1	19.5	20.4	20.2	0	18.1	19.2	19.0	0
	S18	15.9	12.4	12.8	13.2	0	12.4	12.4	12.4	0
	S19	38.7	37.0	38.0	37.9	0	36.1	37.7	37.6	0
	S20	30.4	25.5	26.2	26.2	0	30.4	30.4	30.4	0
	S21	24.1	22.4	23.7	23.3	0	19.8	21.6	21.2	0
	S22	15.6	13.0	13.3	13.3	0	15.6	15.6	15.6	0
	S23	49.6	45.6	46.6	46.3	0	45.3	49.0	48.3	0
Medium-sized	M1	20.3	20.2	20.3	20.3	0	18.5	20.0	19.7	0
	M2	15.2	14.9	15.2	15.1	0	13.0	14.2	14.2	0
	M3	12.6	10.9	12.1	11.9	0	10.7	11.1	11.2	0
	M4	16.5	14.6	15.7	15.7	0	14.6	14.9	15.4	0
Large	L1	12.8	10.5	12.6	12.4	0	10.8	12.7	12.1	0
	L2	14.1	13.3	13.9	13.8	0	13.3	13.7	13.7	0
	L3	11.1	10.5	10.9	10.9	0	9.2	10.9	10.7	1
	L4	15.2	14.6	15.0	14.9	0	13.6	14.9	14.7	0
	L5	15.5	15.3	15.4	15.4	0	14.4	15.1	15.1	0
	L6	12.9	12.7	12.9	12.9	0	11.0	11.9	11.9	0

Note: Due to the obligation of banking secrecy, the banks are represented by code names and not by their actual names. The sequence of banks is random. The median and average CAR after idiosyncratic failures are calculated based exclusively on the sample of banks to which a bank is exposed.
Sources: CNB and author's calculation.

Table C Impact of Domestic and Foreign Bank Idiosyncratic Failures on the CAR, 31 December 2006, Θ=100%

	Bank	Initial CAR	Domestic bank idiosyncratic failure				Foreign bank idiosyncratic failure			
			Minimum CAR	Median CAR	Average CAR	Number of CAR < 10%	Minimum CAR	Median CAR	Average CAR	Number of CAR < 10%
Small	S1	18.0	14.4	17.6	17.0	0	15.2	17.4	17.0	0
	S2	18.2	17.4	17.9	17.8	0	16.4	16.7	17.0	0
	S3	19.1	16.1	18.1	17.8	0	17.6	18.4	18.4	0
	S4	13.9	12.0	13.7	13.4	0	12.2	12.6	12.9	0
	S5	14.4	13.4	14.0	13.9	0	12.9	13.7	13.6	0
	S6	12.0	10.7	11.6	11.4	0	9.6	10.8	10.8	3
	S7	18.9	18.4	18.6	18.6	0	16.8	16.9	16.9	0
	S8	12.6	11.5	12.6	12.1	0	10.6	11.1	11.4	0
	S9	16.2	15.7	15.9	15.9	0	12.4	13.4	13.4	0
	S10	12.7	12.4	12.6	12.5	0	11.2	12.0	11.8	0
	S11	10.6	8.3	9.1	9.2	8	8.8	9.5	9.7	4
	S12	10.3	9.2	9.6	9.7	3	7.9	9.8	9.2	3
	S13	45.7	45.7	45.7	45.7	0	45.4	45.4	45.4	0
	S14	17.6	17.3	17.4	17.4	0	14.6	17.3	16.8	0
	S15	35.3	29.9	30.4	31.6	0	35.3	35.3	35.3	0
	S16	29.7	26.7	27.6	28.1	0	29.7	29.7	29.7	0
	S17	17.2	16.0	16.6	16.5	0	14.0	15.6	15.4	0
	S18	12.5	10.5	11.0	11.1	0	12.1	12.1	12.1	0
	S19	25.7	24.9	25.2	25.2	0	23.0	24.8	24.6	0
	S20	18.5	12.3	15.1	14.4	0	18.5	18.5	18.5	0
	S21	14.3	12.1	13.6	13.3	0	12.2	12.2	12.4	0
	S22	13.7	11.3	11.5	11.8	0	11.6	11.8	11.8	0
	S23	32.1	30.7	30.7	30.7	0	27.3	29.0	29.1	0
Medium-sized	M1	14.2	14.0	14.2	14.1	0	12.5	13.3	13.4	0
	M2	12.0	10.9	11.8	11.6	0	9.7	11.2	10.9	3
	M3	14.4	13.5	13.7	13.8	0	13.3	13.7	13.7	0
	M4	11.4	10.2	11.2	11.0	0	10.0	10.1	10.6	0
Large	L1	13.5	12.2	13.5	13.3	0	12.4	13.5	13.1	0
	L2	16.0	15.5	16.0	16.0	0	12.2	15.8	15.7	0
	L3	12.2	12.1	12.2	12.2	0	11.4	12.2	12.0	0
	L4	12.6	12.0	12.6	12.5	0	11.1	12.4	12.2	0
	L5	13.9	13.9	13.9	13.9	0	13.0	13.7	13.6	0
	L6	13.3	12.8	13.2	13.2	0	11.9	12.7	12.8	0

Note: Due to the obligation of banking secrecy, the banks are represented by code names and not by their actual names. The sequence of banks is random. The median and average CAR after idiosyncratic failures are calculated based exclusively on the sample of banks to which a bank is exposed.
Sources: CNB and author's calculation.

Table D Impact of Domestic and Foreign Bank Idiosyncratic Failures on the CAR, 31 December 2007, Θ=100%

	Bank	Initial CAR	Domestic bank idiosyncratic failure				Foreign bank idiosyncratic failure			
			Minimum CAR	Median CAR	Average CAR	Number of CAR < 10%	Minimum CAR	Median CAR	Average CAR	Number of CAR < 10%
Small	S1	15.5	12.2	13.0	13.5	0	12.9	15.4	14.8	0
	S2	13.2	13.2	13.2	13.2	0	11.4	12.4	12.3	0
	S3	19.6	15.7	18.6	18.0	0	16.1	19.0	18.4	0
	S4	16.1	12.5	14.6	14.8	0	14.6	15.8	15.6	0
	S5	12.7	11.8	12.1	12.2	0	10.9	11.6	11.6	0
	S6	10.1	8.9	9.7	9.6	5	7.7	8.8	8.8	12
	S7	18.3	16.9	18.2	18.0	0	16.1	16.2	16.7	0
	S8	10.5	8.5	9.5	9.5	3	8.3	9.8	9.4	3
	S9	15.7	15.4	15.5	15.5	0	13.6	14.0	14.4	0
	S10	11.7	9.7	11.3	10.9	2	9.1	10.9	10.8	1
	S11	10.1	7.9	9.1	9.0	9	7.9	9.7	9.3	4
	S12	10.1	9.1	9.6	9.6	2	8.0	8.2	8.4	6
	S13	45.8	43.4	43.7	44.2	0	45.8	45.8	17.5	0
	S14	16.3	14.7	14.7	14.7	0	13.8	16.1	15.5	0
	S15	33.2	23.0	28.6	28.5	0	33.2	33.2	17.5	0
	S16	32.3	29.2	31.0	30.9	0	32.3	32.3	17.5	0
	S17	17.7	15.8	16.9	16.9	0	14.5	16.0	16.0	0
	S18	18.5	16.0	17.2	17.1	0	15.7	15.7	15.7	0
	S19	24.9	22.1	23.9	23.8	0	23.3	24.1	24.2	0
	S20	17.5	6.2	15.1	13.7	1	17.5	17.5	17.5	0
	S21	19.9	19.3	19.6	19.6	0	18.3	19.1	19.0	0
	S22	17.5	14.8	16.1	16.0	0	15.5	16.2	16.2	0
	S23	33.5	32.6	32.6	32.6	0	33.1	33.2	33.2	0
Medium-sized	M1	23.6	23.2	23.3	23.4	0	22.0	23.0	22.9	0
	M2	10.7	9.2	10.3	10.1	2	8.9	9.8	9.9	9
	M3	27.8	26.5	27.1	27.1	0	26.0	27.2	27.0	0
	M4	10.4	7.9	10.1	9.8	5	9.0	9.1	9.5	8
Large	L1	10.8	9.9	10.5	10.5	1	9.8	10.6	10.4	5
	L2	15.3	14.9	15.2	15.2	0	12.3	15.1	14.7	0
	L3	11.7	11.1	11.6	11.4	0	10.5	11.0	11.0	0
	L4	19.3	18.6	19.1	19.0	0	17.7	18.8	18.8	0
	L5	17.9	17.7	17.9	17.8	0	17.1	17.7	17.6	0
	L6	12.3	12.1	12.2	12.2	0	11.2	11.7	11.7	0

Note: Due to the obligation of banking secrecy, the banks are represented by code names and not by their actual names. The sequence of banks is random. The median and average CAR after idiosyncratic failures are calculated based exclusively on the sample of banks to which a bank is exposed.
Sources: CNB and author's calculation.

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