Interbank Exposures:
An Empirical Examination of Systemic Risk in the Belgian Banking System

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First draft: January 2004
This draft: August 2004

Abstract

Robust (cross-border) interbank markets are important for the well functioning of modern financial systems. Yet, a network of interbank exposures may lead to domino effects following the event of an initial bank failure. The "structure" of the interbank market is a potentially important driving factor in the risk and impact of interbank contagion. We investigate the evolution of contagion risk for the Belgian banking system over the period 1993-2002 using detailed information on aggregate interbank exposures of individual banks and on large bilateral interbank exposures. We find that a change from a complete structure (where all banks have symmetric links) towards a "multiple money centre" structure (where the money centres are symmetrically linked to some banks, which are themselves not linked together) as well as a more concentrated banking market have decreased the risk and impact of contagion. Moreover, an increase in the proportion of cross-border interbank assets has lowered the risk and impact of local contagion. Yet, this reduction was probably accompanied by an increase in contagion risk arising from foreign banks, although even here the contagion risk appears fairly limited.

JEL codes: G20, G15

Keywords: Interbank markets, financial stability, financial integration, contagion

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We thank Mathias Dewatripont, Philipp Hartmann, Dirk Heremans, Alfred Lehar, Yaron Leitner, Peter Praet, Andrea Schretler, Thierry Timmermans, Kostas Tsatsaronis, Christian Upper, Mark Van Achter, Quentin Wibaut, Gunther Wuyts, the members of the Research and Analysis Group of the International Cooperation & Financial Stability Department at the NBB, and the participants at the IfW-SUERF workshop on "Banking Risks in International Markets", the SMYE 2004, the Symposium of the ECB-CFS Research Network on "Capital Markets and Financial Integration in Europe", the FIRS conference on "Banking, Insurance and Intermediation" and the ECB workshop on "Financial Stability" for providing helpful discussions and comments. We especially thank Janet Mitchell for her detailed guidance and invaluable suggestions. The views expressed in this paper are those of the authors and do not necessarily reflect the views of the National Bank of Belgium. The first author acknowledges financial assistance from FWO-Flanders.

1. Introduction

Events like the terrorist attacks of September 11, 2001 and Russia's default on its sovereign bonds leading to the near collapse of Long-Term Capital Management in 1998, have rekindled interest in the functioning of interbank markets (for an early analysis, see Mc Andrews and Potter (2002) and Furfine (2002), respectively). Market participants have an interest in a well functioning and robust interbank market. Central banks use the interbank market to implement the interest rate reflecting the stance of monetary policy. Moreover, at the micro-economic level, financial institutions reallocate liquidity through interbank markets from institutions with a cash surplus to those with a cash deficit. At the macro-economic level, interbank markets strengthen financial integration but they also increase linkages and common exposures to risks within the banking sector. As a consequence, these markets represent an important channel of contagion through which problems affecting one bank or one country may spread to other banks or other countries.

This paper empirically addresses the implications of domestic and cross-border interbank linkages for financial stability. The main objective is to evaluate the risk that a chain reaction in the interbank market – i.e., a situation where the failure of one bank would lead to the default of one or more of its interbank creditors – could create wider systemic risk. Furthermore, we want to investigate the relevance of the interbank market structure for interbank contagion risk.

Our empirical analysis considers the stability of the Belgian financial system. The Belgian financial system is an interesting case. Indeed, the Belgian interbank market[1] is very international and the Belgian banking sector underwent a period of consolidation in the years 1998-2001. Moreover, the structure of the Belgian interbank market has changed over time: it has moved from a "complete" structure (where all banks have symmetric links) towards a "multiple money centres" structure (where the centres are symmetrically linked to some banks without these banks being linked together). These observations raise several interesting questions, which are also relevant for the analysis of the stability of financial systems in other countries. How have consolidation and internationalisation affected the interbank market? How important is the actual interbank market structure in explaining interbank contagion risk? To what extent could the failure of banks in another European country affect Belgian banks through cross-border interbank exposures? How has interbank contagion risk evolved over time? How does the assessment of contagion risk in Belgium compare with assessments in other countries?

[1] By Belgian interbank market, we refer here to the set of interbank exposures where at least one of the counterparts is a bank incorporated in Belgium.

Understanding the potential consequences of the failure of one (foreign or domestic) bank might have on other domestic banks is an important aspect of financial stability.[2] We undertake a stylised, mechanical exercise – resembling a stress test – to examine the potential for interbank contagion to occur in Belgium. Namely, we simulate the consequences of non-repayment of interbank loans of a given bank on the capital of its bank lenders (and any further domino-like effects from the latter banks). In order to isolate contagion, we assume that the initial default is caused by a sudden, unexpected and idiosyncratic shock. This kind of shock, which is not totally unlikely (examples are the failure of Barings in the United Kingdom, Drexel Burnham Lambert in the U.S., Bank Van Loo or Bank Max Fischer in Belgium) may trigger a systemic crisis. For instance, worries of systemic crisis and domino effects justified the bail-out of Continental Illinois.[3] Simulations are based on an estimated matrix of bilateral exposures. We assume that no adjustments have been made in interbank exposures to the failing banks. This assumption implies clear limitations; for example, it rules out preventive measures that might be taken by regulators or individual banks, such as timely reduction of exposures to the failing bank. More generally, the assumption excludes any behavioural changes (which could also include bank panics) arising from market expectations about failing banks. We will address these issues in a sensitivity analysis where we relax different starting points of the baseline model. In particular, the impact of banks' expectations, a too-big-to-fail policy, banks' co-ordination, multiple failures, and netting of exposures are investigated.

In the analysis below we distinguish between potential contagion risk initiated by the failure of a Belgian bank versus potential contagion risk from abroad, i.e. implied by the failure of a foreign bank. The increase in international financial integration implies a shift towards a continued reliance on cross-border interbank flows. The question of potential contagion risk from abroad therefore deserves an in-depth analysis. We also investigate how the risk of contagion associated with the failure of a Belgian bank has evolved over time. In addition, we test the sensitivity of our results to several values of Loss Given Default ("LGD"), which allows us to partially take into account the moderation of interbank contagion risk arising from the increasing use of risk mitigation techniques, such as collateralised interbank loans or repurchase agreements (repos).

Our empirical analysis shows that the risk of contagion due to domestic interbank defaults has decreased over the past decade and is currently very low. For example, for a LGD of 100% and in the worst-case scenario, banks representing less than five percent of total balance sheet assets – excluding the assets of the first-domino – would be affected by contagion. Our results reveal that the interbank market structure is important in explaining our contagion measures over time. In

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[2] Especially as banking crises and bank failures may take place. Lindgren, Garcia and Saal (1996) offer an overview of the impact of recent banking crises.

[3] The Federal Reserve decided immediately to step in. Later, Volcker, the Chairman of the Federal Reserve, was asked why he acted so rapidly and aggressively. "Simply," he said, "As if we had not stepped in, the ultimate domino effect that so many people have feared for so long, would have occurred and wiped out the Western financial system."

particular, we find that both a move from a complete structure towards a "multiple money centres" structure and a more concentrated banking market decrease the risk and impact of contagion. Moreover, an increase in the proportion of cross-border interbank assets decreases the risk and impact of local contagion. This, however, suggests that the potential contagion risk stemming from foreign interbank exposures[4] has gained importance. According to our simulations, the failure of some foreign banks could have a sizeable effect on Belgian banks' assets. However, the foreign banks whose interbank defaults have significant effects in our simulations are all internationally recognised and have high investment grade ratings. Thus, in reality, these banks are unlikely to default. Moreover, our simulations indicate that cross-border interbank defaults have a major effect on the Belgian financial system only for high values of LGDs. Belgian banks currently maintain relatively high proportions of secured interbank exposures, which tend to lower LGDs.

Our simulations add to the literature studying contagion following from a network of interbank linkages in three respects. First, we present empirical evidence that the interbank market structure is a crucial explanatory factor of interbank contagion risk. To our knowledge, it is the first paper that formally tests for the impact of market structure on contagion risk. Second, we point out that it is important to take into account the time-variation of interbank exposures. Third, we analyse the importance of international financial integration by looking at the source of an initial failure, i.e. domestic versus international.

The rest of the paper is organised as follows. Section 2 provides a literature review of the link between interbank markets and contagion risk. Section 3 introduces the data set and highlights the important features of the Belgian interbank market that might have a bearing on contagion risk. Section 4 presents and discusses the results of the simulation exercise as well as the regression results of the impact of the (inter)bank market structure on our contagion measures. In section 5, we report additional sensitivity tests. Section 6 concludes.

2. Literature Review

2.1. Contagion risk

Contagion on interbank markets can occur in at least three types of situations: (i) when aggregate liquidity is insufficient, (ii) when market expectations create "spillovers" and (iii) when the collapse of a bank induces a domino effect. We successively examine these three situations in more detail.

In the aggregate, the interbank market only redistributes liquidity across banks; it does not create liquidity. A lack of aggregate liquidity could occur, for instance, if banks have excessive confidence in the ability of interbank markets to absorb transitory liquidity shocks, so that they under-invest in liquid assets (Bhattacharya and Gale (1987)).[5] Interbank exposures may create problems if aggregate liquidity provision is insufficient. In this case, banks try to avoid liquidation of their long-term assets, and therefore liquidate their claims on other banks (possibly in other regions). A financial crisis in one region could then spread by contagion to other regions and thereby introduce liquidity problems in the latter (Allen and Gale (2000)). Without the interlinkages between banks operating in different regions, the financial crisis would not spread between regions.

"Spillovers" through market expectations represent a second potential channel for contagion. For example, bank runs may occur when depositors observe other customers withdrawing their funds from the bank. The depositors not facing liquidity shocks may then decide to withdraw too, in the fear that they will ultimately be unable to recover their deposits (especially if banks must begin liquidating illiquid long-term assets in order to meet the high liquidity demand). These beliefs then become self-fulfilling (see Diamond and Dybvig (1983)).[6] Other forms of market spillover include withdrawals by depositors from (or unwillingness by other banks to provide liquidity to) a bank engaging in similar activities as those of a failing bank. Financial contagion may also occur across bank types. For example, the failure of a bank investing in certain assets could cause investors to infer that "similar" banks will get into trouble. Of course, regulatory intervention such as suspension of convertibility or deposit insurance may alleviate the problem of bank runs and banking panics (for an overview see Freixas and Rochet (1997)).

A third source of contagion is the domino effect itself. The failure of one individual bank may initiate a domino effect if the non-repayment of interbank obligations by the failing bank jeopardises the ability of its creditor banks to meet their obligations to their (interbank) creditors. Contagion occurs then "mechanically" through the direct interlinkages between banks. Domino effects arise across regions or bank types, depending on the interlinkages. Our paper mainly focuses on this specific source of contagion.

2.2. Factors influencing the level of contagion risk

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[4] Interbank exposures between Belgian banks have dropped from 30 percent in 1993 to only 15 percent in 2002 of total Belgian interbank exposures.

[5] In practice, however, central banks play a key role in preventing liquidity shortages. See also subsection 2.2.3.

[6] Bank runs may also occur in the interbank market when banks withdraw their interbank deposits following other withdrawals.

The extent to which a crisis could propagate depends on several institutional features. We provide examples of this at three levels: (i) the bank level, (ii) the interbank market level, and (iii) the authority/supervisory level.

2.2.1. The bank level

Risk mitigation techniques, such as collateralised interbank loans (e.g. repos) reduce the risks of contagion. The existence of a repo market may lead, however, to the disappearance of the uninsured international interbank market (Freixas and Holthausen (2001)). This can occur as a result of asymmetric information; a bank that attempts to obtain an unsecured cross-border loan may be suspected of having had the loan denied by other domestic banks which have more information about the borrower. *Netting agreements* between banks – i.e. agreements to take account of net exposures only – are another institutional feature at the bank level to control interbank exposures. A problem at one bank is then less likely to initiate a "domino effect" on the interbank market. Emmons (1995), however, shows that netting of interbank claims shifts the bank default risk away from interbank claimants towards non-bank creditors, i.e. the risk is transferred to the banks' creditors who are not included in the netting agreement.

2.2.2. The interbank market level

A first important factor determining the degree of contagion is the *structure of interbank linkages*. This structure can take different forms. Allen and Gale (2000) distinguish three interbank market structures: the complete structure where banks are symmetrically linked to all other banks of the system, the incomplete market structure where banks are only linked to neighbouring banks, and the disconnected incomplete market structure where two disconnected markets coexist. They show that complete structures are less prone to contagion than incomplete market structures, since with complete structures, the impact of a financial crisis in one region is absorbed by a large number of regions. Freixas et al. (2000) add a fourth structure: the money centre. In this structure, the money centre is symmetrically linked to other banks of the system, which are themselves not linked together. They show that, in some cases, the failure of a bank linked to the money centre will not trigger the failure of the money centre, but the failure of the money centre itself may trigger failures of the linked banks. Figure 1 presents examples of matrices of bilateral exposures[7] representing a simplified 4-bank system and summarises one potential outcome for each of the four characterised structures. In the complete market structure, each cell of the matrix of bilateral exposures (except the diagonal) should be positive. In the incomplete structure, the matrix of bilateral exposures is filled in with zeros except positions between neighbouring banks. In a matrix representing a

[7] The matrix of bilateral exposures summarises all the interbank loans (rows) and deposits (columns) existing between the banks of the system.

disconnected structure, the cells reporting the positions between two banks belonging to two different markets, as well as the diagonal, should be equal to zero. Finally, the matrix of bilateral exposures of a money centre is filled with zeros except the column and the row of the bank at the centre.

A second factor at the interbank market level, however linked to the previous one, is *banking market concentration*. Economic theory does not provide an unambiguous response to the question of the impact of increasing concentration in banking markets on the stability of interbank markets, although some authors do find that such a trade-off exists in certain circumstances.[8]

2.2.3. The regulatory / supervisory level

Several regulatory initiatives have been taken to decrease the risk of (cross-border) financial contagion. For instance, *limits to large exposures* imposed by authorities on banks[9] contribute to reducing contagion risk. The *use of cross-border financial collateral* in the European Union has been facilitated by the Financial Collateral Directive, adopted by the European Parliament and the Council in 2002.[10] Banking supervisory authorities and the central banks of the European Union have furthermore recently agreed on a *Memorandum of Understanding on high-level principles of co-operation in crisis management situations.*[11]

Potential *central bank intervention*, as well as the presence of safety nets, also lowers contagion risk. Central banks may decide to provide liquidity to the market as a whole when aggregate liquidity is insufficient, or directly to individual banks when the market fails to provide liquidity to

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[8] For an overview of these issues see e.g. Carletti and Hartmann (2002). Carletti et al. (2002) examine the effects of bank mergers on reserve management and on interbank market liquidity. They argue that the probability of the banking system experiencing a liquidity shortage following a merger hinges on several factors, including the cost of refinancing on the interbank market relative to the cost of raising deposits and the structure of the post-merger liquidity shocks to banks. Allen and Gale (2004) show that contagion is less likely to occur in imperfect competition than in a perfectly competitive interbank market. However, concentration increases the probability of a "too-big-to-fail" type of intervention in a crisis, which may stimulate ex ante risk-taking behaviour on the part of large banks and increase the impact of a crisis. Moreover, in the absence of a too-big-to-fail type of intervention, the severity of contagion may be reinforced by a high degree of concentration.

[9] See e.g. Directive 2000/12/CE of the European Parliament and the Council relating to the taking up and the pursuit of the business of credit institutions for financial institutions incorporated in Europe and earlier the Directive 92/121/EEC on the monitoring and control of large exposures of credit institutions. Limits are formulated in terms of banks' own funds. The EU Directive states that a bank's maximum exposure to a single counterparty may not exceed 25 % of regulatory own funds, and the cumulative amount of individual exposures exceeding 10 % of regulatory own funds may not exceed 800 % of those own funds. The Directive, however, allows for some exceptions.

[10] Directive 2002/47/EC of the European Parliament and the Council of 6 June 2002 on Financial Collateral Arrangements. The directive aims at encouraging the cross-border use of financial collateral, mainly by eliminating legal uncertainty concerning the use of collateral and by providing a uniform regime for banks with regard to the taking of financial collateral. This could further stimulate the cross-border integration of interbank markets. See e.g. National Bank of Belgium (2002)

[11] See ECB Press Release, 10 March 2003. With the adoption of this memorandum, the authorities have expressed their commitment to co-operate to ensure the stability of the financial system at the EU level. This agreement enhances the practical arrangements for handling banking crises in order to facilitate an early assessment of the systemic risk of a crisis.

sound financial institutions. Moreover, although interbank exposures are not explicitly covered by deposit insurance, issues such as "too-big-to-fail" may introduce implicit deposit insurance for these exposures.

2.3. Empirical evidence

Two empirical approaches are implemented to measure contagion, each having their strengths and weaknesses. A first approach tries to isolate contagion from other shocks affecting the economy. Therefore, it simulates the consequences of an individual bank failure given observed or estimated interbank exposures and looks at the potential domino effects, i.e. first round and potential further round effects. This is the approach we take in this paper. Sheldon and Maurer (1998) apply this approach to study the issue of systemic risk in the Swiss interbank market. They conclude that the potential of contagion arising from interbank linkages in Switzerland is quite low although the failure of a large Swiss bank would have serious implications. The results of Upper and Worms (2002), using this technique for the German interbank market, suggest that contagion risk in Germany is not always confined to a limited number of small banks. Indeed, they conclude that a bank failure can trigger contagion in a sizeable part of the German banking system, although safety nets considerably reduce this risk. In a similar study for the UK, Wells (2002) finds that contagion would only occur following the failure of some large UK banks, which generally have a high credit rating. Furfine (2003), using data on bilateral exposures stemming from overnight U.S. federal funds transactions, finds that multiple rounds of failures are unlikely, and that aggregate assets at failing banks never exceed 1% of total assets of the commercial banks. Finally, Cifuentes (2003), simulating the risk of contagion in the Chilean banking system finds that the risk of contagion is higher in concentrated systems.

A second approach to estimate contagion risk takes account of a larger variety of shocks. Elsinger et al. (2002) simulate the joint impact of interest rate shocks, exchange rate shocks, and stock market movements on interbank payment flows of Austrian banks. These states of the world determine the net value of the bank and the feasibility of interbank payments. They distinguish between insolvency due to correlated exposures and due to domino effects. Their simulations indicate that although the probability of contagious default is low compared to the total default probability, there are situations in which up to 75% of the defaults are due to contagion.[12] Lehar (2003) looks at correlations between bank portfolios. He estimates these correlations and uses them to compute different measures of systemic risk. Gropp and Vesala (2003) use the tail properties of distance to default to study contagion risk. They find the presence of both domestic and cross-border contagion within Europe, although domestic seem to prevail over cross-border. Müeller (2003) combines a network and a simulation approach, to assess the risk of contagion in the Swiss

[12] Elsinger et al. (2002) also use their simulation to compare two generated matrices of bilateral exposures representing a complete and an incomplete structure. They find more contagion when they use a complete market structure.

interbank market and takes account of credit and liquidity effects in bank contagion. The advantage of this second line of research is that it allows for heterogeneity in individual bank failure probabilities and takes into account a system wide view. However, as we want to focus on contagion risk and perform a stress test, starting from an individual failure may yield more insights in the evolution of risk over time, in the propagation mechanism and ultimate consequences of contagion risk. In addition, some of these techniques use market data but time-series of market data for Belgian banks are limited. Indeed, few Belgian banks are listed and the listed banks underwent merger processes.

3. Description of the data

The data come from a confidential database (*Schéma A*) containing banks' balance-sheet statements and a set of financial information collected for prudential supervision purpose. This database provides valuable information with respect to interbank positions:

- at an aggregate level, each bank reports monthly its total interbank loans and deposits and provides breakdowns of these "aggregate positions" according to the type of loan or deposit, the geographical origin of the lender or the borrower[13] and the residual maturity of interbank loans or deposits. The aggregate positions used in this paper cover a period ranging from December 1992 to December 2002.

- at an individual bank level, banks report their "large exposures"[14] to single obligors, including their interbank exposures. Time-series of large exposures are however not available.[15] We use a cross section of data on large exposures to banks for December 2002. Belgian banks reported 109 large exposures to domestic banks and 226 large exposures to foreign banks (Table 1). These exposures accounted for a total value of € 126 billion. On average, the value of a domestic large exposure is lower than the value of a foreign large exposure. Banks reported large exposures amounting to 79.5% of the domestic interbank loans and to 70.1% of the foreign interbank loans.

Except where otherwise stated, figures are reported on a company basis, i.e. they include banks incorporated in Belgium (i.e. Belgian banks and Belgian subsidiaries of foreign banks) as well as their foreign branches, and consequently exclude Belgian branches of foreign banks or foreign subsidiaries of Belgian banks. On a company basis, the Belgian banking system, at the end of 2002, comprises 65 banks representing total assets of € 792 billion. The banking system is characterised

[13] i.e. Belgium, one of the other European Union members or the rest of the world.
[14] i.e. exposures exceeding 10 % of their own funds
[15] Reliable data on large exposures are only available from Q3-2002 onwards.

by a high degree of concentration since the four largest banks account for 85 % of total assets of Belgian banks. This concentration results from several mergers over the period 1998-2001 and from an overall decrease in the number of banks.[16]

The interbank market evolution in Belgium was partly determined by an overall evolution of money markets in Europe over the last decade. The establishment of the Economic and Monetary Union (EMU) changed radically the European financial landscape and allowed a greater market integration. Baele et al. (2004) find that the euro area money markets have reached a very advanced level of integration. This "near-perfect" integration fostered a higher internationalisation of interbank transactions, also observable in the Belgian data. In addition, the launch of the EMU in Europe required efficient cross-border payment systems. To this end, the implementation of Target[17], in 1997, facilitated the integration of European money markets and the setting-up of international bank relationships. In Belgium, the entry point to Target is the real-time gross settlement system Ellips.[18] Ellips is structured in two tiers, with direct-participants and indirect participants.[19] Direct participants must have an account with the central bank. At the end of 2002, there are 17 direct participants and 76 indirect participants. In our data set, accounts that direct participants must have with the central bank are not considered as interbank exposures. On the other hand, accounts between participants and sub-participants are considered as interbank exposures. One might expect that the two-tier structure and design of payment systems and the subsequent access to international payment systems, potentially influences the developments of interbank markets and the structure of the resulting interbank linkages.

As shown in Table 2, the interbank loans of Belgian banks represent a gross exposure of € 176 billion at the end of 2002 while interbank deposits amount to € 228 billion. Over the period considered, interbank loans always account for 20 to 30 % of total assets of Belgian banks and interbank deposits for 29 to 35 % of their total liabilities (Table 3).[20]

Interbank loans and deposits present similar structures. On both sides of the balance sheet, term and secured loans/deposits represent the larger portions of interbank positions (Table 2). The current level of secured loans is the consequence of a shift in the strategy of Belgian banks in the beginning of the 1990's, probably nurtured by the monetary policy reform in Belgium in 1991 which fostered the use of repos between Belgian banks (Table 3).[21]

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[16] On a company basis, the number of banks decreased by 47 banks, from 112 in 1992 to 65 in 2002.

[17] Trans-European Automated Real-time Gross settlement Express Transfer system.

[18] ELectronic Large value Interbank Payment System.

[19] Payment orders of an indirect participant are exchanged through its direct participant.

[20] These figures are in line with EMU averages although one can observe huge differences between some countries.

[21] We may expect the use of secured loans by Belgian banks to be further stimulated by the EU directive on Financial Collateral.

Another noteworthy characteristic of interbank positions of Belgian banks is their very high degree of internationalisation (Table 2 and Table 3). Belgium is a particularly open economy and so is its interbank market. Actually, at the end of 2002, less than 15 % of interbank exposures of Belgian banks were to other Belgian banks. These very high level of internationalisation point to a potential origin of the risk of contagion: given that the lion's share of the interbank exposure is situated abroad, Belgian banks might be more sensitive to international bank failures than to domestic ones. Manna (2004) reports that the share of interbank deposits traded within the euro-area on a cross border basis increased from 20.6% in 1998 to 25.2% in 2002. Countries with very large domestic markets exhibit smaller share of cross-border activity.[22] With that respect, Belgium, with its very high level of internationalisation could be a good indicator of the future evolution of national money markets and interbank linkages in other European countries if market integration further progresses.

As shown in Table 4, interbank positions of Belgian banks are mostly short-term. Less than 5 % of the exposures are longer than one year and only about 24 % of interbank loans have a maturity exceeding 3 months.

4. Empirical analysis of systemic risk on the Belgian interbank market

4.1. Overview of the methodology

The methodology, based on Upper and Worms (2002), aims at assessing the impact on the Belgian financial system of the sudden and unexpected default of each banking counterpart of Belgian banks. The test of contagion uses a (N x (N+M)) matrix of interbank bilateral exposures, X, to study the propagation mechanisms of crises. The matrix of bilateral exposures summarises the interbank exposures of Belgian banks towards the other (N-1) Belgian banks and the M foreign banks:

$$X = \left[\begin{array}{ccccc|ccc} x_{1,1} & \cdots & x_{1,j} & \cdots & x_{1,N} & w_{1,N+1} & \cdots & w_{1,M} \\ \vdots & \ddots & \vdots & \iddots & \vdots & \vdots & & \vdots \\ x_{i,1} & \cdots & x_{i,j} & \cdots & x_{i,N} & \vdots & & \vdots \\ \vdots & \iddots & \vdots & \ddots & \vdots & \vdots & & \vdots \\ x_{N,1} & \cdots & x_{N,j} & \cdots & x_{N,N} & w_{N,N+1} & \cdots & w_{N,M} \end{array}\right]$$

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[22] Manna (2004) reports that in 2002, the share of cross-border interbank deposits amounts to approximately 15% in France, Germany and Finland, to 30% in Italy, Spain and the Netherlands and exceeds 50% in Belgium and Portugal.

with $\sum_{j=1}^{N} x_{ij} = a_i$; $\sum_{i=1}^{N} x_{ij} = l_j$ and $\sum_{j=N+1}^{M} w_{ij} = fa_i$

where x_{ij} represents the gross exposure of the Belgian bank i to the Belgian bank j, w_{ij} represents the gross exposure of the Belgian bank i to the foreign bank j, a_i represents the domestic interbank assets of bank i, l_j represents the domestic interbank liabilities of bank j and fa_i represents the foreign interbank assets of bank i.

The simulations successively study the impact of the failure of each of the N Belgian banks and each of the M foreign banks for a given loss given default (LGD). The initial failure is assumed to cause an additional failure when the exposure of one bank to failed banks is large enough to offset its Tier-I capital. More specifically, bank i fails subsequently to other failures when

$$C_i - \sum_{j=1}^{N} \lambda_j \theta x_{ij} - \sum_{j=N+1}^{M} \lambda_j \theta w_{ij} \prec 0$$

where C_i refers to the tier-I capital of bank i, θ refers to the LGD and λ_j is a dummy variable equal to 1 if bank j fails and 0 otherwise. The LGD is assumed to be constant and identical for all failed banks. We assume that in the event of bankruptcy, there is no netting so we use gross exposures x_{ij} and w_{ij} rather than net exposures (x_{ij} - x_{ji}). The initial default may cause several rounds of failures when the combined effects of the failed banks trigger new failures at each round. The contagion stops when banks that failed during the last round do not cause any additional failures, i.e. when the system is again stable.

The matrix of bilateral exposures is unknown and hence, must be estimated. We employ three estimation procedures. Each of them is based on different data on interbank exposures (i.e. data at an aggregate level or at an individual bank level). The first one (hereafter called *large exposures technique*) consists of using the matrix of bilateral exposures based on large exposures only. The second one (hereafter called *aggregate exposures technique*) consists of using the information contained in the aggregates a_i and l_j and making an assumption on how they are distributed in the matrix. The third technique (hereafter called *mixed technique*) combines both of the previous data sources. We now provide details on each of the three alternatives.

Banks are required to report their large interbank exposures (i.e. exposures to single counterparties exceeding 10 % of own funds). This kind of information allows us to fill in several cells in the matrix of bilateral exposures but not to reconstruct the full matrix, since smaller exposures are omitted. The latter are probably less significant in terms of contagion risk. The large exposure data do not require any additional assumptions on the distribution of bilateral exposures, and they include exposures to foreign banks.

The aggregate exposures technique is based on the observed aggregates a_i and l_j, which only provide incomplete information on interbank exposures of Belgian banks to Belgian banks, i.e. the column and row sums of the matrix X, i.e. the marginal distribution of the x_{ij}. Since this information is partial, we need to make an assumption on the distribution of the individual interbank exposures. Following other papers[23], we assume that banks seek to maximise the dispersion of their interbank activities. With the appropriate standardisation, this would be equivalent to assuming a matrix X^0 such that $x_{ij} = a_i l_j$. However, such a distribution would neglect an important feature of the interbank market which is that banks do not have interbank exposures to themselves, so we have to add the constraint that $x_{ij} = 0$ for each i=j.

The constrained matrix of bilateral exposures should, however, stay as close as possible to X^0. Technically, this is equivalent to minimising the distance function (DF) (measured by the relative entropy) between X^0 and the constrained matrix.[24] This is done by solving the following problem:

$$\min \sum_{i=1}^{N} \sum_{j=1}^{N} x_{ij} \ln\left(\frac{x_{ij}}{x_{ij}^0}\right) \qquad \text{(DF)}$$

subject to $\sum_{j=1}^{N} x_{ij} = a_i$;

$\sum_{i=1}^{N} x_{ij} = l_j$;

$x_{ij} \geq 0$;

$x_{ij} = 0$ when $x_{ij}^0 = 0$

and (0 ln (0/0)) = 0.

This kind of problem is easily solved with the RAS algorithm.[25] Note, however, that this approach allows the construction of a matrix of bilateral exposures between Belgian banks only. The same exercise with foreign banks is indeed impossible as we unfortunately do not have information on liabilities of foreign banks. Estimations based on this technique consequently assume that fa_i are equal to zero.

The third technique mixes both approaches by incorporating large exposures in the matrix of bilateral exposures and by using the a_i and l_j, net of large exposures, to calculate the residual, unreported, exposures. This is equivalent to making an assumption on the distribution of smaller exposures only and it amounts to modifying the problem (DF) by incorporating new constraints

[23] Wells (2002), Upper and Worms (2002) and Elsinger et al. (2002).

[24] It can be shown that the matrix that minimises the relative entropy is asymptotically equal to the matrix with the most likely interbank loans and deposits distribution.

[25] See e.g. Blien and Graef (1997).

reflecting the large exposures. However, since time-series of large exposures are not available, analyses over time are only based on the aggregate exposures technique.

All of these techniques, and the general contagion exercise, involve biases – some of which tend toward underestimation and others toward overestimation of contagion risk.[26] The sources of underestimation of contagion risk include the measure of interbank exposures, which is based on interbank loans and deposits only and consequently does not include other interbank exposures, such as off-balance-sheet exposures. The distributional assumption with the aggregate exposure and mixed techniques of maximum dispersion of banks' interbank exposures also potentially leads to an underestimation of contagion risk as there are less peaks in the distribution[27] (on the other hand, the distributional assumption also creates interbank linkages that do not exist and that are new ways for contagion propagation). Moreover, indirect effects of the failure of foreign banks are not taken into account, since we are not able to measure contagion between foreign banks.[28] Another source of underestimation is the fact that credit risk is the only source of interbank contagion; liquidity risks[29] are ignored. Furthermore, we use a conservative definition of bank failure as banks may fail before their tier-I capital is exhausted. Finally, bank panics by depositors are assumed not to occur.[30] On the other hand, since banks are assumed not to be able to refinance or to raise additional capital, we overestimate contagion risk. We also assume that they are not able to anticipate crises and to subsequently reduce their interbank exposures. The absence of safety nets also tends to generate an overestimation bias. Another source of overestimation is the measure of interbank exposures that is on a company basis and not on a consolidated basis.[31] The extent to which contagion risk will actually be underestimated or overestimated in our simulations will obviously depend upon the importance of each of these sources. We test the sensitivity of our results to some of these biases in section 5.

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[26] A bias against contagion minimises Type II errors, i.e. incorrectly accepting a false hypothesis. This implies a trade-off in terms of Type I errors, i.e. incorrectly rejecting a true hypothesis. In other words, in the presence of a bias against contagion, we might be able to state that there is a potential for contagion. On the other hand, we would not be able to say that contagion is non-existent.

[27] The distributional assumption also rules out the possibility of having interbank relationship lending. Cocco et al. (2003) find evidence of lending relationships in the interbank market. Interbank lending relationships could help mitigate the risk of contagion (as, for instance, monitoring could be more efficient) but could also give rise to very high peaks in the matrix of bilateral exposures.

[28] When we measure the impact on Belgian banks of the failure of a foreign bank, we disregard the "foreign second and further round effects". However, the failure of a foreign bank is likely to have an impact on its domestic market, and some foreign banks (possibly counterparties of Belgian banks) may default subsequent to the first failure, worsening the overall situation of Belgian banks. We undertake a type of sensitivity analysis in Section 4.4. to try to compensate for this limitation.

[29] Liquidity risk is the risk that a bank experiences a liquidity shortfall because its counterparty fails to meet its obligations. For instance, a bank may face a liquidity shortfall because its counterparty postpones a repayment or because it takes time to realise collateral.

[30] Bank panics may occur following an individual bank's failure if depositors make inferences about systemic weakness based on observation of the individual failure (see Aghion et al., 2000).

[31] Interbank exposure data were not available on a consolidated basis. Although the use of data at a company level leads to the implicit assumption that cross-border intra-group exposures are between different banks, our actual simulations reveal few cases where such exposures cause "contagion."

The fact that the contagion exercises are mechanical and potentially involve biases suggests that the results reported below should be interpreted in much the same spirit as those of a stress test. Yet, despite the caveat, this type of exercise represents one of the only means of obtaining any quantitative assessment of interbank contagion risk. Moreover, because this type of exercise has also been undertaken by other authors, it allows for some international comparisons. Furthermore, a consistent use of the methodology with time-series data allows estimating the evolution of the contagion risk over time. The results may thus provide general indications regarding the relative importance of different sources of interbank contagion.

We use a set of three complementary indicators of contagion :

- the worst-case-scenario (WCS) is defined as the scenario for which the percentage of total banking assets represented by banks losing their entire Tier-I capital is the largest. As this may be considered as an extreme measure, we also provide information on the next-to-worst case scenario (N2WCS). WCS and N2WCS are measures of the potential impact of a crisis due to a domino effect.
- the number of cases of contagion (CC) is defined as the percentage of banks initiating contagion when failing. CC measures the likelihood of the occurrence of a contagion effect conditionally to a bank failure, on the assumption that each first domino has the same probability of default.
- the number of rounds (Rounds) in the WCS is defined as the number of rounds of contagion for a given LGD in the WCS. The sequential nature of the algorithm provides information on Rounds. Although Rounds is somewhat artificial, as it depends on the algorithm and as contagion processes may be considered as instantaneous, it provides useful information on the structure of the interbank market. In particular, the maximum number of successive rounds of contagion in a pure money centre structure will be limited to three while in a complete structure, it may be equal to the total number of banks.

4.2. Structure of the Belgian interbank market

Section 2.2.2. highlighted the tight link between the structure of the interbank market and the risk of contagion. Prior to any assessment of the contagion risk, it is insightful to better characterise the structure of the interbank market. In order to study the pattern of relationships between Belgian banks, Table 5 presents a matrix of bilateral exposures based on the mixed technique.[32] For presentation purposes, we grouped banks by size in 5 groups (G1 to G5; so G1 is the group containing the largest banks). Natural thresholds in bank size distribution were used in order to determine groups' composition. So G1 comprises the 4 banks whose assets exceed € 99 billion, G2 comprises 5 banks with assets between € 8 and 14 billion, G3 comprises 7 banks with assets between € 3 and 6 billion, G4 comprises 15 banks with assets between € 1 and 2.6 billion and G5 comprises 34 banks with less than € 700 million in assets. Recall that bilateral interbank positions are determined before the grouping procedure. Therefore, the number of groups that we use does not affect the results set out below. Note also that EMU, RoW and total interbank rows and columns are directly observed and they are thus independent of distributional assumptions.

Interbank loans and deposits correlate with assets size (Table 5). As far as domestic interbank operations are concerned, we observe that most interbank transactions seem to transit through large banks. Indeed, positions between G1 banks and other banks exceed by far positions between G2 to G5 banks. This structure has not always been prevalent in Belgium. Table 6 shows the evolution over time of the total amount G2-G5 cells could account for.[33] The first row of the table shows the maximum amount these cells could represent. This maximum is calculated independently from any distributional assumption. It is defined as the minimum between the sum of domestic interbank deposits of G2-G5 banks (i.e. the sum of the l_j of G2 to G5 banks) and the sum of their domestic interbank loans (i.e. the sum of their a_i).[34] The second row of the table presents the observed G2-G5 total in the aggregate exposure technique. Both series show a downward trend. In 1993, the structure of the interbank market is more similar to a complete structure where estimated exposures between G2-G5 banks represent 36% of the domestic market (and could not exceed 68% with any alternative distributional assumptions). However, the interbank positions between G2-G5 banks decrease drastically between 1993 and 2002 (it is estimated to 8.1% with the aggregate exposure technique and to 10% with the mixed technique). So, although we still assume a complete structure[35], small and medium-sized banks do not seem to have significant exposures to each other in 2002. We observe the same trend in the maximum, which is independent of any distributional assumption (although the share of small and medium-sized banks is a little bit higher than with the aggregate exposure technique). In fact, it mainly reflects the very high concentration of interbank positions in large banks on both sides of the balance sheet.[36]

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[32] The same exercise based on large exposures or on the aggregate exposure techniques provides similar results.

[33] G1 banks are the large banks. We define large banks as banks whose assets exceed 10% of the total assets of the Belgian banking system. Note that our results are robust to alternative thresholds.

[34] By definition, the sum of G2-G5 cells will never exceed the minimum of domestic interbank loans and domestic interbank deposits of Belgian banks. In fact, taking the maximum of both may even constitute an overestimation of the total G2-G5 as it does not take account of constraints such as a null diagonal.

[35] Assuming a maximum dispersion of interbank activities is similar to assuming a complete structure of claims as described in Allen and Gale (2000).

[36] The concentration on the interbank market increased over the last decade. As far as interbank activities are concerned, the Herfindahl index currently exceeds 25 % while the market share of the five main players reaches about 90 %

Although interbank activities with foreign banks are mainly concentrated in large banks (Table 5), access to international interbank markets does not seem to be strictly limited to large banks only.[37] Nevertheless, we observe that the proportion of foreign interbank loans or deposits tends to decrease with bank size category. There can be several rationales explaining this smaller share of international interbank activities for smaller banks: they may not reach the critical size or be internationally less known not allowing them to conclude transactions on the international interbank markets. This would be in line with one of the scenarios presented in Freixas and Holthausen (2001), where large banks with a good international reputation act as correspondent banks for their domestic peers in order to overcome asymmetric information problems.

The very limited interbank positions between G2 to G5 banks, combined with their decreasing share of international financing suggests that large banks (G1) tend to operate as a money centre à la Freixas et al. (2000). One important difference in relation to the structure described by Freixas et al. (2000) is that several money centres would be linked together, as reflected by the substantial position between the G1 banks.[38] Thus, each large bank tends to function as a money centre linked to the other money centres. The Belgian interbank market would thus be characterised by a "multiple" money-centres structure vs. the "single" money centre of Freixas et al. (2000).

4.3. Contagion triggered by the default of a Belgian bank

4.3.1. Comparing results for large exposures, aggregate exposures and mixed techniques-Q4-2002.

Table 7 presents the results of the contagion exercise assuming that the initial interbank defaulter (the so-called "first domino") is a Belgian bank. The first, second and third panel of the table present the results where bilateral exposures come from the mixed technique, the large exposures, and the aggregate exposures, respectively. Results are reported for five different LGD. In December 2002, there were 65 banks incorporated in Belgium, i.e. 65 potential sources of contagion. The table is thus based on 975 different scenarios (i.e. 3 techniques x 5 LGD x 65 banks). The columns provide the results of the simulations for each technique and for each LGD. The second column gives the number of scenarios that generate contagion (each line summarises 65 different scenarios). The third column presents the median scenario. The median scenario gives the median value, across all of the scenarios where contagion occurs, of the percentage of total banking assets represented by banks losing their tier-I capital. The two following columns provide some statistics on the state of the banking system in N2WCS and the WCS, respectively. The table displays the percentage of assets represented by, and the number of, failing banks and banks losing respectively between 100 % and 70 %, between 70 % and 40 %, between 40 % and 10 % or less

[37] Note that international interbank positions are not subject to the distributional assumption.

[38] Unreported individual positions between large banks show that large banks hold cross-deposits in other large banks.

than 10 % of their tier-I capital. Finally, the two remaining columns present two indicators of risks associated to the first domino for the WCS, namely the level of Tier-1 capital (as a percentage of total assets) and the level of losses for bad loans (as a percentage of commercial loans). For each indicator, the quartile to which the first domino belongs is indicated. 1 is the *low risk* quartile (i.e. the highest capitalisation or the lowest losses for bad loans) and 4 the *high risk* quartile (i.e. the lowest capitalisation or the highest losses for bad loans). Although these risk indicators are reasonable proxies for the riskiness of the first domino, they only provide an assessment of the soundness of the bank relative to the sector. In addition, there could be specific reasons, not necessarily linked to risks, justifying special levels for these ratios for a given bank. Similarly, an apparently sound bank may fail because of fraud, risk concentration, etc.

As Table 7 shows, the frequency of contagion occurring in the simulations is limited. Under the extreme assumption of 100 % LGD, only 18 out of the 65 simulated Belgian bank defaults do cause the failure of another Belgian bank. The knock-on effects are also limited. In the median scenarios, the percentages of assets represented by banks losing their tier-I capital are extremely low. In the WCS, which is always caused by the default of a large bank, simulations show that banks that would lose their tier-I capital as a result of the interbank defaults never represent more than 4.4 % of the total assets of Belgian banks.[39] Thus, the default of a Belgian bank in the interbank market, in the context of this exercise, does not cause a large Belgian bank to lose its entire tier-I capital. Moreover, if we assume an LGD of 40 %, which is probably more realistic given that secured loans account for more than 50 % of total interbank loans[40], the losses are lower. In this case, banks accounting for more than 90 % of the assets lose less than 40 % of their tier-I capital. Although N2WCS losses are less important, they remain close to the WCS-outcome. These scenarios are caused by different banks which, however, exhibit similar risk indicators, i.e. banks with a low capitalisation but low losses for bad loans.

[39] This figure comes from the mixed technique. The figure decreases to 3 % for the simulations using large exposures data and to 3.8 % for simulations using aggregate exposures.

[40] The statistical estimation of an LGD for Belgian banks is very difficult, since fortunately very few Belgian banks have failed in the last decades. Moreover, actual losses on a defaulting bank can prove very complicated to calculate, since they depend on the time horizon chosen. Altman and Kishore (1996) estimate average recovery rates on defaulting bonds of financial institutions (for the period 1978-1995) to be about 36 % However, recovery rates vary by type of institution: mortgage banks 68 %, finance companies, 46 %; financial services, 42 %; commercial banks, 29 %; savings institutions, 9 %. Moreover, the LGD for bonds is probably very different from the LGD for comparable loans (which in our case comprise secured and unsecured assets). James (1991) estimates that losses average 30 % of the failed bank's assets and that the direct expenses associated with bank closures average 10 % of assets, making a total of about 40 %. Seeing that more than 50 % of interbank loans granted by Belgian banks are secured, it may therefore be realistic to assume a recovery rate of somewhere between 60 and 80 % (i.e. an LGD between 40 and 20 %). On the other hand, as domino effects may be considered as instantaneous, one could also argue that the time pattern of recovery does not matter and that a LGD of 100 p.c. should be used to simulate liquidity shocks. Yet the time pattern of recovery may matter, depending on the maturity of the liabilities.

The three techniques deliver comparable results, especially for failing banks that are central to our analysis. This comparability validates our use of the aggregate exposures technique for the estimation of contagion risk over time that we will present in the next subsection.

4.3.2. Simulations based on aggregate exposures: evolution over time

The question we address is whether contagion risk between Belgian banks evolved over time. The simulations used to study the evolution of contagion over time are based on the aggregate exposure technique, and cover the period Q4-1992 to Q4-2002. We use 20 different LGD. Thus for each quarter, the number of scenarios tested amounts to 20 times the number of banks (between 65 and 113). We use the propagation mechanism explained earlier to study the evolution of three indicators of contagion, namely WCS, CC and Rounds. The behaviour of the first indicator over the period 1993-2002 is summarised in Chart 1 (for 20 different LGDs). The Second indicator is presented in Chart 2. The evolution of the third one is presented in Table 8.[41]

Chart 1 shows that, over the last decade, WCS has been subject to three major evolutions. Between 1993 and 1997, the WCS consistently worsens. Between 1997 and 1999, the WCS improves; i.e., the curve in Chart 1 decreases each year. Finally, between 1999 and 2002 the curve flattens. Thus, the amount of contagion generated in simulations with current data appears to be at a record low. These trends are particularly striking for an LGD of 60 % In this case, the percentage of total banking assets affected by contagion, excluding the first domino, varies over the period from 86 % to 3 %. N2WCS seems to be affected by the same structural changes as WCS. Overall, the level of N2WCS is similar to the level of WCS. Although variations in the percentage of banks initiating contagion are less pronounced (Chart 2), this indicator also evolves over time. Indeed, curves representing this indicator before 1999 seem to indicate a greater potential for contagion than curves from 1999 onwards, at least for high levels of LGD.

Table 8 shows the propagation mechanisms of contagion for a LGD of 60 %[42], in the worst-case scenario, over the last ten years. The table presents the results for Q2 and Q4 of each year between 1992 and 2002. Each row represents the WCS of the quarter. A distinction is made between large banks (defined as banks with assets exceeding 10 % of total assets of Belgian banks), medium sized banks (totalling in between 10 % and 3 % of total assets) and small banks. Each column represents an additional round of contagion. The table indicates that points in time where the WCS reaches its maximum are characterised by "long periods" of contagion (spreading over sometimes 11 rounds) with an important number of banks defaulting. It also shows that the default of a large

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[41] For presentation purposes, Chart 1presents the results for Q2 only. However, tests reported in sub-section 4.3.3. show that the trends in the WCS presented in Chart 1 are not sensitive to the quarter chosen. However, in some rare cases and for some specific LGDs, the percentage of balance sheet assets affected by contagion might diverge from the general trend.

bank is always directly preceded either by the default of another large bank, or by the default of a medium-sized bank. Indeed, the tier-I capital of large banks is never totally absorbed by the combined default of several small banks. However, the default of a small bank may trigger the failure of several small and medium-sized banks and in turn of a large bank. Note also that in some cases, no large bank fails, even in the WCS.

4.3.3. Factors influencing the domestic contagion

Several factors could influence the incidence and impact of contagion. In subsection 2.2., we distinguished explanatory factors at the bank level, at the market level and at the regulatory level. We now investigate which factors influence our three previously defined domestic contagion indicators. This section focuses on explanatory factors related to the structure of the inter/bank market[43].

Two main trends in the banking landscape could explain the changes in our simulation results over the period 1993-2002. First, the estimated matrix of bilateral exposures underwent some structural changes, possibly reflecting changes in the financial environment, changes in the interbank market structure and the rising concentration in the banking market. Indeed, as described earlier, large banks now seem to show an increased tendency to operate as multiple money centres[44], where the failure of a bank linked to the money centre does not trigger the failure of the money centre itself. As shown by Freixas et al. (2000), for certain parameter values, a single money centre structure could reduce the contagion risk as banks at the periphery do no longer trigger contagion. A multiple money centres structure could also reduce contagion if the exposures between banks at the centre are such that they do not propagate contagion. These changes should have an impact on the contagion indicators (see the Appendix for a theoretical analysis). The very simple framework presented in the Appendix leads to the following hypothesis:

Hypothesis 1:

A (estimated) money centre structure compared to a complete structure implies that:

- if the money center bank is well capitalised, the worst case scenario (WCS) decreases;
- if the money center bank is well capitalised, the number of cases of contagion (CC) decreases;

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[42] The 60 % LGD was chosen as it was probably the level showing the most important variation in the WCS.

[43] Factors at the bank level, such as the increased recourse to risk mitigation techniques are already taken into account since the results are given for different LGDs. Moreover, we do not have information on particular netting agreements that would exist between Belgian banks. It is also difficult to take account of changes at the regulatory/supervisory level since the time period we use is limited and comprises several regulatory/supervisory initiatives with potentially overlapping results. In addition, using explanatory variables on the structure of the interbank market over time allows us to capture regulatory and supervisory changes.

- the number of rounds of contagion in a given scenario (Round) decreases.

Second, following consolidation and international financial integration, (large) Belgian banks have further increased their cross-border interbank exposures.[45] Consequently, the bilateral interbank exposures between the large Belgian banks could be such that they would no longer cause contagion between Belgian banks. Based on this observation, we formulate a second hypothesis:

Hypothesis 2:

When banks decide to internationalise their interbank exposures and to relatively reduce their domestic exposures, then following a domestic default, we expect that :

- the worst-case-scenario (WCS) decreases;
- the number of cases of contagion (CC) decreases;
- the number of rounds of contagion in a given scenario (Round) could decrease (because less banks will fail) or increase (if contagion processes propagate less rapidly).

In order to test these two hypotheses, we define 9 variables (Table 9). The two first variables directly relate to our two hypotheses. They provide proxies to capture the structure of the interbank market (i.e. money centre vs. complete structure) and the degree of internationalisation of banks, respectively. To capture the interbank market structure, we create a variable LB that measures the domestic interbank exposures of large banks as a percentage of the total domestic exposures. In a money centre, this ratio should be equal to one since small banks are not linked together and all interbank transactions transit through the money centre. In a complete structure, we expect LB to be smaller. The degree of internationalisation is proxied for by DOM which is defined as the total domestic interbank exposure of Belgian banks as a percentage of their total interbank exposures. This ratio indicates the level of internationalisation of interbank exposures. A ratio equal to 1 would represent a "closed" system relying only on the domestic interbank market. A ratio equal to 0 would represent a fully internationalised system. Another variable that is likely to impact on contagion is the leverage of banks (KIS). In addition, KISLDUMMY aims at identifying periods in which large banks are well capitalised. It is a dummy variable equal to one when the average tier-one capital ratio of large banks exceeds the long-term average of the ratio and 0 otherwise. KISLDUMMY is used in interaction with LB. This interaction variable captures the extent to which both a change in the structure and a higher capitalisation of money centers drive the contagion indicators. In order to control for macroeconomic changes (and other potential shocks

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[44] Or, at least, the matrices used to calculate the contagion effect seem to show a trend towards a multiple money centres structure.

[45] Although the share of international interbank loans has always been high for large banks, it has increased over the last decade. In December 1992, the interbank loans granted by large Belgian banks to foreign banks accounted for 79 % of total interbank loans. This proportion reached 89 % at the end of 2002.

affecting the data), we use the GDP growth rate (GDP) and the term spread of the interbank interest rate (INT) defined as the spread between the 1-year and the 1-month interbank interest rate (Bibor before 1999 and Euribor after).[46] Finally, we also use variables to control for potential seasonal effects (quarterly dummies Q2, Q3, Q4).[47]

We observe a relatively high correlation between the variables LB and DOM (Table 10). The high correlation between these variables is not too surprising. Indeed, an increase in LB goes together with an increase in concentration as large banks become more important. This might reduce competition. In order to increase competition and benefit from more advantageous conditions on their interbank transactions, banks may try to internationalise their interbank portfolio. A higher concentration then may lead to a higher degree of internationalisation. Technically, the relatively high correlation might prevent us from obtaining statistically significant results when including these variables jointly in a regression framework. In order to deal with multicollinearity problems, we run regressions with each variable taken individually and all variables simultaneously.

We run OLS regressions using quarterly data (Q4-1992 to Q4-2002) and estimate the following model for several LGDs:

Contagion indicator given LGD = $\alpha + \beta$ GDP + ϕ INT + δ KIS + γ Quarter Dummies + χ market structure + error term

With contagion indicator = WCS, CC or Round
Market structure = LB, DOM and/or (LBxKISLDUMMY).

The results are presented in Table 11 to Table 13. The three panels in Table 11 report the results using WCS as dependent variable, for levels of LGD 100%, 80% and 60%, respectively.[48] We observe that for each LGD, LB and DOM are significantly different from zero. A 10% increase in LB (i.e. a move towards a money centre structure) would lead to a decrease of 23%, 29% and 14% of the WCS for the 100%, 80% and 60% LGD respectively. Similarly, a 10% decrease in DOM (i.e. a higher internationalisation of interbank assets) would lead to a decrease in the WCS of 38%, 41% and 23% for the 100%, 80% and 60% LGD respectively. The regressions for the CC indicator of contagion (Table 12) show results similar to the WCS. The number of cases of contagion tends

[46] Macro-economic conditions might affect the ability/willingness to take or grant interbank loans and might influence the behaviour of interbank players. Therefore, we need to control for these potential effects.

[47] For each variable, we performed Phillips-Perron tests to test for unit roots. The series appear stationary. We can reject the hypothesis of a unit root at a 10% level for all the independent and explanatory variables with exception of the WCS for an LGD of 80% and 60% and Dom and KIS. Although we can not formally reject the null hypothesis of unit roots for these series, there is a strong economic rationale to reject it as they are by construction constrained between zero and one.

thus to decrease when moving to a money centre structure or when internationalisation increases. The number of rounds (Table 13) decreases in LB and/or an increase in DOM. The number of rounds in the WCS thus reduces by a move towards a money centre structure and by a higher internationalisation.

KIS has negative coefficients in the WCS and in the CC cases. Yet, these coefficients are not always statistically different from zero. In particular, it seems that the impact of a higher capitalisation is statistically significant when the LGD is not too high. In other words, during the periods in which banks were holding more capital, contagion was less likely for lower LGD and higher LGD were required to observe important effects. Yet, even with a higher capitalisation, ceteris paribus, contagion was not stopped when the LGD was high. Coefficients of KIS in the regression using the number of rounds in the WCS are positive or negative, depending on the LGD. Actually, the impact of KIS on the number of rounds is twofold. First, a higher capitalisation may reduce contagion, and subsequently reduce the number of rounds of contagion. Second, a higher capitalisation may slow down contagion, potentially increasing the number of rounds (with smaller effects at each round).

In models where both LB and LB*KISLdummy are used, we observe that both LB and the interaction variable are negative and statistically significant (except for the 60% LGD where LB*KISLdummy is not always significantly different from zero). A move to a complete structure decreases contagion indicators. This effect is reinforced when money centres are well capitalised.

The unreported coefficients of the quarterly dummy variables are in most cases insignificant. In other words, we do not observe any quarter effect on contagion indicators. The macroeconomic variables are also generally not significantly different from zero.

Our results seem to be robust to the specification used. However, coefficients of LB or of DOM are sometimes not significant when used jointly while they are when each variable enters individually. In order to test the robustness of our results, we used several alternative specifications for the regression model. A first set of models is based on instrumental variables that proxy LB and DOM. We use instrumental variable to control for the fact that the same data set is used to generate simulations and to partially construct LB and DOM. In order to proxy for LB, we employ the Herfindahl index based on total assets (concentration in a money centre structure will tend to be higher than in a complete structure as the money centre bank tends to be larger than banks at its periphery) and to proxy for DOM, we compute an index of bank internationalisation based on total

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[48] The results using the 40% and the 20% are less significant. This is not too surprising as changes over time in the WCS, in CC or in round are much more important for an LGD of 100% than for an LGD of 20% where little or no contagion at all is observed.

assets. A second set of models uses lagged LB and DOM. Finally we also test alternative specifications for the money market structure such as the average of the ratio (exposure of bank i to small and medium size banks / exposure of bank i to large banks) over all small and medium sized banks. The unreported results in general confirm our previous findings. .

4.4. Contagion triggered by the default of a foreign bank

Banks' balance sheets data for the end of 2002 show that about 85 % of Belgian interbank loans are granted to foreign banks. Foreign interbank exposures thus represent a potential source of contagion that may be more important than the domestic contagion risk. We therefore extend the contagion exercise to the foreign interbank market. Table 14 reports the results of the contagion simulations when a foreign bank is the first defaulter (the "first domino"). Absence of data on the total interbank exposures of foreign banks vis-à-vis Belgian banks, however, prevents us from using the aggregate technique for our simulations. The simulations are therefore limited to the use of large exposure data of Belgian banks. Table 14 reports results for 5 different LGDs. We identify 135 foreign banks to which Belgian banks are exposed. The table is thus based on 675 different scenarios (each line representing 135 scenarios). The presentation of Table 14 is similar to Table 7.

Table 14 shows that for a 100% LGD the default of one large foreign bank can lead to the failure of 7 Belgian banks whose assets account for 20 % of total Belgian bank assets. These numbers are considerably higher than the comparable figures for contagion simulations with Belgian banks as first domino's. The results for the WCS also indicate that even for a LGD of 40 %, the default of a foreign bank can have a significant impact on Belgian banks. [49]

Interestingly, contagion occurs less frequently (in less than 10 % of cases) in the foreign-bank failure simulations than in the simulations where the first domino is a domestic bank. At most 13 of the 135 foreign counterparties listed by Belgian banks (in their reporting of large exposures) trigger contagion in our simulation. However, as discussed above, foreign bank failure can affect a larger proportion of Belgian banking assets. Note, however, that large differences exist between the median and the worst-case scenarios. For an LGD of 100 %, only 3 of the 13 simulations that involved contagion entailed the failure of banks representing at least 10 % of the total assets of the Belgian banking system. The N2WCS shows that, for reasonable LGDs, contagion is very unlikely. In addition, all of the foreign banks representing the first domino in the WCS are European banks and all rank as investment grade, which suggests that actual interbank defaults by these banks are

[49] Note that a small number of scenarios represented in Table 14 involve failures due to cross-border intra-group positions; however, these scenarios represent exceptions rather than the rule.

unlikely. Unfortunately, the absence of a long time series of bank large-exposure data prevents us from studying changes in the international risk of contagion over time.[50]

Our contagion analysis can not incorporate indirect effects of the failure of foreign banks (i.e., failure of other foreign banks because of failure of a given foreign bank). One way to roughly take account of indirect effects would be to simulate the impact of the combined default of several foreign banks coming from the same country. Belgian banks provide a breakdown of their aggregate interbank exposures (the fa_i) by E.U. countries. The data are available for the last five years. Table 15 presents results of simulations where we assume that *x* % of the interbank exposure of Belgian banks to banks in a particular EU country are unrecoverable. We use the propagation mechanism explained earlier to measure the impact on the Belgian system. The first row of the table provides descriptive statistics on the exposure of Belgian banks to E.U. countries. The 5 remaining rows summarise the results of our simulations, for 5 different LGD. The numbers represent the percentages of Belgian banking assets of failing Belgian banks. Simulations are calculated for each E.U. member (except Belgium).

Table 15 shows, for example, that if Belgian banks suddenly become unable to recover 80 % of their interbank loans to French banks, Belgian banks representing 22 % of the total assets of Belgian banks would incur losses (directly or indirectly) exceeding their tier-I capital. It is perhaps surprising to observe that with the exception of France, the Netherlands and the United Kingdom, simulations involving defaults on other countries' interbank loans (including Germany and Luxemburg) do not result in significant contagion in the Belgian banking sector. For example, for an LGD of 100 %, a simulation of the failure of all German banks shows that Belgian banks losing their entire tier-I capital represent less than 1 % of total Belgian bank assets. Moreover, when we use lower LGDs, only bank defaults in the UK would yield significant levels of contagion in Belgium. This in fact reflects Britain's role as a money centre and the importance of British banks as counterparts of Belgian banks. Manna (2004) confirms that London is an important nexus for all EMU banks, as UK banks account for more than one third of their cross border interbank deposits.

Although the previous results are quite stable over 1999-2002[51], with France and the U.K. often representing major risks, other neighbouring countries sometimes showed a higher potential for contagion. For instance, in Q2-2000, a loss rate of 100 % on Germany would have offset the Tier-I capital of banks representing 93 % of the Belgian banking system. In Q2-1999, a loss rate of 100 % on Luxembourg would have had similar effects. These jumps in simulated country impact probably reflect larger interbank positions with those countries. We do not observe any significant increase in the cross-border contagion risk over 1999-2002. However, such increase may have taken place

[50] Note that results for Q3-2002 are similar to results for Q4-2002.

earlier, in years in which internationalisation of interbank exposures of Belgian banks substantially increased.

5. Further Sensitivity Analysis

As mentioned earlier, the conclusions of our analysis are subject to different assumptions, leading to a potential over/underestimation of the contagion risk. The first subsection presents additional contagion exercises relaxing important assumptions. The contagion exercises presented in this subsection are based on the aggregate exposures technique with Belgian banks as first defaulter (see 4.3.2.).We first describe the different robustness checks before turning to the simulation results. We present the results of seven robustness checks, all implying relaxing a different assumption. The second subsection compares the results of our baseline simulations for Belgium with results obtained for other countries.

5.1. Sensitivity tests

1. Banks' expectations

We aim to incorporate banks' expectations by assuming that banks are able to withdraw a part of their interbank assets before the failure of the initial bank takes place. We assume that the part that may be withdrawn depends on the maturity structure of the interbank loans the bank has granted to the initial defaulter. On an aggregate basis, the residual maturity of more than 35 % of interbank loans granted by Belgian banks does not exceed 8 days (presumably much of it is even overnight).[52] The bank granting these short-term loans can decide not to renew them if it anticipates the failure of its debtor. In particular, in this robustness check, we assume that banks correctly anticipate failures and aim at withdrawing the short-term loans granted to all failed banks before the failure. To the extent that they succeed, short-term positions no longer trigger contagion.[53]

In order to estimate the short-term bilateral positions, we assume that the maturity structure of interbank loans granted to each counterpart of a given bank is the same.[54] For instance, if 28 % of

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[51] Simulations are based on country breakdowns of interbank loans of Belgium banks. Unfortunately, these data are only available for the period ranging from 1999 to 2002.

[52] Please note that the breakdown by maturity is unfortunately not available for Q2-1993.

[53] Of course, such behaviour could also accelerate difficulties.

[54] We could have used the same assumption (i.e. aggregate exposure technique) as previously to break the short-term interbank loans and deposits down. However, banks do not make a distinction between Belgian and foreign counterparts

interbank assets of bank i have a shorter maturity than 8 days, we assume that 28 % of each interbank exposure of bank i can be withdrawn at each moment. If banks anticipate the failure of one bank, they are able to withdraw a part of their exposures, at the expense of the other creditors who will probably experience higher LGDs.

2. Safety nets

Another potential bias is linked to the assumption of the absence of a safety net. Although interbank loans are not covered by explicit deposit insurance, issues like "too-big-to-fail" (TBTF) introduce implicit deposit insurance. We have therefore tried to assess the impact of a TBTF policy on the results. To proxy for TBTF in our simulation, we assume that large Belgian banks would not be allowed to fail.[55] These banks would thus not create initial and additional contagion and could even stop it. This policy (i.e. the TBTF policy and the 10% threshold), however, constitutes a working assumption made by the authors in order to test the sensitivity of the results. There is absolutely no certainty regarding the effective application of such a threshold or such a policy in case of a large bank failure.

3. Banks co-ordination

Banks could co-ordinate in order to avoid liquidation. Leitner (2004) defines a model in which liquid banks bail out illiquid banks because of the threat of contagion. In the informational contagion model of Manz (2002), the action of the regulator in eliminating co-ordination failure allows to avoid inefficient outcomes that would have not realised if creditors had been able to co-ordinate by themselves. In these two models, co-ordination reduces the risk and extent of contagion.

Figure 2 presents a simplified example of a situation in which co-ordination could avoid a domino effect. Suppose there are three banks: bank A, B (exposed to bank A) and C (exposed to bank B). The first domino is bank A. Merging bank B and bank C would give a bank with an exposure of 5 to bank A and a capital of 4.3. Assuming a 100% LGD, the failure of bank A triggers the failure of bank B and the failure of bank B triggers the failure of bank C. Merging both banks would not have an impact on contagion as the new bank would not be resilient to a loss of 5. With a 50% LGD, the failure of bank A triggers the failure of bank B and indirectly of bank C if banks do not co-ordinate. The merged entity, however, would be able to resist to a shock of 2.5 as it would present a tier-1 capital of 4.3. In this case, merging both banks is optimal as it allows avoiding domino effects.

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when they report their maturity breakdowns so we do not dispose of the split of interbank loans / deposits granted by Belgian banks to Belgian banks (i.e. the short-term a_i and l_j).

In order to address co-ordination, we start from the WCS and work sequentially.[56] We assume that neither banks, nor the regulator, know the full matrix of bilateral exposures. Banks only know their direct counterparts. After the initial shock on the first domino, banks observe their losses. At that moment, we assume that banks have time to start "merger discussions" with other banks in order to avoid liquidation.[57] Other banks will accept such merger if thanks to this operation, they avoid their own failure. As the matrix of bilateral exposures is unknown to participants, we assume that mergers are only possible between banks failing in the "second round" (subsequently to the failure of the first domino) and their direct counterparts, i.e. banks failing in the "third round". We simulate the consequences of each possible merger involving one or more banks that would have failed in the second round and one or more banks that would have failed in the third round.[58] For each simulation, we try to combine two objectives of supervisory authorities. First, we identify the merger that minimises the assets of the failing banks. Second, if two mergers have the same effect, we identify, among these two possible mergers, the one that minimises the increase in concentration (measured by the Herfindahl-Hirschman index - "HHI").

4. Failure threshold

Another sensitivity analysis is based on an alternative definition of the failure threshold. Our baseline simulations assume that failure threshold is reached when losses of a given bank exceed its Tier-1 capital. The alternative threshold introduced here is the sum of Tier-1 and Tier-2 capital, including revaluation reserves, internal security fund, perpetuals and other instruments with a subordinated nature and for which the principal of interest payments may be suspended in case of losses and long-term subordinated debts. This higher threshold will make contagion less likely.

5. Reaction to a common shock

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[55] We define here large banks as banks representing more than 10 % of the total assets of Belgian banks.

[56] One could argue that domino effects are instantaneous and that co-ordination is impossible. This depends on the speed of the contagion process and of potential regulatory intervention (such as suspension of convertibility). The losses may be realised long after the failure of the first domino, leaving time to the bank impacted by the default of the first domino to try to co-ordinate with some other banks. The speed of the process will depend on the liquidity structure of the bank and potential liquidity effects such as runs, regulation, and the willingness of regulators to give time to avoid long term effects.

[57] Such period could be due, for instance, to a lag between the failure of the first domino and the realisation of losses, due to an arbitrary decision of the regulator, or due to procedures such as Chapter 11.

[58] The total number of mergers involving at least one bank that failed in the second round and one bank that failed in the third round is equal to the number of possible combinations of banks that failed in the second round times the number of possible combinations of banks that failed in the third round. For instance, in 1997, in the WCS, two banks fail in the second round (which makes three possible combinations : (1,0), (0,1) and (1,1)) and 1 in the third round. In total, there were thus three different possible mergers. The number of potential combinations of banks failing in a given round is equal to $\sum_{p=0}^{p=n} C_n^p$ where n is the number of banks, p is the number of merging banks, from 1 to n, $C_n^p = \frac{n!}{p!(n-p)!}$ and assuming that 0! is equal to one.

In earlier simulations, we assumed that the initial shock was idiosyncratic. The initial shock, triggering banks' contagion could however affect the whole banking system. The knock-on effects of a common exposure to a single shock are more important. Therefore we devise a procedure to simulate the consequences of (i) the combination of a macro shock and an idiosyncratic shock, and (ii) multiple failures (2 or 3 banks). In order to simulate a macro-shock, we assume that each bank suffers from losses amounting to 10% of its tier-1capital. The macro-shock is combined with an idiosyncratic shock, i.e. the failure of one of the bank of the system. The multiple failures procedure simulates the impact of each possible joint default of 2 or 3 banks of the system.

6. Netting of interbank exposures

We performed contagion simulations based on netted matrices of bilateral exposures. To the extent that netting reduces the actual exposure of each bank to its counterparts, this should reduce contagion.

7. Loss-given-Default

Simulations are based on a fixed and constant loss given default. Yet we may expect that the LGD will differ from bank to bank and from round to round. One way to do this is to endogenise the LGD. Endogenising the LGD requires, however, additional assumptions on seniority of (interbank) debts and on the bankruptcy costs. Such assumptions would not be less arbitrary than assumptions on LGD. Another possibility to measure the impact of the fixed LGD is to simulate domino effects using random LGD's. We performed a test in which we randomly generate LGD's. The LGDs are uniformely distributed over [0-1]. We simulate 10000 different scenarios for each bank of the system.

The results for the different sensitivity tests are summarised in Table 17 to Table 21. Table 17, Table 18 and Table 19 present how the WCS, the number of cases of contagion and the number of failing banks in the WCS respectively evolve under the alternative assumptions. Table 20 presents the results assuming co-ordination. Table 21 presents the evolution of propagation mechanisms with the TBTF assumption.

The results in Table 17 reveal how the WCS evolves under alternative assumptions. Although the extent of contagion differs under different assumptions, the time pattern of the WCS remains broadly similar under each of the assumption (i.e. an increase in the WCS from 1993 to 1997 and a subsequent decrease). The netting assumption is the only exception. Indeed, allowing for netting reduces contagion in each of the yearly cross-section towards very low levels. Moreover, the WCS assuming netting becomes flat over 1992-2002. The table also reveals that incorporating TBTF or banks' anticipation decreases the percentage of banks' assets affected by the contagion in the WCS.[59] The analysis of the impact of banks' anticipation and TBTF is generally similar. The contagion still reaches significant levels but for high LGDs only, which are less probable, especially taking into account the percentage of secured interbank deposits. Although allowing for multiple failures increases the level of the WCS, its level remains very low in 2002. Increases in contagion indicators due to multiple failures are captured by the simulation of a double default and the marginal impact of simultaneously allowing for a third default is limited.

Table 18 presents the evolution in the number of cases of contagion under the different assumptions. The number of cases of contagion remains quite stable and similar to the baseline. One significant exception, however is due to the TBTF assumption. The number of observed cases of contagious bank failures significantly decreases when we assume that large banks are bailed-out. In particular, cases of contagion caused by the bankruptcy of a large bank in the first round no longer occur. The four cases of contagious failures simulated in Q2-2002 were all related to large banks and consequently disappear, so that contagion totally vanishes.[60] Since contagion cases were often caused by large banks, the number of cases of contagion each year generally decreases by about 50 %. Interestingly, though, this also shows that large banks were not always the only initiators of contagion.

Table 19 presents the number of failing banks under alternative assumptions. The evolution in the number of failing banks in the WCS is quite similar to the evolution of the WCS. Indeed, we observe the same time pattern for each assumption, except for the netting assumption in which contagion is very low.

Table 20 presents the evolution of the WCS over time assuming co-ordination. We observe that in some cases co-ordination would prevent contagion from taking place. It seems that contagion can be stopped when the total assets accounted for by banks failing in the third round (i.e. "sound" banks as they are not affected by contagion if contagion is stopped at the second round) significantly exceed those of banks failing in the second round. The induced increase in HHI necessary to prevent contagion from taking place is relatively modest. For instance, a merger involving 4 banks in 1998 would have prevented contagion. This merger would have caused an increase in the HHI of 0.33%, from 12.06% to 12.39%.[61] These results are of course heavily

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[59] Rescued banks are counted as failed and thus increase the % of total balance sheet assets affected excluding the first domino. However, they no longer propagate contagion.

[60] The fact that medium-sized and small banks do not initiate contagion tends to provide additional support for the multiple money centres structure hypothesis where banks at the periphery are not linked together and consequently do not initiate or propagate contagion.

[61] Markets in which the HHI is in excess of 18% are considered to be concentrated. Transactions in which the HHI increases by more than 1% in concentrated markets, for instance, presumptively raise antitrust concerns under the Horizontal Merger Guidelines issued by the U.S. Department of Justice and the Federal Trade Commission.

dependent of the chosen contagion propagation mechanism and on the design of the merger operation. For instance, it is possible that allowing the merger of banks failing in the fourth round would significantly decrease contagion in other years.

A final remark concerns the propagation mechanisms in simulations incorporating the TBTF policy. Table 21 presents how the pattern of contagion of the previously WCS (in the absence of safety net) for the period between Q2-1995 and Q2-1997[62] evolves with this TBTF assumption. The table compares contagion in the baseline case and under the TBTF assumption. Each column represents an additional round of contagion. In two cases (Q4-1995 and Q2-1996), the contagion is directly stopped since the first bank to fail was a large one. The number of rounds of contagion appreciably decreases. It is interesting to note that in each scenario, at least one large bank has to be rescued.

5.2. International comparison

Our results suggest that interbank contagion risk in Belgium has evolved over time. Any attempt to compare our results with the results of simulations for other countries must therefore take this time dimension into consideration. Table 22 compares our results with the results of other studies using the same methodology. It indicates that the simulated failure of a Belgian bank in December 1998 produced weaker contagion effects than the simulated failure of a German bank in the same period, at least for high LGDs. Indeed, the worst-case scenario curves are higher for the German banking system than for the Belgian system except for the case of an LGD of 40 %. When we compare our results with those for the UK (Bank of England FSR), which uses data for end 2000, we find that the Belgian simulations produced a greater impact of contagion than for the UK. However, contagion occurred in a higher proportion of cases in the UK.

6. Concluding remarks

The interbank market is a channel through which problems at one bank might spillover to other banks in the financial system. This paper has exploited a unique time series data set to analyse the risk and impact of contagion due to interbank exposures of Belgian banks. We have used time series information on the total amounts of interbank exposures of Belgian banks as well as banks' reported large bilateral interbank exposures. In contrast to previous studies simulating the risk of contagion, these data have allowed us to investigate the evolution of contagion over time and of

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[62] This period is chosen because it was the most damaging in terms of contagion.

some of its determinants, such as the interbank market structure and the increase in the international integration of interbank markets.

In our simulations, we start from data on interbank exposures and track the consequences of non-repayment of (a fraction of) interbank loans on the equity capital of other banks, including any further domino-effects. This exercise is subject to an important caveat. The methodology does not allow to directly incorporating the role of market expectations or potential preventive measures taken by regulators and individual banks. We therefore perform a number of sensitivity analyses. The exercise provides insights regarding the potential impact of “stress” situations on the Belgian financial system. Within the constraints of the available data set, our simulations suggest that the risk of contagion due to domestic interbank defaults has decreased over the past decade.

Our results reveal that the interbank market structure is important in explaining the time series behaviour of the incidence and impact of our contagion measures. The structure of the Belgian interbank market has moved over time from a complete structure à la Allen and Gale (2000) towards a multiple money centres structure. This change in interbank market structure, accompanied by a rise in concentration, has decreased the risk and impact of contagion.

Interbank exposures between Belgian banks currently represent only 15 % of total Belgian interbank exposures, suggesting that the potential contagion risk stemming from foreign interbank exposures is more important. Our simulations indeed suggest that the failure of some foreign banks could have a sizeable effect on Belgian banks' assets.

The threat of contagion originating from foreign interbank borrowers, however, should probably not be exaggerated. First, our simulations indicate that cross-border interbank defaults have a major effect on the Belgian financial system only for high values of Loss Given Default (LGD). Belgian banks currently maintain relatively high proportions of secured interbank exposures, which tend to lower LGDs. Second, the foreign banks whose interbank defaults had significant effects in our simulations are all internationally recognised and have high investment grade ratings. Third, risks associated with foreign exposures appear to be concentrated in a very small number of countries.

The findings of the paper highlight some specific regulatory issues. First, to the extent that the large money centres are resilient, we should not observe significant domestic contagion processes. Second, the default of some large foreign banks have the potential of triggering significant domino effects in Belgium. This result suggests that it is important for regulators to monitor potential cross-border sources of interbank systemic risk. Yet, domestic regulators do not have any control on these foreign banks. Fostering international regulatory co-operation is thus essential. Finally, the current structure and characteristics of the Belgian interbank market reflect several changes that have taken place over the past decade. Integration of money markets at the European level, increased recourse by banks to secured interbank exposures and several major mergers between Belgian banks have resulted in a trend towards market tiering and appear to have reshaped the risk of contagion. In the coming years changes in the microstructure of interbank markets may further alter the structure of interbank markets, thus keeping alive the debate about interbank contagion risk.

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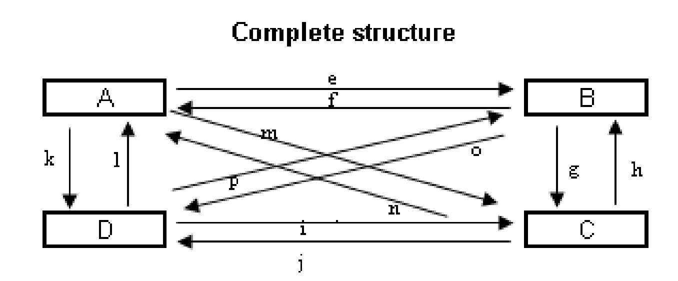
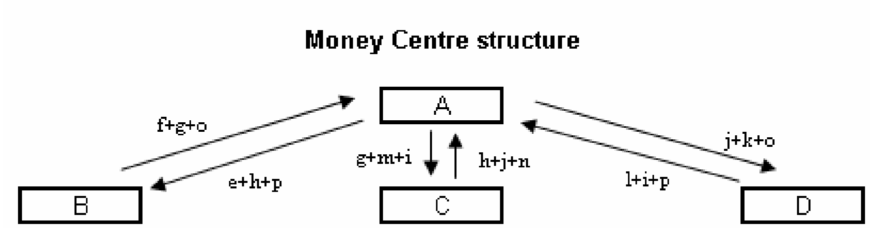
Appendix . Complete structure vs. money centre.

Starting from a complete structure, an interbank market could evolve towards a money centre structure. Ceteris paribus (i.e. Tier-1 capital of individual banks, LGD (θ), liquidity needs, excess cash, etc. remain constant), which structure is more prone to contagion?

The complete structure is characterised by a network of relationships linking each bank of the system with all the other banks. In such structure, each bank holds a deposit in all the other banks of the system. These deposits and the associated money flows are identified by lower-case letters, from e to p.



If banks "decide" to move towards a interbank money centre structure, ceteris paribus, they will have the same liquidity needs and excess cash. For instance, B had previously a deposit in A amounting to f, a deposit in C amounting to g and a deposit in D amounting to o. It now has a deposit amounting to f+g+o in the money centre. Similarly, in the complete structure A, C and D were holding deposits in B amounting to e+h+p, which becomes, in the money centre structure, the deposit of A. Note that the net position of A remains unchanged. In the complete structure, the net position of A was equal to e+m+k-f-l-n and in the money centre structure : e+h+p+g+m+i+j+k+o-l-i-p-h-j-n-f-g-o = e+m+k-f-l-n.



The financing needs of banks belonging to the system are thus equally fulfilled in each structure.

Risk of contagion

We assume the same propagation mechanism as in the simulation, i.e. tier-I capital must be offset by losses. The tier one capital of each bank is represented by a greek letter :

Tier I of A = α,
Tier I of B = β,
Tier I of C = χ and
Tier I of D = δ.

1. The bank A fails :

In the complete structure, the failure of bank A will trigger additional failures if

$\beta - \theta f < 0 \Rightarrow \beta < \theta f$
or if $\chi - \theta n < 0 \Rightarrow \chi < \theta n$
or if $\delta - \theta l < 0 \Rightarrow \delta < \theta l$

In the money centre structure, the failure of bank A will cause another round of failure if

$$\beta - \theta(f+g+o) < 0 \Rightarrow \beta < \theta(f+g+o)$$

or if $$\chi - \theta(h+j+n) < 0 \Rightarrow \chi < \theta(h+j+n)$$

or if $$\delta - \theta(l+i+p) < 0 \Rightarrow \delta < \theta(l+i+p)$$

Observations:

In each case, **when the bank A fails**, the money centre structure seem to be more contagious than the complete structure, since:

$$\theta f \leq \theta(f+g+o)$$
$$\theta n \leq \theta(h+j+n)$$
and $\theta l \leq \theta(l+i+p)$

However, contagion excluding first domino in the worst case scenario measured as a percentage of interbank assets of the system could be technically smaller since assets of A accounts for

$(k+e+m)/(e+f+g+h+\ldots+n+o+p)$ of total interbank assets in the complete structure

and to

$(e+h+p+g+m+i+j+k+o)/(e+f+g+\ldots+n+o+p + o+p+g+h+j+i)$ of total interbank assets in the money centre structure

(say $(k+e+m)/(e+f+g+h+\ldots+n+o+p) = x/z$ and $y = h+p+g+i+j+o$)

then the assets of A represent x/z in the complete structure and $(x+y)/(z+y)$ in the money centre structure

So the interbank assets of A always represent a higher share of total interbank assets in a money centre structure than in a complete structure (unless $y = 0$ which would mean that there are no relationships between B, C and D and thus we would be in a money centre case…)

Finally, in a money centre structure, there won't be a third round of failure *after the failure of A* while in the complete structure, third rounds are possible.

2. Bank B fails (this could be C or D)

In the complete structure, the failure of bank B will cause another round of failure if

$$\alpha - \theta e < 0 \Rightarrow \alpha < \theta e$$

or if $$\chi - \theta h < 0 \Rightarrow \chi < \theta h$$

or if $$\delta - \theta p < 0 \Rightarrow \delta < \theta p$$

In the money centre structure, the failure of bank B will cause another round of failures if and only if

$$\alpha - \theta(e+h+p) < 0 \Rightarrow \alpha < \theta(e+h+p)$$

The probability of failure of bank A following the direct failure of bank B is not necessarily more important in a money centre than in a complete structure. Moreover, if A is well capitalised, the failure of bank B will not be able to trigger contagion on other banks of the system while it would be feasible in the complete structure.

Conclusions

When the money center fails, ceteris paribus, the propagation of contagion seems to be easier in a money centre than in a complete structure. However, if the money centre itself is robust enough, the complete structure could potentially lead to more contagion.

Since we observe a natural concentration in a money center structure, when the money centre bank is the first domino, the observed contagion excluding the first domino could be technically reduced by the fact that the first domino is larger than the other one.

In a simple money centre structure, we have maximum 3 rounds of contagion (including the first one), whatever the number of banks at the periphery. In a complete structure, the maximum number of rounds is equal to the number of banks.

Figure 1 – Interbank market structures and matrices of bilateral exposures

Complete Structure

	Bank A	Bank B	Bank C	Bank D
Bank A	0	+	+	+
Bank B	+	0	+	+
Bank C	+	+	0	+
Bank D	+	+	+	0

Incomplete Structure

	Bank A	Bank B	Bank C	Bank D
Bank A	0	+	0	0
Bank B	0	0	+	0
Bank C	0	0	0	+
Bank D	+	0	0	0

Money Centre

	Bank A	Bank B	Bank C	Bank D
Bank A	0	+	+	+
Bank B	+	0	0	0
Bank C	+	0	0	0
Bank D	+	0	0	0

Disconnected Incomplete structure

	Bank A	Bank B	Bank C	Bank D
Bank A	0	+	0	0
Bank B	+	0	0	0
Bank C	0	0	0	+
Bank D	0	0	+	0

Note :

Each matrix represents a stylised matrix of bilateral exposures. Each line represents the interbank assets of a bank and each column represents its interbank liabilities. + indicate positive positions

Figure 2 - Bank Co-ordination - Example

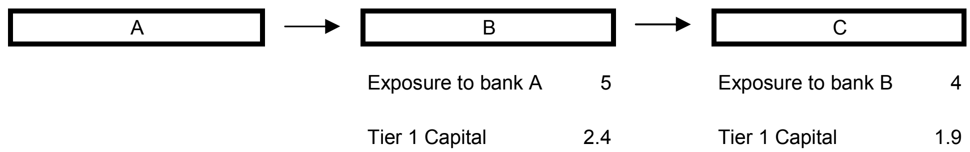


Table 1 - Large exposures of Belgian banks

	Number	Value (in million €)	Average value of a large exposure (in million €)	% of interbank assets
Domestic exposures	109	20661	189.5	79.5%
Foreign exposures	226	105527	466.9	70.1%
Total	335	126187	376.7	71.5%

Source : NBB.

Note : The table provides summary statistics on large exposures of Belgian banks. December 2002.

Table 2 - Structure of interbank loans and deposits of Belgian banks

Interbank loans	Belgium	EMU	RoW	*Total*
Sight deposits	603	1047	2017	*3667*
	0.3%	*0.6%*	*1.1%*	*2.1%*
Term loans	10909	48020	22816	81744
	6.2%	*27.2%*	*12.9%*	*46.3%*
Secured loans	10680	32623	43844	87147
	6.1%	*18.5%*	*24.8%*	*49.4%*
Other	3788	110	16	3914
	2.1%	*0.1%*	*0.0%*	*2.2%*
Total	*25980*	*81799*	*68692*	*176472*
Interbank deposits				
Sight deposits	739	2892	2868	6499
	0.3%	*1.3%*	*1.3%*	*2.8%*
Term deposits	16771	26670	80927	124368
	7.3%	*11.7%*	*35.4%*	*54.4%*
Secured deposits	15308	46425	35894	97627
	6.7%	*20.3%*	*15.7%*	*42.7%*
Total	*32818*	*75988*	*119688*	*228494*

Source : NBB

Note : December 2002, € million; % in italics

Table 3 - Interbank loans and deposits of Belgian and EMU banks

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
EMU BANKS											
Interbank loans	25.9%	26.5%	25.8%	28.5%	26.1%	25.6%	24.6%	23.3%	22.1%	22.6%	
Interbank deposits	26.2%	26.2%	26.7%	30.1%	27.9%	28.2%	28.4%	27.5%	26.7%	26.2%	
Net position	-0.3%	0.2%	-0.9%	-1.5%	-1.8%	-2.5%	-3.8%	-4.2%	-4.6%	-3.6%	
BELGIAN BANKS											
Interbank loans	22.1%	23.1%	23.1%	25.7%	26.5%	25.3%	25.3%	24.3%	19.7%	21.6%	22.2%
Interbank deposits	28.3%	29.0%	29.9%	33.3%	34.8%	34.6%	34.3%	35.1%	31.1%	30.3%	28.7%
Net position	-6.2%	-5.9%	-6.8%	-7.6%	-8.3%	-9.2%	-9.0%	-10.8%	-11.4%	-8.7%	-6.5%
Secured interbank loans	7.2%	15.0%	20.6%	24.8%	29.4%	29.4%	34.1%	44.3%	40.7%	41.2%	50.5%
Domestic interbank loans	29.3%	32.4%	30.5%	32.1%	37.1%	33.9%	37.3%	26.9%	21.3%	22.5%	14.7%

Source : OECD, NBB.

Note : The percentages represent the share of interbank assets and deposits in total assets. They are based on weighted average.
Figures for December of each year.
EMU banks: all banks except for Greece, Luxembourg and Portugal : commercial banks only; Ireland from 1995 onwards only.
Secured interbank loans of Belgian banks and domestic interbank loans of Belgian banks are percentage of total interbank loans of Belgian banks.

Table 4 - Residual maturity of interbank loans and deposits of Belgian banks

	<= 8 days	8 days - 1 month	1-3 month	3-6 months	6 months - 1 year	> 1 year	Un-determined
Loans	28.0%	22.6%	25.3%	11.5%	8.4%	2.9%	1.3%
Deposits	39.5%	25.4%	17.2%	9.3%	6.7%	1.8%	0.1%

Source: NBB.

Note : The table provides a breakdown of interbank loans and deposits according to their residual maturity. Percentages are percentages of total interbank loans and deposits. December 2002.

Table 5 - Bilateral interbank exposure by size categories - December 2002

	% of assets of banking system	G1	G2	G3	G4	G5	EMU	RoW	Total interbank loans	% of foreign interbank loans
G1	85.06%	14.3	1.0	6.1	2.4	2.2	70.6	64.0	160.5	84%
G2	6.83%	2.8	0.1	0.8	0.6	0.1	4.2	2.8	11.4	62%
G3	3.51%	3.2	0.0	0.0	0.0	0.0	5.1	0.2	8.6	62%
G4	3.35%	2.9	0.2	0.1	0.5	0.4	0.9	1.4	6.3	35%
G5	1.26%	1.8	0.1	0.3	0.9	0.1	1.0	0.3	4.5	30%
EMU		71.4	3.0	0.6	0.8	0.2				
RoW		111.7	3.3	1.5	2.6	0.6				
Total interbank deposits		208.0	7.8	9.5	7.8	3.5				
% of foreign interbank deposits		88%	82%	23%	43%	20%				

Source : own calculation

Note : Figures in billions of euros
December 2002.
Domestic exposures : Estimates of the matrix of bilateral exposures based on the mixed technique. The mixed technique combines two sources of information: large exposures and total interbank loans and deposits of each individual bank. It maximises the distribution of total interbank loans and deposits taking account of constraints on large exposures.
Banks were grouped by size for expositional purposes. G1 comprises the 4 banks whose assets exceed € 99 billion, G2 comprises 5 banks with assets between € 8 and 14 billion, G3 comprises 7 banks with assets between € 3 and 6 billion, G4 comprises 15 banks with assets between € 1 and 2.6 billion and G5 comprises 34 banks with less than € 700 million in assets.
Foreign exposures : based on reported figures.

Table 6 - Interbank share of non-large banks.

	Q2-1993	Q2-1994	Q2-1995	Q2-1996	Q2-1997	Q2-1998	Q2-1999	Q2-2000	Q2-2001	Q2-2002	Q4-2002
Maximum	68.1%	42.4%	48.2%	46.5%	53.6%	40.4%	33.5%	40.0%	40.4%	23.2%	25.8%
Aggregate exposure technique	36.4%	30.0%	32.0%	30.7%	35.4%	17.1%	14.6%	20.5%	18.5%	6.1%	8.1%

Source : own calculation

Note : The percentages represent the maximum and the calculated percentages of the domestic interbank exposures small and medium-sized banks account for. Figures are for the second quarter of each year. The percentages are percentages of total aggregate exposures of Belgian banks. The maximum is based on the minimum of the total interbank loans and total interbank deposits of small and medium-sized banks. The calculated percentages are computed on the basis of the aggregate exposure technique.

Table 7 - Contagion exercise: Belgian bank as initial defaulter

LGD (%)	Number of scenarios where contagion occurs (out of 65 possible scenarios)	Median scenario assuming contagion Percentages of balance sheet assets represented by failing banks (excluding assets of "first domino")	Next-to-worst case scenario		Worst Case Scenario (excluding first domino)											
			Banks failing		Banks failing		Banks losing 100-70% of tier-I capital		Banks losing 70-40% of Tier-I capital		Banks losing 40-10% of tier-I capital		Banks losing less than 10% of Tier-I capital		Risk Indicators	
			% Balance sheet assets	# of banks	% Balance sheet assets	# of banks	% Balance sheet assets	# of banks	% Balance sheet assets	# of banks	% Balance sheet assets	# of banks	% Balance sheet assets	# of banks	Quartile Level of capitalisation	Quartile level of losses for bad loans
							Mixed technique at Q4 – 2002									
100	18	0.48%	3.85%	19	4.38%	21	14.54%	10	20.78%	8	38.57%	12	21.72%	14	4	2
80	15	0.48%	3.83%	18	3.91%	20	0.81%	5	2.91%	9	68.72%	13	23.64%	18	4	2
60	14	0.48%	3.76%	17	3.77%	15	0.08%	4	19.03%	9	36.42%	18	40.71%	19	4	2
40	10	0.39%	1.45%	7	2.74%	7	0.84%	3	0.08%	4	36.08%	20	60.26%	31	4	2
20	5	0.14%	0.71%	≤2	0.71%	≤2	0.14%	≤2	0.61%	5	5.79%	20	92.75%	37	4	2
							Large Exposures at Q4 – 2002									
100	12	0.46%	2.33%	11	2.97%	4	0.01%	≤2	0.29%	3	2.34%	6	94.38%	51	3	2
80	10	0.44%	1.89%	5	2.27%	9	0.16%	4	1.14%	≤2	32.68%	11	63.75%	40	4	2
60	10	0.16%	0.48%	6	1.77%	≤2	0.33%	4	0.08%	≤2	14.05%	7	83.77%	51	4	2
40	7	0.14%	0.39%	4	1.77%	≤2	0.00%	≤2	0.37%	5	13.98%	5	83.88%	54	4	2
20	3	0.03%	0.02%	≤2	0.14%	≤2	0.00%	≤2	0.00%	≤2	0.07%	4	99.79%	60	4	2
							Aggregate Exposures at Q4 – 2002									
100	4	3.33%	3.75%	15	3.79%	17	0.09%	3	53.67%	17	2.29%	12	40.17%	16	4	2
80	4	2.13%	3.75%	14	3.75%	15	0.03%	≤2	0.94%	9	55.01%	21	40.27%	18	4	2
60	4	1.73%	3.04%	9	3.33%	11	0.42%	4	0.12%	5	55.67%	25	40.46%	20	4	2
40	2	2.98%	2.91%	5	3.04%	9	0.29%	≤2	0.45%	6	55.23%	25	40.98%	23	4	2
20	2	0.50%	0.50%	3	0.50%	3	0.00%	≤2	2.54%	6	1.31%	12	95.66%	44	4	2

Source : own calculation

Note : The table presents the results of the contagion exercises for December 2002 assuming that the first defaulter is a Belgian bank. The first panel of the table is based on a matrix of bilateral exposure estimated with the mixed technique, the second panel on the large exposures technique and the third on the aggregate exposures technique. Results are reported for 5 different LGD. Each line is based on 65 different scenarios (i.e. the individual failure of each of the 65 Belgian banks). The second column gives the number of scenarios that generate contagion (each line summarises 65 different scenarios). The third column presents the median scenario. The median scenario gives the median value, across all of the scenarios where contagion occurs, of the percentage of total banking assets represented by banks losing their tier-I capital. The remaining columns provide some statistics on the state of the banking system in the next-to-worst case and worst-case scenarios . The table presents the percentage of assets represented by, and the number of, failing banks and banks losing respectively between 100 % and 70 %, between 70 % and 40 %, between 40 % and 10 % or less than 10 % of their tier-I capital. Cells where there is two or less than two banks are marked with the symbol ≤ 2 in order to make single bank identification impossible. The two last columns present risk indicators of the first domino in the WCS. Two risk indicators are presented, the level of tier-1 capital (as a % of total assets) and the losses for bad loans (as a percentage of total commercial loans). For each indicator, the quartile to which the first domino belongs is indicated, 1 being the first quartile (highest capitalisation or lowest losses for bad loans) and 4 being the last quartile (lowest capitalisation or highest losses for bad loans).

Table 8 - Contagion propagation over time for a LGD of 60% - Worst case scenario - number of failing banks at each round of contagion.

		1st round	2nd Round	3rd Round	4th Round	5th Round	6th Round	7th Round	8th Round	9th Round	10th Round	11th Round
jun-02	Large	1										
	Medium											
	Small		7	1								
dec-01	Large	1										
	Medium		1									
	Small		10	5								
jun-01	Large	1										
	Medium		1									
	Small		7	7								
dec-00	Large	1										
	Medium		1									
	Small		6	8								
jun-00	Large	1										
	Medium		1									
	Small		5	7	1							
dec-99	Large	1		1								
	Medium		1									
	Small		1	21	8	1						
jun-99	Large	1										
	Medium		1									
	Small		7	8	1							
dec-98	Large	1		1	1							
	Medium		1									
	Small		9	9	3	5	2					
jun-98	Large	1			1							
	Medium			1								
	Small		3	1	7	11	3					
dec-97	Large	1										
	Medium			1								
	Small		3	7	9	1	2					
jun-97	Large					1	2	1				
	Medium			1	1							
	Small	1	2		9	4	10	10	2	2		
dec-96	Large						1	2				
	Medium			1		1		2				
	Small	1	2	1	10	2	1	13	6			
jun-96	Large	1			2	1						
	Medium			1		1						
	Small		5	9	6	13	6					
dec-95	Large	1						1	1		1	
	Medium					1				1		
	Small		3	3	1	1	7	6	6	4	3	6
jun-95	Large				1	2	1					
	Medium			1								
	Small	1	3	2	12	8	10	2				
dec-94	Large	1										
	Medium					1	1					
	Small		3	5	5	5	9	5				
jun-94	Large	1										
	Medium					1						
	Small		3	8	3	8	9					
dec-93	Large	1										
	Medium					1	1					
	Small		3	1	13	7	3	1				
jun-93	Large											
	Medium											
	Small	1	3	4	1	4						
dec-92	Large											
	Medium											
	Small	1	2	2								

Source : own calculation

Note : The table presents the number of banks failures for each round of contagion. Each row represents a different quarter. The columns represent the different rounds of contagion. The first round is constituted by the first domino. For each round, the table provides the number of large (>10% assets), medium-sized (> 3% of assets) and the small banks failing. The table is based on contagion exercises using the aggregate exposure technique to estimate the matrix of bilateral exposures.

Table 9 - Definition of explanatory variables

Variable	Definition	Rationale	Min	Max	Median
		Variables capturing the hypotheses			
LB	Domestic interbank exposures of/to large banks as a percentage of the total domestic exposures.	Proxies for the type of interbank market structure. In a money centre, this ratio should be equal to one since small banks are not linked together. To the extent that the structure moves to a complete structure, this ratio decreases.	0.636	0.941	0.700
DOM	Domestic interbank exposures as a percentage of the total interbank exposures.	This ratio indicates the level of internationalisation of interbank positions. A ratio equal to 1 would represent a "closed" system relying only on the domestic interbank market. A ratio equal to 0 would represent a fully internationalised system.	0.147	0.373	0.297
		Variables capturing other structural changes			
KIS	Non-weighted average of the ratio Tier-I capital of Belgian banks on assets of Belgian banks.	A higher capitalisation of banks should increase their resiliency to shocks and decreases indicators of contagion.	0.075	0.109	0.089
KISLDUMMY	Dummy variable equal to one when the tier-one capital ratio of large banks exceeds its long-term average and zero otherwise	Used in combination with LB as interaction variable measuring to what extent the money centres need to be well-capitalised to reduce contagion.	0	1	
		Variables capturing macroeconomic evolution			
GDP	Quarterly GDP growth.	Banks profits should increase when the GDP growth is high as the quality of their assets improves.	-0.041	0.058	0.017
INT	Term spread of the interbank interest rate (Bibor before 1999 and Euribor from 1999 onwards)	The term spread of the interbank interest rate represents the difference between the 1-year and the 1-month interbank interest rate. A high spread will constitute a positive environment for banks whose interbank liabilities are short-term and whose interbank assets are long term (which is to a certain extent the position of Belgian banks - see Table 4). A low spread on the other hand will constitute a negative environment for these banks.	-0.016	0.019	-0.002
		Other control variables			
Q2 Q3 Q4	Dummy variables identifying quarters	Control for seasonal effects			

Table 10 - Correlation between variables

	LB	DOM	KIS	GDP	INT	LBxKISLDummy
LB	1.00	-0.76	0.55	-0.01	-0.11	-0.70
DOM		1.00	-0.53	0.12	-0.04	0.31
KIS			1.00	-0.35	0.44	-0.37
GDP				1.00	-0.67	-0.06
INT					1.00	-0.01
LBxKISLDummy						1.00

Note: The table presents the correlation coefficient between the 5 explanatory variables. LB represent the share of interbank market large banks account for, DOM represents the interbank domestic exposure of Belgian banks, KIS is the non weighted average of the ratio Tier-I capital on assets of Belgian banks GDP is the quarterly GDP growth rate, INT is the term spread of the interbank interest rate and.LBxKISLdummy is an interaction variable between LB and KISLdummy is a dummy variable equal to one when the tier-one capital ratio of large banks exceeds its long term average and zero otherwise.

Table 11 - Regression results for WCS.

Intercept	GDP	INT	KIS	LB	DOM	LB* KISLdummy	R²	DW
				LGD 100%				
2.69	2.03	0.88	-3.41	-2.28			0.61	1.26
(6.66)***	(0.87)	(0.1)	(-0.58)	(-4.69)***				
1.65	-3.25	-0.22	-0.83	-0.97		-0.58	0.86	2.82
(5.91)***	(-0.63)	(-0.15)	(-0.23)	(-2.85)**		(-7.61)***		
-0.01	6.06	1.74	-4.26		3.8		0.73	1.35
(-0.01)	(0.92)	(0.89)	(-0.96)		(6.82)***			
0.56	1.59	1.79	-0.69	-0.89	3.02		0.76	1.62
(0.956)	(0.844)	(0.261)	(-0.145)	(-1.755)*	(4.327)***			
1.23	-0.05	-2.5	-0.45	-0.78	0.78	-0.51	0.87	2.72
(2.69)**	(-0.04)	(-0.48)	(-0.13)	(-2.05)**	(1.14)	(-5.13)***		
				LGD 80%				
3.23	-1.04	-9.98	-4.92	-2.87			0.73	1.04
(8.47)***	(-0.47)	(-1.24)	(-0.89)	(-6.27)***				
2.41	-13.26	-2.83	-2.87	-1.84		-0.46	0.85	2.17
(7.36)***	(-2.19)**	(-1.67)	(-0.69)	(-4.62)***		(-5.17)***		
0.3	-1.26	-1.15	-9.15		4.1		0.75	1.24
(0.54)	(-0.18)	(-0.54)	(-1.9)*		(6.79)***			
1.36	-1.42	-9.18	-2.52	-1.65	2.66		0.81	1.49
(2.35)**	(-0.77)	(-1.37)	(-0.54)	(-3.33)***	(3.89)***			
1.83	-2.59	-12.23	-2.35	-1.57	1.07	-0.36	0.86	2.11
(3.44)***	(-1.54)	(-2.03)*	(-0.57)	(-3.57)***	(1.35)	(-3.14)***		
				LGD 60%				
2.58	0.74	-10.28	-13.33	-1.36			0.59	1.09
(6.09)***	(0.3)	(-1.15)	(-2.17)**	(-2.66)**				
2.5	-10.57	0.58	-13.15	-1.27		-0.04	0.59	1.11
(5.1)***	(-1.16)	(0.23)	(-2.11)**	(-2.12)**		(-0.3)		
0.91	-7.48	0.53	-13.43		2.35		0.64	1.41
(1.52)	(-0.96)	(0.23)	(-2.57)**		(3.58)***			
1.21	0.46	-9.7	-11.57	-0.46	1.95		0.65	1.31
(1.67)	(0.2)	(-1.15)	(-1.99)*	(-0.74)	(2.28)**			
0.89	1.24	-7.66	-11.68	-0.52	3.01	0.24	0.67	1.36
(1.2)	(0.53)	(-0.92)	(-2.05)**	(-0.85)	(2.75)***	(1.52)		

Note :
Dependent variable is the worst case scenario measured as the percentage of total assets failed banks account for (WCS). Explanatory variables are GDP (the quarterly GDP growth rate), INT (the term spread of the interbank interest rate), KIS (the non weighted average of the ratio Tier-I capital on assets of Belgian banks), LB (the share of interbank market large banks account for), DOM (the interbank domestic exposure of Belgian banks), KISLDummy (a dummy variable equal to one when the tier one capital ratio of large banks exceeds its long term average and zero otherwise) and three dummy variables for the quarters (not reported). Each cell displays the t-statistic for the OLS coefficient. For each OLS estimation, the R^2 and the Durbin-Watson are given.
The sample comprises 41 observation (one per quarter between Q4-1992 and Q2-2002).
The first panel of the table assumes an LGD of 100%, the second panel a LGD of 80% and the third panel a LGD of 60%.
Significance level of the t-tests: (***) at the 1 % level, (**) at the 5 % level and (*) at the 10 % level.
Source: own calculation

Table 12. Regression results for CC.

Intercept	GDP	INT	KIS	LB	DOM	LB* KISLdummy	R²	DW
				LGD 100%				
1.49	0.77	1.36	-1.26	-1.14			0.67	1.23
(8.75)***	(0.78)	(0.38)	(-0.51)	(-5.55)***				
1.09	-0.22	-0.09	-0.27	-0.64		-0.22	0.85	2.07
(8.06)***	(-0.09)	(-0.13)	(-0.15)	(-3.86)***		(-6.01)***		
0.38	5.06	0.75	-3.28		1.55		0.67	0.92
(1.46)	(1.49)	(0.75)	(-1.44)		(5.42)***			
0.84	0.64	1.64	-0.42	-0.71	0.93		0.74	1.29
(2.982)**	(0.705)	(0.501)	(-0.185)	(-2.947)**	(2.785)**			
1.14	-0.11	-0.31	-0.31	-0.66	-0.09	-0.23	0.85	2.13
(5.03)***	(-0.16)	(-0.12)	(-0.18)	(-3.53)***	(-0.28)	(-4.72)***		
				LGD 80%				
1.48	-0.11	-3.27	-0.93	-1.25			0.7	1.28
(8.83)***	(-0.11)	(-0.92)	(-0.38)	(-6.16)***				
1.15	-4.59	-0.83	-0.11	-0.83		-0.18	0.81	2.37
(7.49)***	(-1.61)	(-1.04)	(-0.05)	(-4.42)***		(-4.42)***		
0.34	1.09	-0.09	-3.6		1.6		0.65	1.26
(1.24)	(0.31)	(-0.09)	(-1.51)		(5.33)***			
0.89	-0.23	-3.01	-0.17	-0.85	0.85		0.75	1.53
(3.15)***	(-0.26)	(-0.92)	(-0.07)	(-3.53)***	(2.54)**			
1.12	-0.82	-4.54	-0.08	-0.81	0.05	-0.18	0.81	2.35
(4.36)***	(-1.01)	(-1.55)	(-0.04)	(-3.83)***	(0.14)	(-3.25)***		
				LGD 60%				
1.2	0.7	-5.04	-6.85	-0.38			0.68	1.31
(7.97)***	(0.8)	(-1.6)	(-3.16)***	(-2.13)**				
1.15	-5.22	0.6	-6.74	-0.33		-0.03	0.69	1.39
(6.63)***	(-1.63)	(0.67)	(-3.06)***	(-1.55)		(-0.53)		
0.63	-4.69	0.59	-6.24		0.81		0.74	1.6
(3.07)***	(-1.75)*	(0.74)	(-3.48)***		(3.58)***			
0.64	0.58	-4.81	-6.15	-0.02	0.79		0.74	1.59
(2.58)**	(0.73)	(-1.65)	(-3.05)***	(-0.11)	(2.65)**			
0.54	0.85	-4.12	-6.19	-0.04	1.15	0.08	0.76	1.53
(2.1)**	(1.05)	(-1.42)	(-3.13)***	(-0.2)	(3.03)***	(1.49)		

Note :
Dependent variable is the number of cases of contagion in the worst case scenario (CC). Explanatory variables are GDP (the quarterly GDP growth rate), INT (the term spread of the interbank interest rate), KIS (the non weighted average of the ratio Tier-I capital on assets of Belgian banks), LB (the share of interbank market large banks account for), DOM (the interbank domestic exposure of Belgian banks) , KISLDummy (a dummy variable equal to one when the tier one capital ratio of large banks exceeds its long term average and zero otherwise) and three dummy variables for the quarters (not reported). Each cell displays the t-statistic for the OLS coefficient. For each OLS estimation, the R^2 and the Durbin-Watson are given.
The sample comprises 41 observation (one per quarter between Q4-1992 and Q2-2002).
The first panel of the table assumes an LGD of 100%, the second panel a LGD of 80% and the third panel a LGD of 60%.
Significance level of the t-tests: (***) at the 1 % level, (**) at the 5 % level and (*) at the 10 % level.
Source: own calculation

Table 13. Regression results for Round.

Intercept	GDP	INT	KIS	LB	DOM	LB* KISLdummy	R^2	DW
				LGD 100%				
13.53	-7.87	-47	6.06	-10.33			0.29	1.61
(3.83)***	(-0.38)	(-0.63)	(0.12)	(-2.43)**				
6.79	-73.91	-22.52	22.87	-1.83		-3.77	0.55	2.08
(2.06)*	(-1.21)	(-1.32)	(0.55)	(-0.46)		(-4.2)***		
2.47	-18.15	-8.56	-5.56		15.52		0.32	1.58
(0.47)	(-0.26)	(-0.42)	(-0.12)		(2.69)**			
5.89	-9.44	-43.75	15.86	-5.33	10.86		0.34	1.7
(0.936)	(-0.468)	(-0.597)	(0.312)	(-0.986)	(1.456)			
12.1	-24.68	-83.47	18.07	-4.3	-9.9	-4.69	0.57	2.22
(2.24)**	(-1.45)	(-1.37)	(0.43)	(-0.96)	(-1.24)	(-4.04)***		
				LGD 80%				
16.77	-18.71	-113.65	100.42	-25.34			0.63	0.89
(4.99)***	(-0.96)	(-1.6)	(2.06)**	(-6.27)***				
11.24	-135.76	-30.74	114.23	-18.36		-3.09	0.73	1.12
(3.36)***	(-2.19)**	(-1.77)*	(2.68)**	(-4.5)***		(-3.4)***		
-2.18	-4.69	-15.98	16.9		26.11		0.43	0.8
(-0.35)	(-0.06)	(-0.66)	(0.31)		(3.79)***			
12.11	-19.66	-111.67	106.4	-22.29	6.63		0.64	0.93
(1.99)*	(-1.01)	(-1.57)	(2.16)**	(-4.25)***	(0.92)			
17.7	-33.37	-147.38	108.39	-21.36	-12.03	-4.22	0.74	1.26
(3.27)***	(-1.95)*	(-2.4)**	(2.59)**	(-4.77)***	(-1.5)	(-3.62)***		
				LGD 60%				
23.39	7.23	-151.89	-48.89	-17.82			0.79	2.13
(9.64)***	(0.51)	(-2.97)***	(-1.39)	(-6.1)***				
21.47	-159.57	3.05	-44.09	-15.39		-1.07	0.81	2.21
(7.86)***	(-3.15)***	(0.22)	(-1.27)	(-4.62)***		(-1.44)		
8.93	-80.56	8.54	-100		20.02		0.72	1.7
(2.08)*	(-1.43)	(0.52)	(-2.66)**		(4.23)***			
18.17	6.16	-149.66	-42.18	-14.4	7.43		0.81	2.16
(4.2)***	(0.44)	(-2.97)***	(-1.21)	(-3.87)***	(1.45)			
19.03	4.05	-155.16	-41.88	-14.26	4.56	-0.65	0.81	2.19
(4.18)***	(0.28)	(-3.01)***	(-1.19)	(-3.8)***	(0.68)	(-0.66)		

Note :
Dependent variable is the number of rounds of contagion in the worst case scenario (Round). Explanatory variables are GDP (the quarterly GDP growth rate), INT (the term spread of the interbank interest rate), KIS (the non weighted average of the ratio Tier-I capital on assets of Belgian banks), LB (the share of interbank market large banks account for), DOM (the interbank domestic exposure of Belgian banks) , KISLDummy (a dummy variable equal to one when the tier one capital ratio of large banks exceeds its long term average and zero otherwise) and three dummy variables for the quarters (not reported). Each cell displays the t-statistic for the OLS coefficient. For each OLS estimation, the R^2 and the Durbin-Watson are given.
The sample comprises 41 observation (one per quarter between Q4-1992 and Q2-2002).
The first panel of the table assumes an LGD of 100%, the second panel a LGD of 80% and the third panel a LGD of 60%.
Significance level of the t-tests: (***) at the 1 % level, (**) at the 5 % level and (*) at the 10 % level.
Source: own calculation

Table 14 - Contagion exercise : Foreign bank as initial defaulter

LGD (%)	Number of scenarios where contagion occurs (out of 65 possible scenarios)	Median scenario assuming contagion Percentages of balance sheet assets represented by failing banks (excluding assets of "first domino")	Next-to-worst case scenario		Worst Case Scenario (excluding first domino)										Long Term Fitch rating of the first foreign bank to fail in the WCS
			Banks failing		Banks failing		Banks losing 100-70% of tier-I capital		Banks losing 70-40% of Tier-I capital		Banks losing 40-10% of tier-I capital		Banks losing less than 10% of Tier-I capital		
			% Balance sheet assets	# of banks	% Balance sheet assets	# of banks	% Balance sheet assets	# of banks	% Balance sheet assets	# of banks	% Balance sheet assets	# of banks	% Balance sheet assets	# of banks	
							Large Exposures at Q4 – 2002								
100	13	0.07%	20.01%	0.07	20.01%	7	0.00%	0	1.02%	5	67.36%	8	11.61%	45	AA-
80	9	0.04%	0.29%	≤2	19.97%	6	0.04%	1	0.44%	3	32.34%	6	47.21%	49	AA+
60	8	0.04%	0.08%	≤2	18.15%	4	1.82%	2	0.04%	1	32.78%	9	47.21%	49	AA+
40	3	0.08%	0.08%	≤2	18.08%	1	0.04%	2	1.89%	4	20.22%	7	59.77%	51	AA+
20	1	0.08%	0.00%	≤2	0.08%	1	0.00%	0	0.00%	0	0.00%	0	99.92%	64	A

Source : own calculation

Note : The table presents the results of the contagion exercises for December 2002 assuming that the first defaulter is a foreign bank. The table is based on a matrix of bilateral exposure estimated with the large exposures technique. Results are reported for 5 different LGD. Each line is based on 65 different scenarios (i.e. the individual failure of each of the 65 Belgian banks). The second column gives the number of scenarios that generate contagion (each line summarises 135 different scenarios). The third column presents the median scenario. The median scenario gives the median value, across all of the scenarios where contagion occurs, of the percentage of total banking assets represented by banks losing their tier-I capital. The remaining columns provide some statistics on the state of the banking system in the worst-case scenario (defined as the scenario for which the percentage of total banking assets represented by banks losing their entire tier-I capital is greater). The table presents the percentage of assets represented by, and the number of, failing banks and banks losing respectively between 100 % and 70 %, between 70 % and 40 %, between 40 % and 10 % or less than 10 % of their tier-I capital. Cells where there are two or less than two banks are marked with the symbol ≤ 2 in order to make single bank identification impossible.

Table 15 - Sensitivity of Belgian banks to losses on their interbank exposures to other countries.

	AT	DE	DK	ES	FI	FR	GR	IE	IT	LU	NL	PT	SE	UK
% of total interbank assets	0.70%	7.60%	0.50%	3.20%	0.20%	10.00%	0.60%	6.50%	1.30%	2.80%	10.10%	0.80%	0.10%	27.10%
LGD														
100	0%	1%	0%	0%	0%	22%	0%	0%	0%	0%	42%	0%	0%	94%
80	0%	1%	0%	0%	0%	22%	0%	0%	0%	0%	41%	0%	0%	41%
60	0%	1%	0%	0%	0%	22%	0%	0%	0%	0%	40%	0%	0%	40%
40	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%	1%	0%	0%	40%
20	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%	1%	0%	0%	0%

Source : own computations

Note : December 2002.
The first row of the table provides the percentage of total interbank exposures of Belgian banks each EU country accounts for. The remaining rows provide the results of the contagion exercise assuming that all the banks of a country default at the same time. Results are provided for several LGD. The results are percentages of total assets of the Belgian banking system the failed Belgian banks account for. The calculations are based on figures on a territorial basis. Country abbreviations are AT (Austria), DE (Germany), DK (Denmark), ES (Spain), FI (Finland), FR (France), GR (Greece), IE (Ireland), IT (Italy), LU (Luxembourg), NL (Netherlands), PT (Portugal), SE (Sweden), UK (United Kingdom).

Table 16 - Sensitivity of Belgian banks to losses on their interbank exposures to other countries : evolution over 1999 - 2002.

LGD	100	80	60	40	20
		Q2-1999			
LU	92%	92%	0%	0%	0%
NL	93%	1%	1%	0%	0%
UK	92%	92%	13%	0%	0%
		Q2-2000			
DE	93%	1%	1%	1%	1%
FR	65%	52%	0%	0%	0%
UK	94%	93%	76%	60%	0%
		Q2-2001			
FR	15%	13%	13%	11%	0%
NL	14%	12%	0%	0%	0%
UK	93%	92%	79%	60%	0%
		Q2-2002			
FR	73%	21%	0%	0%	0%
UK	94%	74%	53%	37%	36%

Source : own computations

Note :
The results presented in the table are based on contagion exercises assuming that all the banks of a country default at the same time. Results are provided for several LGD and only for countries triggering an impact exceeding 2% of the total banking assets assuming a 100% LGD. The results are percentages of total assets of the Belgian banking system the failed Belgian banks account for. The calculations are based on figures on a territorial basis. Country abbreviations are DE (Germany), FR (France), LU (Luxembourg), NL (Netherlands), and UK (United Kingdom).

Table 17 – WCS : baseline vs. other assumptions

Assumption	LGD	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
					WCS						
Baseline	100	90.9%	92.0%	87.5%	91.0%	93.3%	82.7%	78.8%	15.5%	13.7%	3.3%
	60	3.3%	14.1%	58.5%	73.0%	86.4%	35.7%	13.6%	13.2%	11.5%	2.9%
	20	0.0%	1.2%	0.6%	0.0%	0.0%	0.5%	0.5%	0.4%	0.3%	0.3%
Anticipation	100	NA	2.9%	73.8%	78.2%	75.5%	50.2%	60.2%	10.3%	9.5%	2.5%
	60	NA	1.9%	29.6%	11.3%	55.9%	8.9%	3.1%	9.7%	8.6%	0.4%
	20	NA	1.8%	1.1%	0.6%	0.6%	0.0%	0.5%	0.4%	0.3%	0.3%
TBTF	100	42.5%	87.8%	75.9%	85.3%	88.9%	5.5%	4.1%	6.1%	4.8%	0.0%
	60	3.3%	4.2%	41.2%	10.2%	55.0%	2.4%	3.9%	2.4%	4.1%	0.0%
	20	0.0%	1.2%	0.6%	0.0%	0.0%	0.0%	0.5%	0.4%	0.3%	0.0%
Tier-2	100	48.5%	86.8%	86.5%	90.2%	89.2%	37.3%	15.4%	13.7%	11.9%	1.6%
	60	1.9%	4.0%	28.2%	26.4%	57.9%	9.9%	0.6%	10.3%	2.8%	1.2%
	20	0.0%	1.2%	0.6%	0.0%	0.0%	0.5%	0.0%	0.0%	0.3%	0.0%
2 failures	100	93.0%	92.0%	89.6%	92.5%	93.3%	82.8%	80.9%	48.9%	32.3%	3.7%
	60	31.6%	72.5%	83.1%	84.8%	88.3%	36.1%	30.9%	14.9%	13.6%	3.4%
	20	0.6%	1.8%	1.1%	1.8%	11.1%	2.3%	1.8%	0.4%	2.5%	0.3%
3 failures	100	93.0%	92.0%	90.0%	92.9%	93.6%	82.9%	80.9%	48.9%	32.3%	4.4%
	60	45.0%	74.0%	83.4%	85.3%	88.5%	55.7%	49.2%	14.9%	13.6%	3.7%
	20	0.6%	1.8%	11.5%	11.1%	13.9%	2.4%	3.2%	9.5%	4.0%	2.7%
Macro shock	100	91.0%	92.0%	92.6%	92.9%	93.6%	87.4%	81.3%	48.9%	32.3%	3.4%
	60	3.7%	75.9%	84.9%	88.6%	87.8%	35.9%	13.6%	14.9%	13.3%	2.9%
	20	0.0%	1.2%	0.6%	0.0%	0.0%	0.5%	0.5%	0.4%	1.9%	0.3%
Netting	100	2.4%	2.6%	2.2%	2.4%	0.8%	3.8%	3.9%	12.6%	4.5%	3.3%
	60	0.7%	2.0%	1.1%	0.6%	0.6%	0.6%	3.3%	1.0%	4.1%	2.8%
	20	0.0%	1.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%	0.0%
Random LGD	# simul	1110000	1100000	1060000	1040000	950000	880000	750000	720000	670000	660000
	95 perc	0.0%	1.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	99 perc	1.9%	6.7%	50.6%	72.9%	75.9%	12.2%	12.4%	11.9%	11.5%	2.9%
	max	76.2%	86.4%	85.4%	90.6%	93.0%	82.5%	73.9%	15.0%	13.7%	3.3%

Source : own calculation

Note : Figures for Q2 of each year. The table presents the evolution of the WCS under alternative assumptions, regarding banks' anticipation, too-big-to-fail mechanisms, the failure threshold, multiples failures and macro shocks, netting and the LGD. Results are provided for three different LGDs.

Table 18 - Number of cases of contagion : baseline vs. alternative assumptions

Assumption	LGD	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
					number of cases of contagion						
Baseline	# sim/LGD	111	110	106	104	95	88	75	72	67	66
	100	9	26	8	9	9	8	5	4	4	4
	60	7	20	7	5	6	4	5	4	4	4
	20	0	12	1	0	0	1	2	1	3	2
Anticipation	# sim/LGD	111	110	106	104	95	88	75	72	67	66
	100	NA	24	7	9	9	3	5	4	4	4
	60	NA	20	5	5	5	1	5	4	4	4
	20	NA	11	0	0	0	0	0	0	3	1
TBTF	# sim/LGD	111	110	106	104	95	88	75	72	67	66
	100	3	21	4	5	5	3	1	1	1	0
	60	2	15	3	2	2	1	1	1	1	0
	20	0	7	1	0	0	0	1	1	1	0
Tier-2	# sim/LGD	111	110	106	104	95	88	75	72	67	66
	100	8	26	7	8	9	8	5	4	4	4
	60	4	20	6	5	5	4	5	4	4	4
	20	0	12	1	0	0	1	0	0	2	0
2 failures	# sim/LGD	6105	5995	5565	5356	4465	3828	2775	2556	2211	2145
	100	1058	2801	834	905	817	675	382	299	268	255
	60	795	2110	717	553	627	394	359	278	257	253
	20	15	1384	117	21	15	97	149	85	192	128
3 failures	# sim/LGD	221815	215820	192920	182104	138415	109736	67525	59640	47905	45760
	100	59272	141257	43030	45193	36761	28151	14111	10795	8881	8068
	60	43777	109856	36412	30047	30445	18343	12716	9533	8146	7879
	20	1642	74989	6730	2196	1391	4573	5503	3444	6065	4033
Macro shock	# sim/LGD	111	110	106	104	95	88	75	72	67	66
	100	11	27	8	9	9	8	6	5	4	4
	60	8	20	7	7	8	6	5	4	4	4
	20	0	15	1	0	0	1	3	2	3	2
Netting	# sim/LGD	111	110	106	104	95	88	75	72	67	66
	100	4	15	7	7	6	8	5	4	4	4
	60	1	11	3	5	2	4	4	4	4	3
	20	0	2	0	0	0	0	0	0	2	0

Source : own calculation

Note : Figures for Q2 of each year. The table presents the evolution of the number of cases of contagion under alternative assumptions, regarding banks' anticipation, too-big-to-fail mechanisms, the failure threshold, multiple failures and macro shocks. Results are provided for three different LGDs. The number of scenarios tested is given for each alternative assumption.

Table 19 - Number of failing banks in the WCS : baseline vs. alternative assumptions

Assumption	LGD	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
					number of banks failing in the WCS						
Baseline	100	72	85	67	63	58	50	43	26	24	14
	60	14	34	41	45	45	28	18	15	16	9
	20	1	2	2	1	1	2	2	2	2	2
Anticipation	100	NA	11	49	41	34	23	2	11	11	7
	60	NA	5	23	12	24	4	6	10	8	3
	20	NA	2	1	1	1	1	1	1	2	2
TBTF	100	48	64	43	44	45	10	13	13	13	1
	60	14	15	22	16	24	5	10	7	8	1
	20	1	2	2	1	1	1	2	2	2	1
Tier-2	100	58	74	64	56	53	35	24	22	20	11
	60	6	12	26	24	30	11	5	12	7	5
	20	0	1	1	0	0	1	0	0	1	0
2 failures	100	70	83	65	60	56	49	41	31	28	19
	60	44	62	44	44	43	28	28	20	19	15
	20	1	3	3	3	6	3	4	2	3	1
3 failures	100	72	83	66	61	55	51	41	31	29	22
	60	48	61	45	45	43	33	29	21	20	17
	20	1	3	11	11	10	4	7	7	6	5
Macro shock	100	73	85	66	63	58	52	44	30	29	15
	60	14	65	51	48	45	28	17	20	18	9
	20	0	1	1	0	0	1	1	1	2	1
Netting	100	10	10	7	9	3	9	11	13	11	12
	60	3	7	4	3	1	3	7	5	7	7
	20	0	1	0	0	0	0	0	0	1	0

Source : own calculation

Note : Figures for Q2 of each year. The table presents the evolution of the number of the number of failing banks in the WCS under alternative assumptions, regarding banks' anticipation, too-big-to-fail mechanisms, the failure threshold, multiple failures and macro shocks. Results are provided for three different LGDs.

Table 20 - WCS assuming co-ordination.

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Contagion without coordination	3.3%	14.1%	58.5%	73.0%	86.4%	35.7%	13.6%	13.2%	11.5%	2.9%
Contagion with coordination	3.3%	14.1%	58.5%	0.0%	0.0%	0.0%	13.6%	13.2%	11.5%	2.9%
delta HHI	0.00%	0.00%	0.00%	0.57%	0.24%	0.33%	0.00%	0.00%	0.00%	0.00%
# banks 2nd round	3	3	3	5	2	3	8	6	8	7
% of assets	1.9%	1.8%	1.1%	4.2%	1.7%	2.3%	11.6%	8.1%	10.8%	2.8%
# banks 2nd round that actually merged	0	0	0	5	2	3	0	0	0	0
# banks 3rd round	4	8	3	10	1	2	8	7	7	1
% of assets	0.6%	1.7%	7.4%	8.4%	6.5%	6.6%	1.8%	3.8%	0.8%	0.0%
# banks 3rd round that actually merged	0	0	0	1	1	1	0	0	0	0
# possible mergers	105	1785	49	31713	3	21	65025	8001	32385	127

Source : NBB

Note : Figures for Q2 of each year. The table presents how allowing for co-ordination modifies the WCS. The first panel presents the evolution over time of the WCS with and without co-ordination. The second panel presents the increase of the Herfindahl index resulting from the merger. The third panel presents the number of banks that could have merged and the number of banks that actually merged. The last row presents the number of different potential mergers involving banks failing in the second and the third rounds in absence of co-ordination. Results are provided for the 60% LGD.

Table 21 - Contagion propagation over time for a LGD of 60% in presence of a Too-Big-To-Fail assumption.

		1st round	2nd Round	3rd Round	4th Round	5th Round	6th Round	7th Round	8th Round	9th Round	10th Round	11th Round
jun-97	Large					1	2	1				
	Medium			1	1							
	Small	1	2		9	4	10	10	2	2		
jun-97 TBTF	Large					1- R	1 - R					
	Medium			1	1							
	Small	1	2		9	4	4					
dec-96	Large						1	2				
	Medium			1		1		2				
	Small	1	2	1	10	2	1	13	6			
dec-96 TBTF	Large						1 - R					
	Medium			1		1						
	Small	1	2	1	10	2	1					
jun-96	Large	1			2	1						
	Medium			1		1						
	Small		5	9	6	13	6					
jun-96 TBTF	Large	1 - R										
	Medium											
	Small											
dec-95	Large	1						1	1		1	
	Medium					1				1		
	Small		3	3	1	1	7	6	6	4	3	6
dec-95 TBTF	Large	1 - R										
	Medium											
	Small											
jun-95	Large				1	2	1					
	Medium			1								
	Small	1	3	2	12	8	10	2				
jun-95 TBTF	Large				1 - R	1 - R						
	Medium			1								
	Small	1	3	2	12	1						

Source : Own calculation

Note : The table presents the number of banks failures for each round of contagion. Each row represents a different quarter. The columns represent the different rounds of contagion. The first round is constituted by the first domino. For each round, the table provides the number of large (>10% assets), medium-sized (> 3% of assets) and the small banks failing. The table is based on contagion exercises using the aggregate exposure technique to estimate the matrix of bilateral exposures. For each quarter, one row presents the results obtained with the basic model and one row presents the results obtained when we assume a TBTF. R stands for rescued.

Table 22 - International comparisons

LGD (Percentages)	Case of multiple failures triggered by a domestic bank	Maximum number of failed banks in a scenario (including "first domino")	Median scenario Percentages of balance sheet assets affected (excluding assets of "first domino")	Worst-case scenario Percentages of balance sheet assets affected (excluding assets of "first domino")
Aggregate exposures - Belgium December 1998 (a)				
75	7	34	0.50%	56.00%
50	2	21	14.49%	28.46%
40	2	16	7.69%	14.87%
25	1	2	0.50%	0.50%
10	0	1	-	0.00%
Upper and Worms (Germany) end December 1998 (b)				
75	N.A.	2444	0.85% (c)	76.30%
50	N.A.	1740	0.66%(c)	61.60%
40	N.A.	115	0.58%(c)	5.00%
25	N.A.	31	0.3%(c)	0.75%
10	N.A.	19	0.26%(c)	0.57%
Aggregate exposures - Belgium December 2000(d)				
100	5	36	3.16%	61.92%
80	5	21	3.10%	13.86%
60	4	16	0.43%	11.64%
40	4	4	0.40%	0.43%
20	3	2	0.39%	0.39%
Bank of England FSR at end 2000(e)				
100	4	N.A.	8.80%	25.20%
80	4	N.A.	1.00%	6.70%
60	3	N.A.	0.00%	6.70%
40	2	N.A.	0.00%	0.00%
20	0	N.A.	0.00%	0.00%

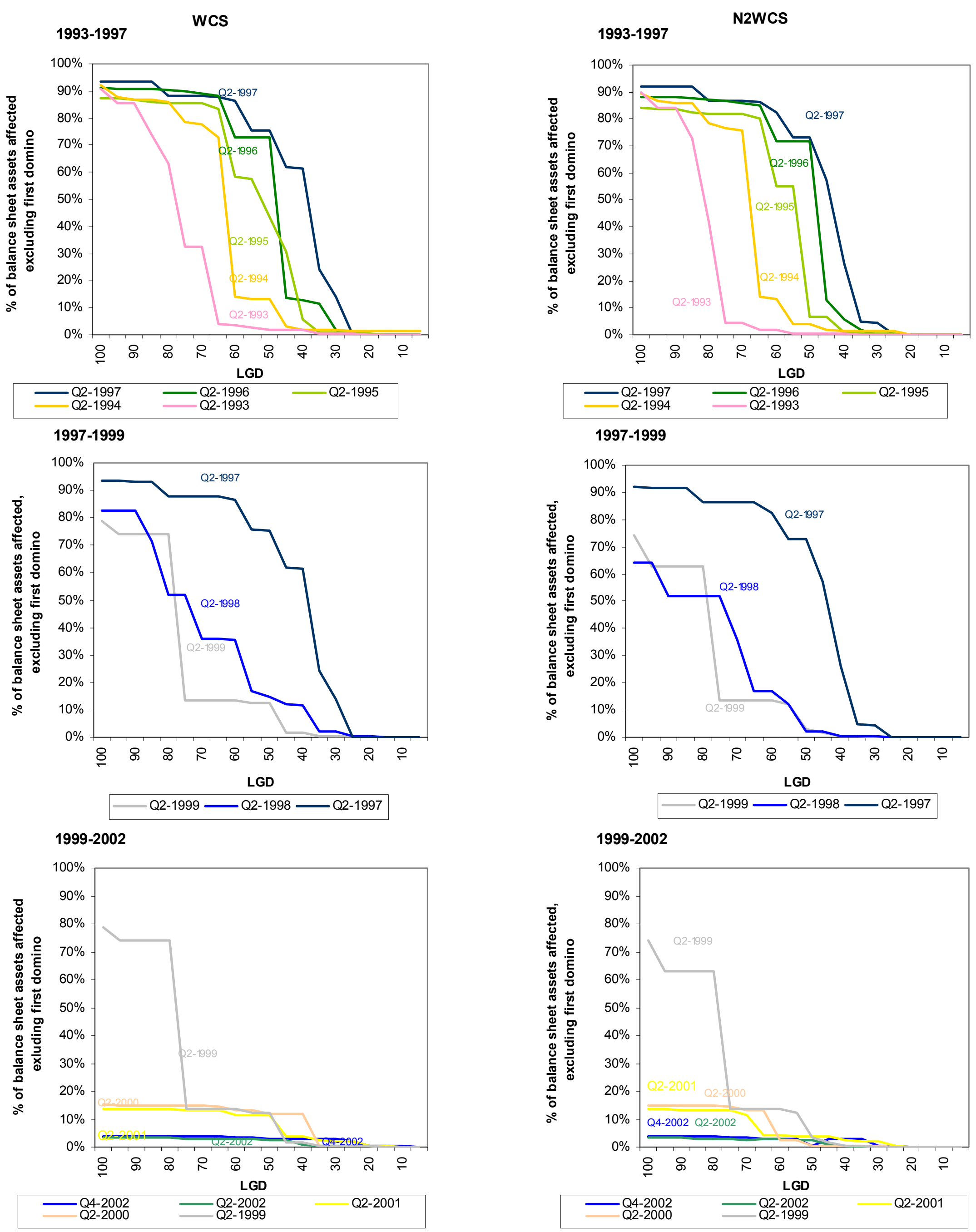
Sources : Upper and Worms (2002), Wells (2002), NBB.

Note : The table presents comparative contagion indicators for Belgium, the United Kingdom end Germany. Results are presented for several LGDs.

Note that as the median is calculated on very few observations; it sometimes increases when LGD decreases.

(a) Out of 80 cases
(b) Out of 3246 banks
(c) Average instead of median - not conditional on multiple failure
(d) Out of 72 cases
(e) Out of 33 possible cases

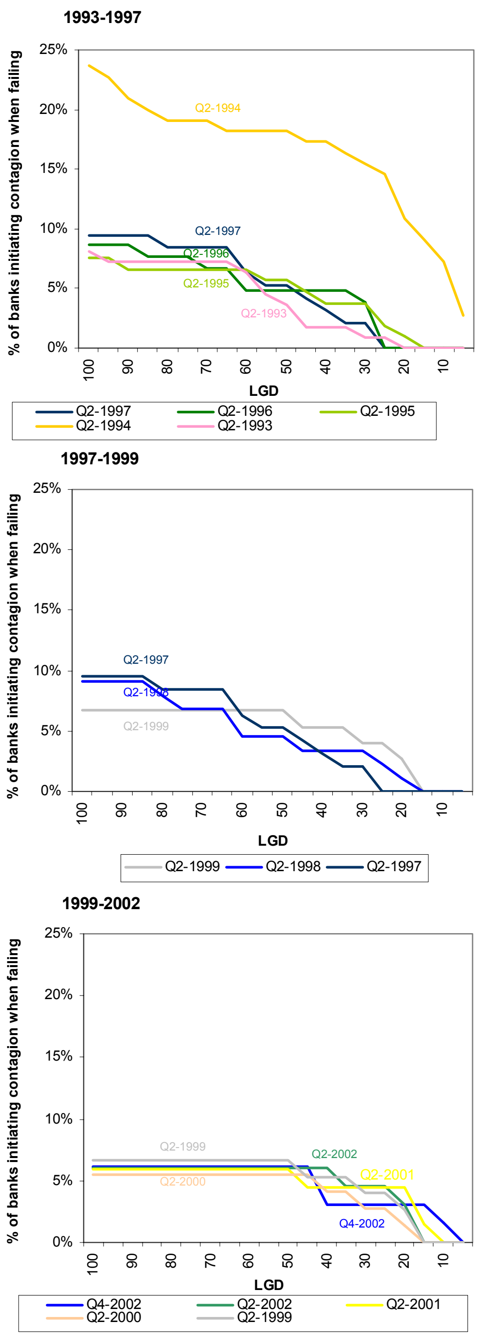
Chart 1 - Contagion effect - Worst case scenario and Next-to-worst case scenario - 1993-2002.



Source : own calculation

Note: The graphs present the evolution of the worst case scenario and of Next-to-worst case scenario for 20 different LGDs over time. The results are based on contagion exercises using matrices of bilateral exposures estimated with the aggregate exposure technique.

Chart 2 - Percentage of banks initiating contagion when failing 1993-2002



Source : own calculation

Note: The graphs present the evolution in the number of cases of contagion for 20 different LGDs over time. The results are based on contagion exercises using matrices of bilateral exposures estimated with the aggregate exposure technique.