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Contagion Risk in the Danish Interbank Market

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Resumé
På baggrund af betalinger foretaget i det danske betalingssystem til store betalinger beregnes et unikt, højfrekvent datasæt, der viser bilaterale eksponeringer mellem banker. Med udgangspunkt i dette datasæt analyseres efterfølgende risikoen for smitteeffekter på det danske interbank marked. Resultatet af analysen er, at risikoen for finansielle smitteeffekter som følge af en uventet konkurs i en stor bank er meget begrænset. Det gælder selv, hvis bankerne antages at tabe hele deres eksponering. I de tilfælde, hvor der identificeres en risiko for smitteeffekter, påvirker det kun mindre banker. Der identificeres på intet tidspunkt sekundære smitteeffekter.

Abstract
This paper uses records of payments in the Danish large value payment system to compute a unique, high-frequency data set on bilateral exposures between banks. The risk of contagion in the Danish interbank market is subsequently analysed using this data set. It is found that the risk of financial contagion due to an unexpected failure of a major bank is very limited. This applies even when banks are assumed to loose all their exposure, i.e. a loss given default of 100 per cent. Where contagion is identified, it affects only smaller banks and no further knock-on effects are found.

1. Introduction

One of the major objectives for central banks is to ensure financial stability. In particular, central banks are concerned with any potential contagion risk, where an event (or shock) in one bank spread to other banks and trigger a loss of value or confidence throughout an entire financial market or system. Analysing contagion risk is therefore an important and necessary area of research for central banks.

Contagion may be divided into direct and indirect contagion. Direct contagion is a consequence of real exposures between banks and represents the risk that a single bank failure may lead to multiple bank failures as the value of claims on the failed bank deteriorate. Indirect contagion is when bad news from one bank leads to a general market conclusion that other banks are also in trouble and induces behaviour, which causes problems for other banks e.g. withdrawal of funds. This working paper will address direct contagion only. Specifically, it is analysed whether overnight deposits in the interbank market are of a size that implies that an unexpected failure of a bank will cause other banks to fail. Thus the analysis is focused on one specific type of credit risk to which banks are exposed. Banks are also incurred to other credit risks as well as other types of risks such as liquidity, operational and market risk.

Most studies of contagion rely on infrequent information provided by banks on their bilateral or aggregated exposures, e.g. their balance-sheet statements. This paper analyses the level of contagion risk between banks[1] by examining records of payments in Denmark's large value payment system, Kronos. The method provides unique, high-frequency, and very precise data on banks' bilateral exposures. This data offers the possibility to examine the risk of contagion in great detail and analyse the direct impact of a bank failure. Moreover, the data allows us to measure any potential secondary knock-on effects.

This working paper is structured as follows. Part 2 presents a brief survey of related research. Part 3 describes the Danish money market. Part 4 reveals how the data is computed. The assessment of contagion risk in the Danish deposit market is depicted in part 5. Part 6 presents the results and part 7 concludes.

2. Related Research

For an overview of the earlier studies on systemic risk De Bandt and Hartmann (2000) provide a comprehensive survey. As opposed to the literature reviewed by De Bandt and Hartmann (2000), this working paper neither addresses contagion risk in the payment[2] and securities settlement systems nor indirect contagion risk. Only work similar in nature to ours is reviewed below.

Generally, contagion risk depends on the structure of the interbank market, i.e. the pattern of borrowing among banks and the level of concentration. Allen and Gale (2000) and Freixas et al (2000) identify three overall market structures.

The first market structure is referred to as a "complete structure" in which every bank has symmetric linkages with the other banks in the economy, i.e. each bank has financial relations to all other banks in the economy. This structure is characterised by a low level of contagion risk. The second market structure is characterised as an

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1 No distinction is made between different types of credit institutions for the purpose of this working paper. They are simply generically referred to as banks.

2 For a game theoretic approach to banks' intraday behaviour in the payment system see Bech & Garratt (2002).

"incomplete structure", where banks have links to only a few banks. This kind of structure is shown to be more fragile to contagion. The third market structure is one characterized by a ‘money centre bank’. The smaller banks are linked to the bank at the centre, but not to each other. In this structure the failure of the money centre can be expected to trigger the failure of other banks, while the failure of the smaller banks would not.

These general observations entail that the identification and determination of the interbank market structure can provide valuable information on the level of contagion risk.

Analysing the risk of contagion requires data on bilateral exposures. Blåvarg and Nimander (2002) analyse contagion risk between the four largest banks in Sweden using quarterly data submitted by the banks to Riksbanken[3]. The data contains bilateral information on deposits, securities holdings, FX transactions and derivatives. They find that failure of one bank will not lead to any other bank loosing its entire core capital. The benefit of the Blåvarg and Nimander approach is that the data, if correctly reported, provides qualitative information on exposures. However, the drawback to a survey approach is that the reporting of exposures can be relatively burdensome for banks, which entails that banks are normally requested to provide data infrequently, e.g. in association with the general reporting to the financial supervisory authorities. This implies that the analyses are only at specific points in time and not on a continuous basis. As actual exposures between reporting days can be significantly higher, serious concerns can be raised regarding the data.

Degryse & Nguyen (2004), Wells (2004) and Upper & Worms (2002) use a slightly different approach. The approach can be considered as a top-down approach where the matrix of bilateral exposures is computed via the banks’ balance sheets and thus their aggregate exposures. Upper and Worms (2002) find that the failure of one German bank could lead to the failure of banks with up to 15 % of the total assets in the German banking sector, suggesting that the failure of one bank can have quite severe impacts for Germany. Degryse & Nguyen (2004) find evidence that the Belgian banking sector has moved from a complete structure to a structure of multiple money centres as well as a more concentrated banking market. At the same

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[3] Central bank of Sweden.

time foreign banks are now controlling a large part of the banking sector. Moreover, they find that if a foreign bank fails the risk of contagion in the local market has increased. This development is particularly interesting from a regulatory perspective as the national market can be severely impacted by failures of banks that are not under direct supervision by national authorities[4]. Using a methodology similar to Upper & Worms (2002) and Wells (2002 and 2004) reveals that in the UK the event of a large banks failure bears the potential for a substantial weakening in the capital of a number of other banks.

Generally, some of the same problems that characterised the study by Blåvarg & Nimander (2002) may also impose difficulties for these studies. Moreover, the estimation of bilateral exposures from banks 'gross exposures' is associated with a great deal of uncertainty compared to the actual bilateral exposures as it requires restrictive assumptions on the distribution of the gross exposures. Consequently, estimated exposures may differ significantly from actual exposures.

Instead of a top down approach, a "micro approach" (or bottom up) can be considered. In Furfine (2003) transactions in the US RTGS[5]-payment system, Fedwire, are used to identify overnight deposits and hence estimate bilateral exposures between banks in the overnight federal funds market. Assuming a recovery rate of 40 per cent (i.e. a LGD[6] of 60 per cent), contagion risk is generally found to only affect smaller banks, although banks with more than 30 billion dollars worth of total assets can be affected in a way that would lead to their discontinuation. The merit of this approach is that exposures can be measured more precisely and for consecutive days over a longer horizon. Overnight deposits are uncollateralised and as such they are a very important part of total interbank exposures, as losses in the case of a default, may be significant. However, it provides only a partial picture of the exposures, as other uncollateralised interbank exposures exist (e.g. longer term deposits, corporate bonds and equity).

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4 This depends on whether it is a branch or a subsidiary. For a further discussion of this matter, see Danmarks Nationalbank (2004). For a more theoretical approach see Harr and Rønde (2005).

5 RTGS – Real Time Gross Settlement. An RTGS system is used by banks for the settlement of large value payments on accounts in the central bank. It is typically owned and operated by the central bank. For a description of the Danish RTGS system, Kronos, see Angelius & Petersen (2002).

6 LGD: Loss Given Default.

Finally, Elsinger et al. (2002) in a network model of interbank exposures, analyse the consequences of macroeconomic shocks for banks insolvency risk in Austria. More precisely, they analyse how real shocks to the economy propagate to the banks taking into account their bilateral exposures. It is found that the Austrian system is very stable and that default events that can be classified as systemic are highly unlikely. Only a small fraction of the defaults are due to contagion. The vast majority of simulated defaults are directly attributable to the macroeconomic shocks.

3. The Danish Money Market[7]

The Danish money market[8] is the market for interbank loan agreements and interest-rate derivatives denominated in kroner with a maturity of up to one year. In the money market counterparties exchange liquidity and manage their short-term interest-rate positions. The three most important structured products are Deposits, Repurchase agreements (repos) and Foreign-exchange swaps (FX swaps).

Deposits are uncollateralised DKK-denominated loans with standardised maturities between 1 day and 12 months.

Repo transactions are collateralised DKK-denominated loans with standard maturity from 1 day up to 6 months. The collateral typically consists of Danish government or mortgage bonds[9]. In a repo the seller (the receiver of liquidity) agrees to buy back the securities at a later date at a set fixed price. The difference between the purchase and sale price reflects the repo rate.

FX swaps are collateralised DKK-denominated loans with standard maturity from 1 day up to 12 months, where the collateral is foreign exchange. FX swaps can be seen as a simultaneous spot and forward foreign-exchange contract: when the spot transaction is settled, DKK are exchanged for the foreign currency, and vice versa when the forward contract is settled. The spot and forward exchange rates applied reflect the interest rate on the FX swap.

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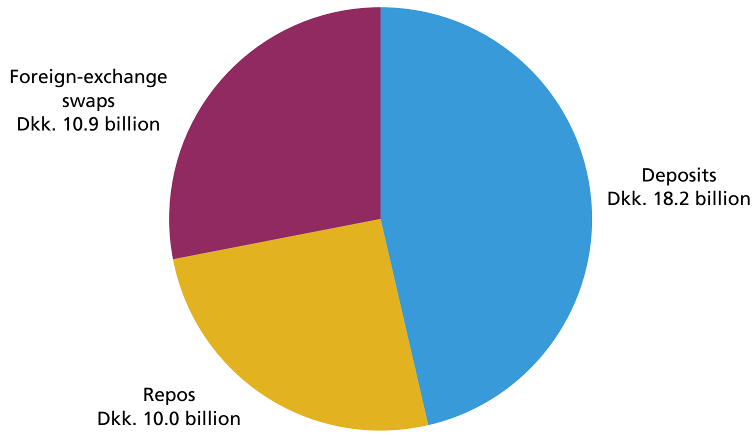
7 For a comprehensive description of the Danish Money Market, see Pedersen & Sand (2002).

8 For the purpose of this working paper no distinction is made between the money market and the interbank market.

9 For a description of the Danish market for mortgage bonds, see Frankel et al (2004).

Deposits with a maturity of one day[10] are divided into two different segments called overnight (ON) and tomorrow next (TN) respectively[11]. In a TN transaction the deal is struck on day 0 while the actual cash is deposited on day 1 and repaid (including interest) on day 2, whereas in an ON transaction cash is deposited the same day as the deal is struck (day 0) and repaid the following day (day 1). TN transactions account for the majority of the day-to-day transactions on the money market.

AVERAGE DAILY TURNOVER OF DAY-TO-DAY LOANS ON THE MONEY MARKET IN 2004 — Chart 1



Note: Foreign exchange swaps and repos are based on daily reports from 12 Danish banks. Deposits are additionally based on payments via Danmarks Nationalbank's payments system Kronos. For deposits the turnover comprises overnight (o/n) and tomorrow-next (t/n) deposits, for repos t/n and spot-next (s/n) repos, and for foreign exchange swaps t/n FX swaps.
Source: Danmarks Nationalbank.

On average, the total turnover of day-to-day deposits in the Danish money market was DKK 18.2 billion per banking day in 2004, cf. chart 1.

4. Data

Inspired by the work of Furfine (1999) and (2003), banks overnight exposures are identified by examining payment records in Denmark's RTGS system, Kronos. This provides a unique opportunity to identify

[10] Overnight includes all deposits from one banking day to the next. I.e. a deposit on a Friday, which is due the following Monday is an overnight deposit.

[11] In principle also spot next (SN) transactions take place, where the deal is agreed on day 0, the deposit takes place on day 2 and the repayment on day 3. However, this market segment is extremely small and thus not considered separately.

a data set of banks' bilateral exposures on a continuous basis. The data is used to analyse the size of banks' bilateral exposures and specifically to investigate if the failure of an important player is likely to trigger financial contagion and thus cause a threat to financial stability.

4.1. Computation of Data

Kronos is owned and operated by Danmarks Nationalbank, where all monetary counterparties hold a current account with the purpose of settling their payments. For each and every transfer via Kronos records are kept. It is these records that are used to estimate the matrix of bilateral exposures.

An algorithm runs through all payments in Kronos in order to identify overnight deposits.

The working of the algorithm is simple. If bank A and bank B agree on an overnight deposit it is reflected by two payments via Kronos. If for instance A has agreed to deposit DKK 100 million overnight to B, at a p.a. rate of 2 per cent, bank A's current account in Danmarks Nationalbank will be debited DKK 100 million and bank B's current account will be credited accordingly. The following day a reverse transaction of DKK 100 million + interest ((2%*100,000,000/360) = DKK 5,555.56) will be made from B to A. Records of these two book-entries are subsequently matched by the algorithm.

The interest rate is unknown as the terms of a deposit is agreed upon on a case-by-case basis on the OTC market[12]. As the interest rate depends on credit worthiness and liquidity conditions it may vary from trade to trade. Consequently, the interest rate is allowed to float within an interval, when the algorithm searches for matching transactions. The interval is set using daily interest rates reports from 12 monetary counterparties[13]. The interval is defined by selecting the highest and lowest reported interest rate plus/minus 25 basis points respectively. The calculation is further described in box 1.

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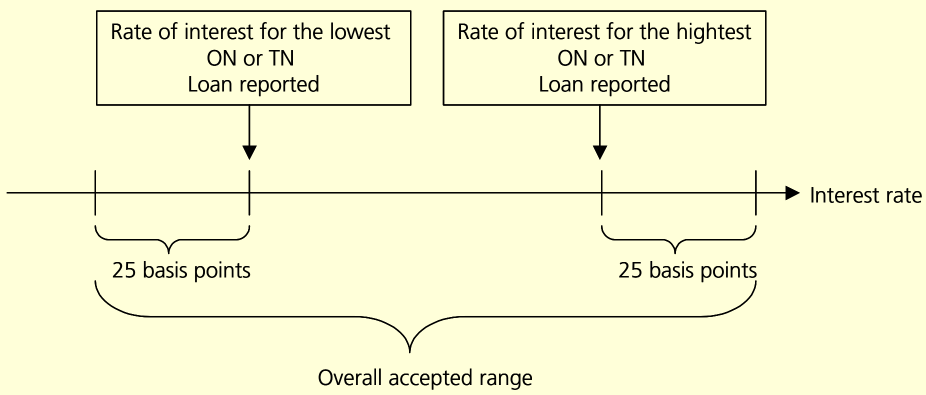
[12] OTC – Over The Counter: A market for securities, foreign exchange etc. where the contact between buyer and seller takes place by telephone, fax, computer or similar.

[13] This information is primarily collected to calculate the CIBOR (Copenhagen InterBank Offer Rate), which is a reference interest rate.

INTEREST RATE INTERVAL — Box 1

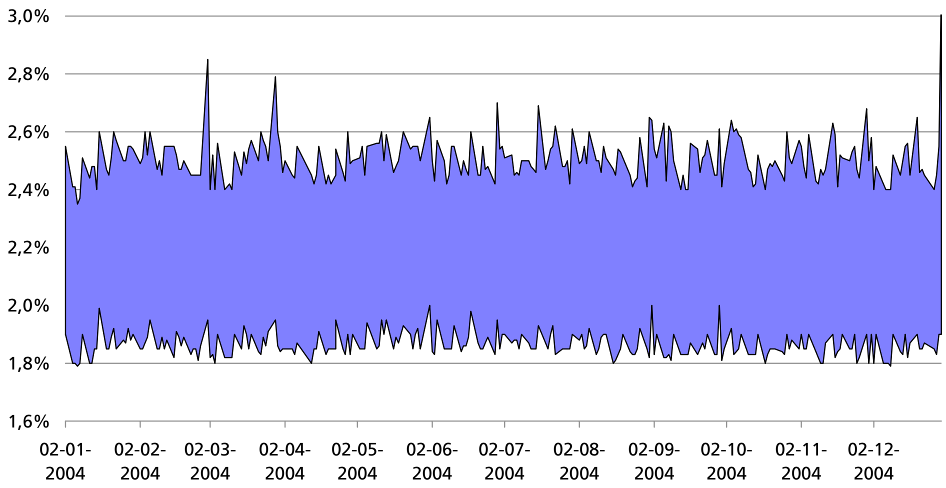
Reports on ON and TN transactions from 12 banks are used to set the interest rate interval. Both types of transactions are included, because no distinction can be made between ON and TN transactions, as only the date and time of the settlement is known, i.e. no information is available regarding the timing of the agreement of the transaction.
For every banking business day yesterday's TN and today's ON interest rates are used. From these interest rates, the lowest r(min) and the highest interest rate r(max) are chosen every day. The r(max) and the r(min) are used to estimate the interest rate interval. The lower boundary of the interest rate interval is estimated as r(min) less 0.25 per cent p.a. and the upper boundary as r(max) added 0.25 per cent p.a. The interval varies daily as the interest rates set by the banks change continuously.

INTEREST RATE INTERVAL OF THE SEARCH ALGORITHM



The interval is not constant as the levels of the lower and upper bound change daily, cf. chart 2.

INTEREST RATE INTERVAL USED IN THE ALGORITHM Chart 2



Note: For a more general description of interest rates and the Danish monetary policy, please refer to Danmarks Nationalbank (2003) 2.
Source: Danmarks Nationalbank

The 25 basis points are added/deducted as the reported interest rates are weighed averages of all trades estimated by the counterparties. Consequently, the interest rate on the individual deposits may differ from the average interest rate. Selecting the correct number of basis points to add/deduct represents a trade-off between including too many observations and neglecting relevant matches.[14]

As the focus is on deposits only, some additional criteria have been applied to the algorithm to ensure that only deposits are caught and not FX swaps or repos. Payments are only considered possible candidates if they are of DKK 1 million or higher. Moreover, the first payment has to be in round lots, i.e. it needs to end on five zeros[15]. FX swaps are backed against collateral and do not distort the data as they are negotiated in dollar. Repos are disregarded as they are backed against collateral, and thus settled through VP Securities Services (the Danish Central Securities Depository) implying that the cash leg is settled on other accounts.

[14] Tests were carried out prior to selecting the 25 basis points (not reported in this paper).

[15] This corresponds to the convention on the money market where deposits are typically agreed in round lots.

4.2. Characteristics of the Data

The data is based on transactions between 117 current account holders of Denmark's Nationalbank in 2004.

The data only capture the exposures between banks, subsidiaries or branches that are represented in Denmark. Thus the activity in the Danish money market by banks represented by a correspondent bank is not captured.

More than 853,000 payments were processed between current accounts averaging 3,370 payments per banking day in 2004. Of these 9.6 per cent were identified as round lots and therefore as possible candidates for overnight deposits. Matching repayments were found for 10,407 transactions corresponding to 1.2 per cent of all payments. On average 41 overnight deposits take place each day with an average value of DKK 201 million per deposit.

The average total of overnight deposits in 2004 was DKK 8.3 billion per banking day. The turnover is more or less the same on the weeks first four banking days. On Fridays, when counterparties have the option of buying certificates of deposits or take up collateralised loans with Danmarks Nationalbank, the average turnover is lowest (DKK 6.8 billion).[16]

The six largest banks account for 60 per cent of the total turnover, while the remaining banks account for 40 per cent. 11 banks were active in terms of both depositing and lending in 2004. In Abildgren and Arnt (2004) the group of medium-sized banks is found to account for 7-13 per cent of the turnover between them. Against this background it can be argued that the Danish money market has characteristics of a complete structure as well as a money centre bank structure.

The tendency for a large part of the turnover to be concentrated on relatively few participants is known from money markets in other countries[17]. For a further discussion of the microstructures in the Danish money market see Abildgren and Arnt (2004).

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[16] Approximately half of the turnover in the overnight deposit market is traded between domestic and foreign participants, while the other half is traded among Danish banks, (Danmarks Nationalbank's monetary-policy counterparties).

[17] See e.g. Furfine (1999)

4.3. Caveats

The number of matched transactions is associated with some uncertainties. For example, the algorithm fails to identify when deposits, to the same bank on the same day, are bundled into one repayment the following banking day. Banks can also choose to repay their obligations by two separate payments, one including the principal and one including the interest (banks have a clear incentive to make just one payment as they are charged a per-transaction fee in Kronos).

Concerning correspondent banking several factors have to be considered.

Firstly, if a small bank without a current account in Danmarks Nationalbank is active in the interbank marked, it will usually trade through a correspondent bank, i.e. settle on an account with another bank. The potential contagion effects are likely to be underestimated if a correspondent bank fails[18]. However, as the Danish payment system is based on direct rather than indirect participation and as it is only the smallest banks that do not hold a current account with Danmarks Nationalbank, this is not likely to affect the analysis.

Secondly, a more substantial limitation is the exclusion of money market transactions with foreign counterparties, without a current account with Danmarks Nationalbank. If a domestic bank A agrees on a transaction with a foreign bank F (who is not a monetary counterparty) and F uses A as their Danish correspondent bank, no *external* transaction takes place. Consequently, no records exist as only F's correspondent account with A (vostro account) is credited in the books of bank A.

If F trades with a domestic bank B, using A as their Danish correspondent bank two payment records are now recorded. In the SWIFT message initiating the transaction, information on the ultimate beneficiary, in this example F, is available. Through this information, transactions between A and B on behalf of others is filtered out. Hence, no transactions with foreign banks without a current account in Denmark are included.

[18] A deposit arranged through a correspondent bank exposes the lender to the correspondent bank until the correspondent bank transfers the funds to the borrower.

The data identified by the algorithm was compared to results from a questionnaire covering 13 banks on a random day. The outcome of this exercise was very positive, as there was a perfect match.

5. Assessment of Potential Contagion Risk in the Danish Deposit Market

The data allows us to set up a matrix of bilateral exposures for the counterparties of Danmarks Nationalbank on any given day. The purpose of the analysis is to examine these bilateral exposures and simulate unexpected failures. Specifically, the analysis will focus on a possible chain reaction caused by an unexpected failure. Banks providing these deposits are assumed to have direct losses if the borrower fails.

In order to examine the risk of contagion a ‘maximum loss threshold’ needs to be defined for each institution. Calling the maximum loss threshold *Ti* for bank *i*, a bank would subsequently fail if its exposure to the bank that initially fails is greater than *T*. However, this only addresses what can be called ‘first order contagion’. Suppose the failure of one bank A leads to the failure of B but initially not to the failure of C as *Tc* (the maximum loss threshold of C) is > *Xac* (C's exposure to A). But given the failure of B (the first order contagion) *Xbc* (C’s exposure to B) needs to be considered as well. I.e. in this case C will fail if *Xbc* + *Xac* > *Tc* and we would have ‘second order contagion’. Naturally, the same applies for third, fourth, etc. order contagion. The maximum loss threshold used in this working paper is described below.

5.1. Maximum Loss Threshold (Default Measure)

Calculating the maximum loss thresholds is critical to the analysis. Generally, a bank may default for two reasons – if it cannot comply with the regulatory capital adequacy requirement or if it cannot raise sufficient liquidity to meet its obligations. In this working paper our attention only concerns the former[19].

If a bank cannot comply with the capital adequacy requirement but continues to be solvent, the Danish Financial Supervisory Authority (Finanstilsynet) can schedule a time limit whereupon the requirement must be met again. A time-limit is only set if it is assessed that a

[19] For an assessment of the risk of default with respect to liquidity see Danmarks Nationalbank (2004).

sustainable solution can be found, which could happen either by transferring capital, reducing activities or via a merger. If not, Finanstilsynet will withdraw the banks' license to operate. Naturally, this will also be the case if the bank is assessed to be insolvent (i.e. a negative solvency ratio).

In this paper a worst-case scenario is assumed, where the bank will default immediately if its solvency ratio falls below the regulatory requirements. As indicated above this is a strong simplification compared to a real event, in which banks may have time to adjust their portfolio.

The capital adequacy requirement states that banks must have a solvency ratio of at least 8 per cent. Moreover, subordinated capital may not exceed 100 per cent of core capital after deduction[20]. The solvency ratio is defined as the regulatory capital to risk-weighted assets (RWA)[21], where regulatory capital consists of core capital and subordinated capital. For simplistic reasons, only the banks' buffers vis-à-vis the solvency ratio of 8 per cent is considered.

Thus it is the excess capital reserves, i.e. the share of *capital in excess of the capital adequacy requirement, and the year's earnings* that make up the total buffer against unexpected losses and ensure that a bank is still a going concern[22]. In box 2 the measure is described in further detail.

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[20] The capital adequacy requirement in Denmark is stated in Financial Business Act 686 of 25/06/2004, which build on the EU Council Directive 93/6/EEC and 2002/12/EC, which follow the Basel Committee's general standards within this sphere.

[21] The total risk-weighted items consist of the credit-risk-weighted assess and off-balance-sheet items, as well as market risks.

[22] For a further description see Danmarks Nationalbank (2004).

MAXIMUM LOSS THRESHOLD Box 2

Given the credit-risk-weight on unsecured deposits of 0,20 according to Basel 1[23] a bank is assumed to default if unexpected losses imply that the following default measure is fulfilled:

$$\frac{\text{regulatory capital} + \text{current earnings} - \text{loss}}{\text{RWA} - 0.2 * \text{loss}} < 8 \text{ per cent}$$

Solving the inequality for the loss, defines the maximum loss threshold T for bank *i*:

$$Loss_i = T_i > \frac{\text{regulatory capital} + \text{current earnings - } 0{,}08 * \text{RWA}}{0{,}984}$$

A measure incorporating regulatory requirements and current earnings represents a plausible scenario as banks may lose their license to operate before core capital is exhausted[24].

5.2. Loss Given Default

Another important factor that needs to be considered is how much the lending bank ends up loosing when the borrowing bank defaults. A liquidation process normally takes several years and thus the final losses are not known immediately. US studies show that banks in the US typically recover 40-95 per cent of their losses[25]. For Denmark evidence from 5 defaults of (small) banks between 1988 and 1994 suggest that 30-87 per cent of losses are recovered[26]. These figures are, however, characterised by some uncertainty and are probably not representative for larger banks. Moreover, they do not specify the recovery rates for uncollateralised demands. Consequently, as a worst-case scenario it is conservatively assumed that the entire exposure is lost (i.e. an LGD of 100 per cent). Later this assumption is relaxed and an LGD of 50 per cent is used, which is closer to what the scarce empirical evidence suggest is realistic.

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23 For further details about Basel I credit-risk weights cf. the above-mentioned legislation.

24 Alternatively the size of the core capital can be used see, e.g. Degryse and Nguyen (2004), Furfine (2003) and Upper and Worms (2002)

25 Quoted from Furfine (2003).

26 Økonomiministeriet (1995). The recovery rates are calculated as the dividend *after* deposits covered by the deposit insurance have been settled.

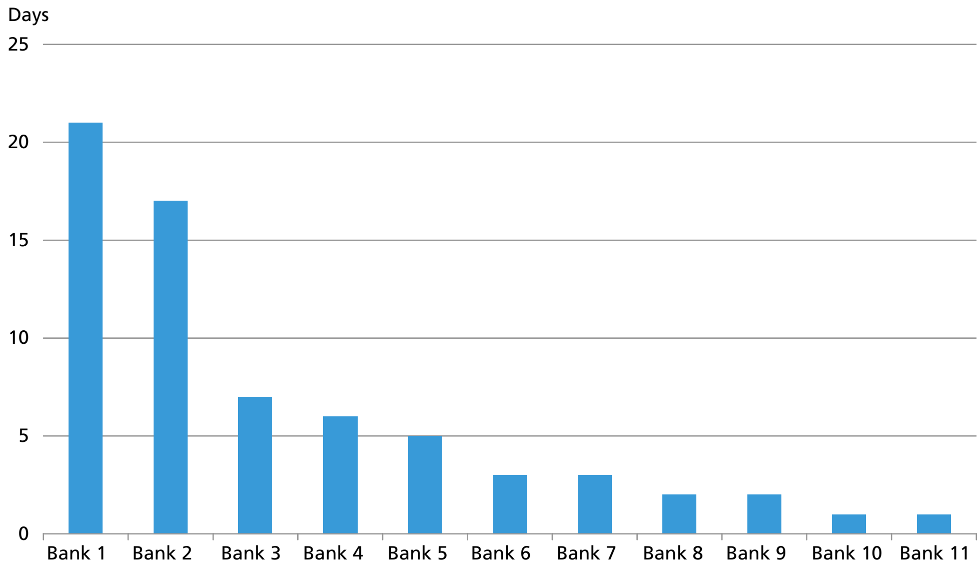
6. Results

The assessment of potential contagion risk in the Danish deposit market is performed using the matrices of bilateral exposures[27]. The primary focus is to assess whether an unexpected failure can lead to a chain reaction and cause other banks to default. Prior to this analysis banks exposures compared to their capital buffer is examined. As discussed in section 5.1, a bank is assumed to default immediately if its capital buffer falls below zero following a loss. This can occur either through bilateral or aggregated exposures.

6.1. Banks Aggregated Exposures

Banks aggregated exposures in proportion to their capital buffer is examined in this section. For contagion to be potentially present, bank's aggregated deposits need to exceed their capital buffer. The extent of the problem is illustrated in chart 4 as the number of days the aggregated exposure surpassed the capital buffer for the individual banks.

NUMBER OF DAYS WHERE THE AGGREGATED EXPOSURES EXCEED THE CAPITAL BUFFER, 2004 — Chart 4



Note: Bank 1,Bank, 2, Bank 3 etc. are not necessarily the same throughout the charts.
Source: Danmarks Nationalbank.

[27] Local branches of foreign banks are not included in the simulations of defaults, as the parent company is under another jurisdiction. Moreover, it is hard to distinguish between the capital of the branch and the capital of the group. In practice this means that the branches are included with an infinite buffer.

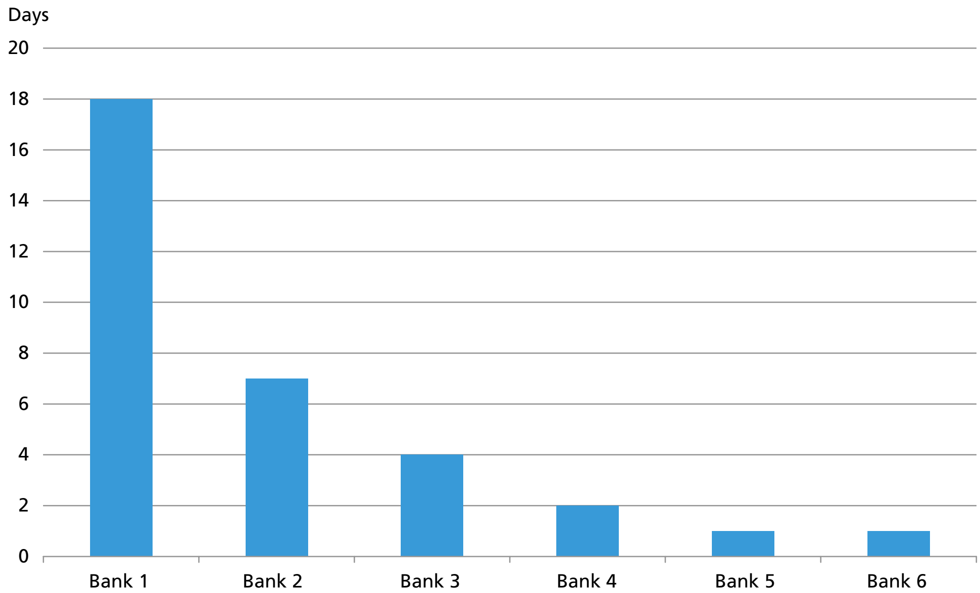
11 banks had aggregated exposures exceeding their capital buffer at least once in 2004. However, the frequency varied significantly between these 11 banks. Two banks surpassed their capital buffer on more than 15 occasions. The remaining nine banks exceeded their capital buffer between one and seven times during 2004.

Adding the number of days the 11 banks were at potential risk provides the upper bound of contagion in 2004. This implies 68 potential contagion incidents in 2004.

6.2. Banks' Bilateral Exposures

Assessing banks' bilateral exposures gives a more refined picture of banks vulnerability. Banks with bilateral exposures larger than their capital buffer are illustrated in chart 5. The chart shows the number of days these banks had bilateral exposures larger than their capital buffer.

DAYS WHEN BILATERAL DEPOSITS EXCEED THE CAPITAL BUFFER, 2004 CHART 5



Note: Bank 1,Bank 2, Bank 3 etc. are not necessarily the same throughout the charts.
Source: Danmarks Nationalbank.

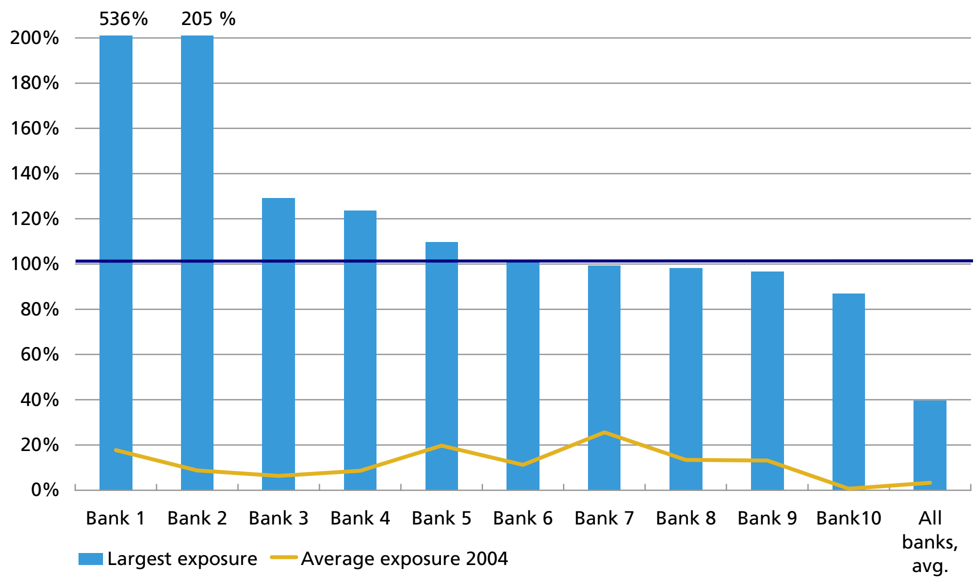
Six banks had bilateral exposures larger then their capital buffer in 2004. This happened on 18 occasions for one bank and less frequently for the others. In the worst-case scenario this could lead to a maximum of 33 potential incidents of first order contagion.

Obviously, it is of far greater concern when banks bilateral exposures exceed their capital buffer than when their aggregated exposures exceed their capital buffer. Aggregated exposures larger than the buffer are only of concern if the initial default leads to multiple defaults. If a bank is exposed to a number of defaulting banks, the bank could ultimately default based on its aggregated rather than bilateral exposures. Should this occur it would be a second order contagion effect.

6.3. Banks Largest Bilateral Exposure

The size of the bilateral exposure compared to the capital buffer quantifies how vulnerable a bank is. The largest bilateral deposits relative to the capital buffer in 2004 are shown in chart 6.

LARGEST BILATERAL EXPOSURE IN PER CENT OF THE CAPITAL BUFFER — Chart 6



Note: Bank 1,,Bank 2, Bank 3 etc. are not necessarily the same throughout the charts.
Source: Danmarks Nationalbank.

Two banks had at least once a bilateral exposure more than double the size of their buffer. As previously shown in chart 5, 6 banks had a bilateral exposure exceeding their capital buffer and additionally, a number of banks had bilateral exposures close to their capital buffer. Hence, the failure of certain counterparties could cause significant reduction in these banks capital. On average the largest bilateral exposure was slightly below 40 per cent of the capital buffer.

6.4. Failure of the Largest Debtor

By simulating unexpected failures of the largest debtor[28], the stability of the Danish interbank market is analysed. An LGD of 100 per cent is applied in the base case, and subsequently the LGD is reduced to 50 per cent. The 50 per cent is chosen on background of the scarce empirical evidence reported in section 5.2

Table 1 summarises the results of these simulations. Failure of the largest debtor would cause another bank to fail on 11 out of the 253 banking days in 2004 if the LDG was 100 per cent. Reducing the LGD to 50 per cent greatly decreased the contagion risk, as only one bank on one day would fail.

BANK FAILURES CAUSED BY THE FAILURE OF THE LARGEST DEBTOR EACH DAY, 2004 — Table 1

Loss given default (LGD)	Failing banks	Banks failing per day
100 per cent	11	1
50 per cent	1	1

Source: Danmarks Nationalbank.

Only first order contagion took place, as no more than one bank would fail on any day by the failure of the largest debtor. The assets in the defaulting banks represented between 1 and 4 per cent of the total assets in the Danish banking sector.

Using the maximum loss threshold as a strict definition of failure or non-failure can misrepresent the actual market situation, if a large number of banks are close to failure because of significant losses. In Annex 1 the sensitivity of the non-failing banks is illustrated for the 11 days where bank failures occurred. Beyond the 11 banks failing, two banks lost more than 40 per cent, and six banks lost between 40 and 20 per cent of their capital buffer. The remaining banks lost less than 20 per cent.

Overall, the simulations suggest that the contagion risk in the Danish interbank market currently seems to be very limited. However, 2004 was a year characterised by very high earnings for the banks. Thus it is important that the banks are aware of possible implications of their exposure, also in case of a deteriorating economic climate.

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[28] The largest debtor is defined as the bank at which most cash is deposited on each day. I.e. not necessarily the same bank on every day. No consideration is given to the probability of the initial default.

7. Conclusion

This working paper presented unique data that made it possible to analyse the risk of contagion in the Danish interbank market in a way not previously possible. By exploiting transaction-based data stemming from the Danish large value payment system, Kronos, this paper has provided a new and more detailed description of the structure in the Danish market for overnight deposits. This has given a unique opportunity to analyse the potential risk of contagions in the Danish market for deposits.

The methodology identified 1.2 per cent of the total number of Kronos transactions as overnight deposits. It was shown that although 60 per cent of the total turnover was due to transactions between the six largest banks, approximately 50 per cent of the current-account holders were active in the market.

Assuming a very conservative worst-case scenario, where the LGD is 100 per cent, simulations of the failure of the largest debtor each banking day showed a risk of contagion on 11 days. On no days multiple rounds of failures were found, i.e. only a risk of first order contagion was identified[29]. By reducing the assumed LGD from 100 per cent in the base case to 50 per cent, the risk of contagion was dramatically reduced. The banks, which were potentially in a risk of failure, were typically smaller institutions with less than 5 per cent of the total assets in the Danish banking system.

Using such a strict definition of failure and non-failure could blur the picture, as a large number of banks may be close to failure, if their losses are significant. It was found that some banks could loose more than 40 per cent of their total capital buffer. Overall, six banks had bilateral exposures exceeding their capital buffer more than once in 2004.

On average the largest bilateral exposure for all banks was slightly below 40 per cent of the capital buffer. The overall average exposure for all banks was 3 per cent, which does not indicate excessive bilateral exposure in the Danish uncollateralised market.

Against this background contagion risk in the Danish interbank market is currently found to be very limited. However, the analysis does not cover all exposures between banks and the activity in the

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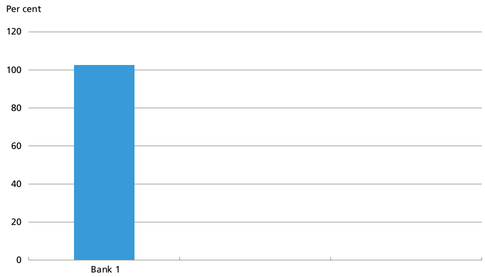
[29] An analysis of the correlation of the share prices for the largest Danish banks suggests that they are not exposed to common factors (Danmarks Nationalbank 2005). This implies that more than one initial failure is a highly unlikely event.

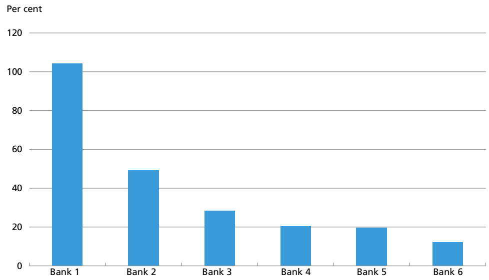
money market may be subject to changes. Additionally, banks are incurred to other kinds of risks and it cannot be ruled out that the timing of bad events coincides. The results of the analysis should thus be interpreted with care and future research in this area is needed.

8. Annex

The following charts illustrate the sensitivity of the non-failing banks. The charts show the 11 days, when bank failures occurred due to failure by the largest debtor.

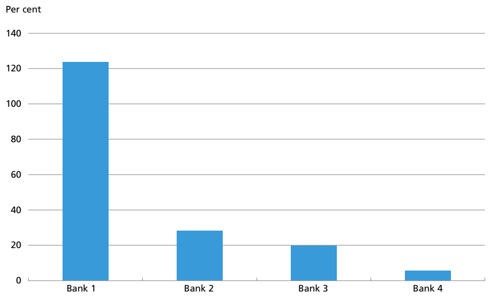
LOST EXPOSURES ON DAY 1 (LEFT) AND DAY 2 (RIGHT) — Chart 1

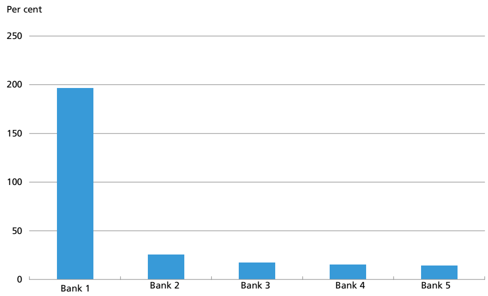




Note: Bank 1,Bank, 2, Bank 3 etc. are not necessarily the same throughout the charts.
Source: Danmarks Nationalbank.

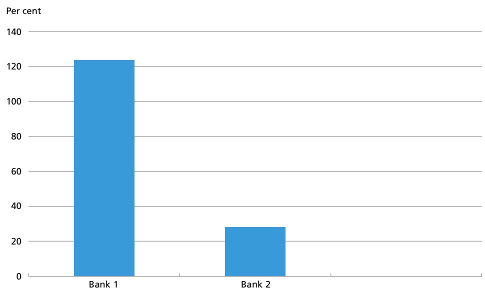
LOST EXPOSURES ON DAY 3 (LEFT) AND DAY 4 (RIGHT) — Chart 2

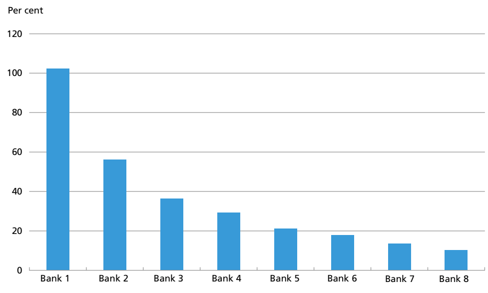




Note: Bank 1,Bank, 2, Bank 3 etc. are not necessarily the same throughout the charts.
Source: Danmarks Nationalbank.

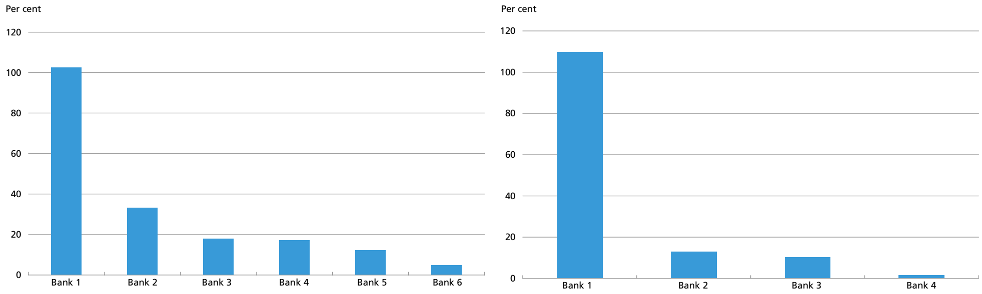
LOST EXPOSURES ON DAY 5 (LEFT) AND DAY 6 (RIGHT) — Chart 3





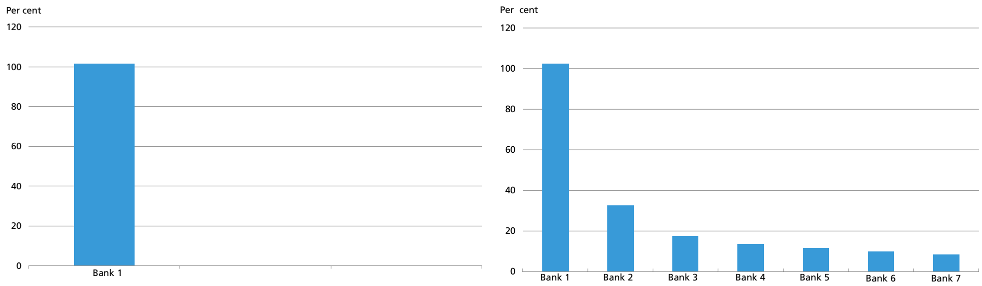
Note: Bank 1,Bank, 2, Bank 3 etc. are not necessarily the same throughout the charts.
Source: Danmarks Nationalbank.

LOST EXPOSURES ON DAY 7 (LEFT) AND DAY 8 (RIGHT) — Chart 4



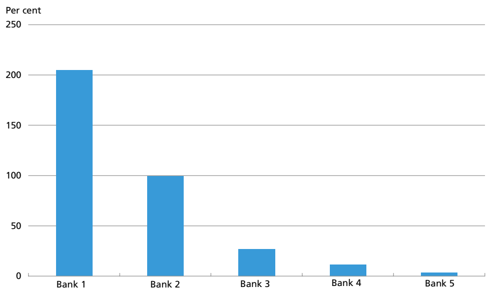
Note: Bank 1,Bank, 2, Bank 3 etc. are not necessarily the same throughout the charts.
Source: Danmarks Nationalbank.

LOST EXPOSURES ON DAY 9 (LEFT) AND DAY 10 (RIGHT) — Chart 5



Note: Bank 1,Bank, 2, Bank 3 etc. are not necessarily the same throughout the charts.
Source: Danmarks Nationalbank.

LOST EXPOSURE ON DAY 11 — Chart 6



Note: Bank 1,Bank, 2, Bank 3 etc. are not necessarily the same throughout the charts.
Source: Danmarks Nationalbank.

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