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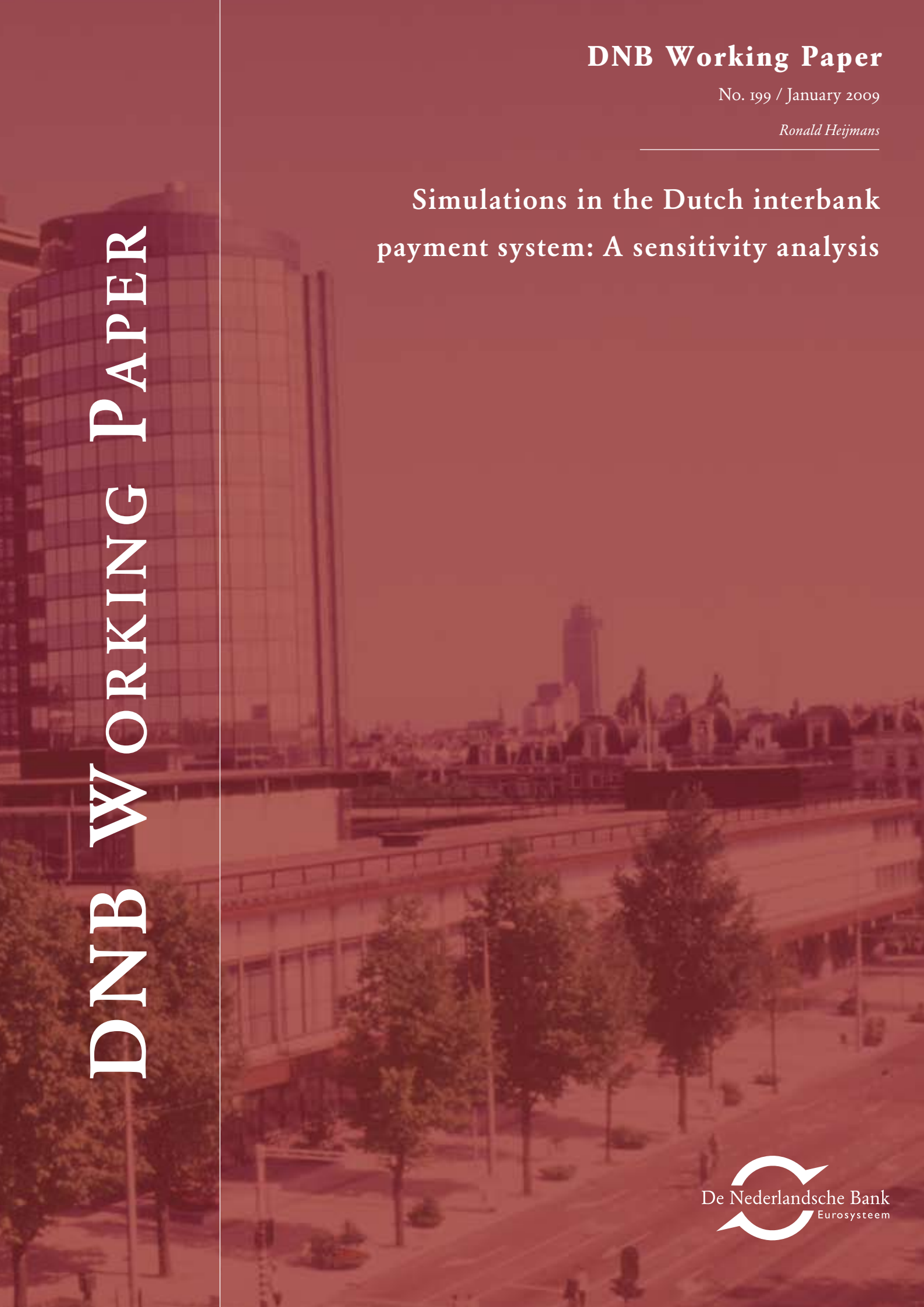

De Nederlandsche Bank
Eurosysteem

Simulations in the Dutch interbank payment system: A sensitivity analysis

Ronald Heijmans *

* Views expressed are those of the author and do not necessarily reflect official positions of De Nederlandsche Bank.

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Simulations in the Dutch interbank payment system: A sensitivity analysis

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Abstract

This paper presents an analysis on the sensitivity of the Dutch interbank payment system with respect to the value transferred and the amount of available collateral. The Dutch system can be characterised as a system with a few large and many relatively small participants. Historical data has been used and modified to create a stress scenario. The changes with respect to the historical data are either an increase or a decrease of payment values of one of the large participants. This change of the payment value has been applied to the three large banks in the Dutch system. The collateral level has also been modified between the different stress scenarios. In total four levels of collateral are investigated of which 2 are based on historical data and 2 on theoretical calculated values, the upper and lower bound. The results of this paper are both in terms of number of banks affected and the amount of unsettled values by the end of the day.

JEL codes: C88, E58, G21
Key words: interbank, payment system, operational disruption, liquidity, stress simulations, TOP, TARGET

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1 Introduction

Total disruptions of payments systems are relatively rare phenomena. Therefore there is not much historical evidence on how payment systems react to a disruption. Even in the current financial crisis the payment systems world wide have functioned without serious disruptions. One of the most well known operational disruptions in the interbank payment system is the attacks on the world trade centre in New York on September 11th 2001. The massive damage on property and communication systems made it more difficult or even impossible for some banks to execute payments to other banks. The impact of such a disruption can have effects beyond the immediate counter parties of the banks disrupted by the shock. In extreme cases it might even disrupt the whole financial system.

To get a better understanding of the potential impact of a disruption in the interbank payment system, simulations are used. The Bank of Finland has developed a payment system simulator (BoF PSS2). This simulator has been proven to be a very useful tool to gain insight in the effect of operational disruptions. Many simulations have been made using the BoF PSS2, i.e. Ledrut (2007) describes the impact of an operational failure, varying the time at which the disruption takes place and McVanel (2007) investigated the impact of unanticipated defaults in Canada's Large Value Transfer System. A new direction into the BoF PSS2 development is the integration of network topology, Soramäki et al (2007).

The simulator provides the possibilities to simulate a delayed net settlement system (DNS) or a real time gross settlement system (RTGS). A DNS, which settles the payments after a predefined amount of time by transferring the net positions, uses the least amount of liquidity. The settlement risk of a DNS is the highest, because in case of a defaulting participant all payments after the last settled transactions may have to be unwound. A RTGS, which settles payments immediately and individually, requires the largest amount of liquidity. The settlement risk, however, is very low. There are many system designs between RTGS and DNS which require less liquidity than in the pure RTGS case.

The goal of this paper is to describe the potential impact on the payment system when one large participant in the Dutch interbank system faces a given (small or large) disruption. The impact of small participants with a disruption will be relatively small for the total payment system as a result of their relatively low payment values. Therefore, the disruption of a small participant in the payment system is not discussed in this paper.

The type of disruptions simulated in this paper is both an increase and a decrease of the outgoing transaction value with a certain percentage. The potential impact is both measured in terms of the number of banks with unsettled payments at the end of the day and the corresponding value of unsettled payments. An increase of the total transaction value by one large participant means that this participant "provides" the other participants with extra liquidity, due to increased obligations, up until

the point that this participant runs out of its own liquidity. The important issue here is how the extra liquidity will be distributed over the participants: Is this done homogeneously or heterogeneously? A decrease in outgoing transaction value by this large participant leads to a decrease of available liquidity to the other participants. In this case it is interesting to see to what extend the other participants are able to deal with this decreased level of liquidity without having a total disruption of the whole payment system. One important parameter in the amount of available liquidity is the amount of collateral the participants have available. Simulations give a good understanding of the potential effect or in other words the sensitivity of a disruption to the payments system.

The outline of this paper is straightforward. Section 2 describes some general characteristics of the Dutch large value payment system and relates it to other systems. Section 3 describes the stress scenarios which have been simulated and gives general characteristics on the three large banks which have been used to create the stress situations. Section 4 continues with the number of banks affected given the defined stress situations and section 5 shows the value of unsettled payments, the amount of collateral used by the affected banks and the total negative end of day balance of the participants without unsettled payments given a certain stress scenario. Finally, section 6 gives a summary and conclusions of this paper.

2 The Dutch Large Value Payment System

2.1 INTRODUCTION

The Dutch large value payment system up until 18 February 2008, called TOP, was a Real Time Gross Settlement (RTGS) payment system. From 1999 to February 2008 it was part of the European system for euro-denominated payments, TARGET[2]. This payment system connected the RTGS systems of the central banks of the euro area, the United Kingdom, Denmark, Sweden and the European Central Bank (ECB).

Access to TOP was restricted to a limited set of participants. It was not directly accessible by the general public. Participants mainly included banks. In addition, The Nederlandsche Bank (DNB) and other central banks, clearing houses, government agencies and some non-commercial organizations like the IMF participated. Connection to participants in other TARGET countries took place through TARGET. Currently TARGET is replaced by TARGET2. The migration to TARGET2 started in November 2007. The local systems, including TOP, have migrated to TARGET2 in three migration phases. The Dutch system migrated on 18 February 2008. Technically, TARGET2 is a centralised platform, but legally it is a decentralised system in which each country designated its own component system. This means that all payments are settled on one technical system. The business relation however is still through one of the central banks which have a connection to TARGET2.

For a payment system to function properly it is essential that participants have sufficient funds, such that payments can be made without delay. The means to achieve this vary across systems. In the Dutch system DNB provides intraday credit (secured by collateral), see Ledrut (2006) who gives a discussion of the optimal provision of intraday liquidity. In effect, participants can use both their own credit balance and their credit facility. Participants can thus execute their outgoing transactions before receiving their incoming transactions for that day. Free intraday credit therefore facilitates a smooth functioning of the payment system and prevents a gridlock. If the closing balance is negative the participating institution will have to pay an overnight fee. In some European countries, like the Netherlands, commercial banks permanently hold (pledged) collateral at the central bank. In other European countries collateral is brought in by means of repos. In the United States banks can obtain intraday credit by paying a fee for the used amount.

2.2 GENERAL CHARACTERISTICS

Figure 1 shows the number and value of transactions in TOP for the period 1-1-1999 to 31-12-2007. The figure distinguishes between domestic and cross border payments. Since 1999 there is a clear increase of both value and volume in TOP. A strong increase in value and volume is observed in 2007.

[2] TARGET: Trans-European Automated Real-time Gross settlement Express Transfer system

On top of a general increasing trend over the years there are two extra causes of the increase in 2007. The first is the introduction of a new urgent retail payment system from mid June 2007. The previous urgent payment system was a netting system, which settled once a day. The newly introduced system is a gross system. The consequence is an increase of 42% in volume and 4% in value. The second cause is the turmoil on the financial market starting in mid 2007. The turmoil on the market has increased both the value and the volume from May on.

From 1999 there is an increase of the total TOP traffic of 56% in value and 71% in volume from EUR 18,150 to EUR 28,426 billion and 3.2 to 5.5 million respectively. The cross border payments have increased by 128% in value and 150% in volume. The increase in cross border payments is important because this means that the Dutch payment market will be more and more directly influenced by foreign participants. The increase of this cross border traffic mainly comes from the three large banks, see section 3.3.

2.3 COMPARISON WITH OTHER INTERNATIONAL SYSTEMS

This section gives a brief comparison of the TOP system with TARGET, CHAPS and Fedwire. Table 1 shows the number of participants and daily averages on transaction value and volume in these systems.

Figure 1: The number and value of transactions in TOP from 1999 to 2007

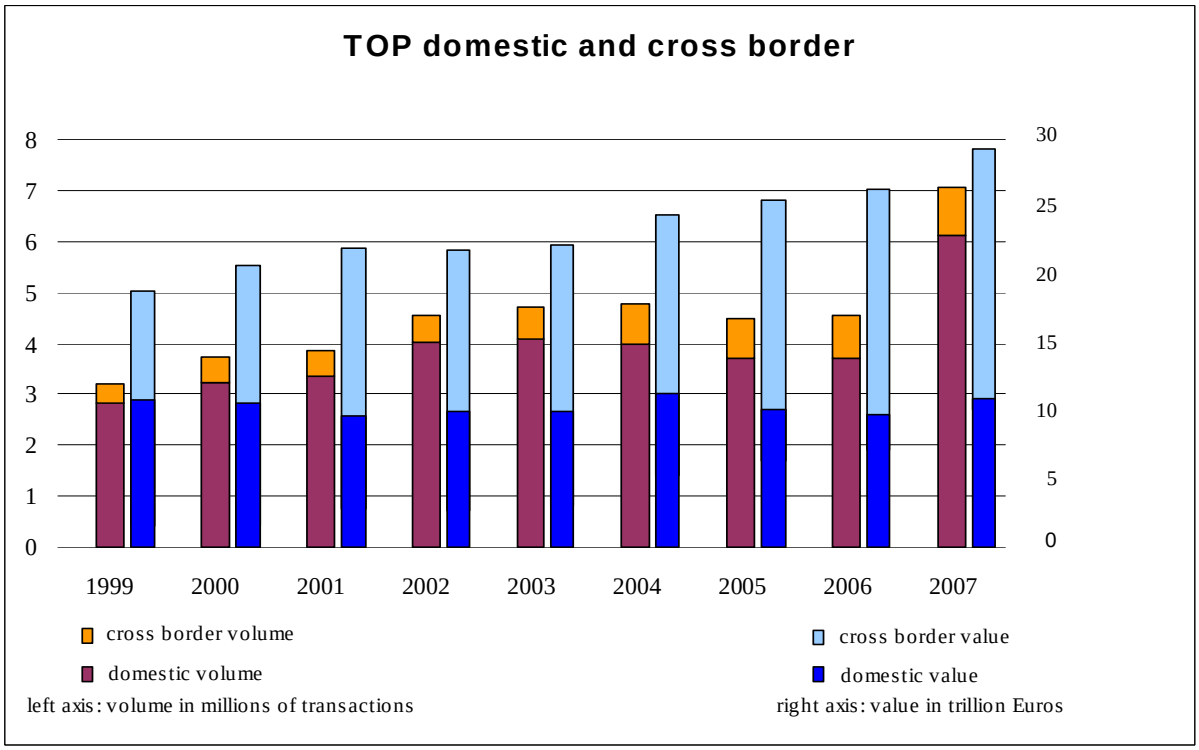


Table 1: Key characteristics on daily payment characteristics TOP, TARGET, CHAPS Sterling and Fedwire.

	TOP[3]	TARGET	CHAPS (Sterling)[4]	Fedwire[5]
Participants	155	10,197	Not available	6,819
Of which direct participants	100	1,126	15	Not available
Transactions (x thousand)	18.4	312	116	519
Value (x billion €€)	120	1,987	297	1,634
Average transaction value (x million EUR)	6.5	6.4	2.6	3.1

Source: TOP (datawarehouse DNB), TARGET (ECB Bluebook), CHAPS and Fedwire (BIS, 2007 #3053).

[3] The values listed for TOP only represent the figures which are reported to the ECB for the Blue Book statistics. This excludes i.e. the incoming cross border payments, which are included in this paper.
[4] The values in Pound sterling are converted via US dollars to Euros.
[5] The values in US Dollars are converted to Euros with the exchange rate EUR/USD 0.8051, which is the average exchange rate over 2005 as listed in Red Book (BIS) 2006

3 Data description

3.1 INTRODUCTION

The data set used for the analysis consists of transaction data of the months December 2005 and April 2006 from the Dutch large value payment system (TOP). It contains all transactions which have been carried out during these two months. The data set contains both payments which have been made during regular opening hours of the TOP system and during the evening settlement. The incoming cross border transactions have been included in the dataset as well.

Some participants have more than one account in TOP. These accounts are used for administrative reasons by the participant. In the simulations these accounts are treated separately. The results however will look at participant level. In case more accounts of one participant have unsettled values at the end of the day as a result of the disruption it will be treated as one. Transactions to and from other TARGET countries can be identified by the country participant number. The individual transactions to and from e.g. a commercial bank of another European country can only be identified by this country participant number.

3.2 STRESS SCENARIOS

A stress scenario in this paper is defined as a modified dataset, based on historical data, given certain conditions. There are two parameters in the historical payment datasets, which have been modified defining these stress scenarios:

1. the outgoing payment value of one participant by a certain percentage (8 different percentages),
2. available collateral values for all participants (4 different values).

The modified payment values have been applied to:

3. three large banks,
4. two different months.

The disruption period is set to:

5. two different lengths.

To define a scenario one option of each of the five items has to be chosen.

For the simulations described in this paper three large banks in the Dutch interbank payment system were selected to create stress scenarios: ABN AMRO Bank, ING Bank and Rabobank. These banks are the three largest banks in TOP with respect to value transferred per day, see Table 2 in Section 3.3. For each of these three banks the value of all outgoing payments for each of the accounts belonging to the participant number of that participant are either increased or decreased by a certain percentage.

The total value of the outgoing payments are 50%, 75%, 90%, 95%, 110%, 125%, 150% and 200% of the total initial value given by the historical data. Each percentage will be called a stress case or a case. The payments of all other banks are left unchanged.

An increase of the value of payments of one participant leads to an increase of available liquidity to the other participants. This increase will continue until this participant runs out of its liquidity. This liquidity is the credit balance on its account and the amount of available collateral. Even though this increase in outgoing value leads to extra liquidity for the other participants as a whole, this does not necessarily mean that each participant will get its share. The interesting question of such an increase in liquidity is whether this liquidity is distributed evenly over all participants. We will see in section 4 and 5 that this is not distributed homogeneously. A decrease on the other hand will lead to an increase of liquidity for the disrupted participant but to a decrease of available liquidity for the other participants.

Each of the cases is calculated for four different collateral values:

- Historical Collateral (HC),
- Historical Collateral excluding open market operations (HCex),
- Upper Bound collateral (UB),
- Lower Bound collateral (LB).

The HC is the total amount of collateral the banks have pledged at DNB. The HCex is the HC minus the open market operations. Open market operations are DNB loans that help banks to meet their requirements. The UB is the value of the collateral a participant needs in order to make all its payments without any delay. The UB can be determined by simulating a business day assuming that the participants have the disposal of unlimited intraday credit. The maximum negative intraday balance is the UB collateral value. The LB collateral is the value of collateral the participant needs to settle all its payments by the end of the business day, provided that the participant would have unlimited intraday credit. Both the UB and the LB are theoretically defined collateral values, calculated by the simulator. The UB would be used by a bank which does not want to delay any payments during the day. This could be compared with a bank which uses repos to bring in collateral. The LB would be used by a bank which wants to make sure it has settled all its obligations by the end of the day but does not have a problem with delays during the day. Section 3.4 describes the different collateral values for ABN AMRO, ING, Rabobank and total collateral of all participants.

The data of December 2005 and April 2006 were used to define stress situations. The December month had 21 and April 18 business days. The reason for choosing two different months is to investigate differences in outcome of stress simulations. If the results of the two months are not comparable, this could suggest that it is not possible to draw general conclusions on the outcome of

one month. This means that in such a case it is very difficult to predict the outcome of a given stress scenario for another month. It is also possible that the two month show similar results but not at the same day of the month. It would be desirable from a statistical point of view to investigate all the months of the year, but this is a rather time consuming operation.

The length of the disruption is either one day or the whole month. A disruption of one day means that the increase or decrease of payments by one of the three large participants starts at the opening and ends at the closing of the TOP system. If there are any unsettled payments at the end of the day these payments will be removed from the queue before the start of the next business days, such that there are no spill over effects from one day to another. When the disruption lasts the whole month the increase or decrease of payments of the large participant also continues the whole month. In case there are unsettled payments at the end of the day these payments will be transferred to the next business day. These payments will be the first ones the system tries to settle for that participant.

The number of simulations carried out for individual business days is 2880. For each of the three banks, the month December 2005 (21 days) and April (18 days) for 8 different decreased or increased outgoing values of the payments for the historical and upper bound collateral. For the historical collateral excluding open market operations and the lower bound collateral only the month December 2005 is simulated. The number of simulations carried out for the stress scenarios continuing the whole month is 144. These are the same as for the single days with the only difference that individual days can not be treated separately because there is a dependence of each day to the previous days.

3.3 PAYMENTS STATISTICS OF THE THREE LARGE BANKS

Table 2 shows the payment statistics for ABN AMRO, ING and Rabobank for December 2005 and April 2006. The table gives information on the distribution between domestic and cross border payments. From Table 2 can be seen that ABN AMRO has 27% of the total value of the daily turnover of TOP, which makes it the largest participant of this system. The cross border payments of ABN AMRO take up approximately 35% of the total cross border value. The three large banks take up almost 60% of the total value and 35% of the volume of payments. The cross border value and volume of the three large banks is approximately 75% and 60%, respectively.

This is an important characteristic because this paper looks at the potential impact of a disruption on the domestic market. In the cases in which a large participant reduces its payments (50%, 75%, 90% and 95% cases) less liquidity will be provided to the other participants. In the situation that the large participant mostly pays to and receives from cross border TARGET participants, there would be a small effect on the domestic market. In the opposite situation in which the large participant mostly pays to and receives from domestic participants the potential effect is maximised for the domestic market. When the large participant increases its payments (110%, 125%, 150% and 200% cases) the situation is different. In the situation that a large part of the payments go to and come from cross

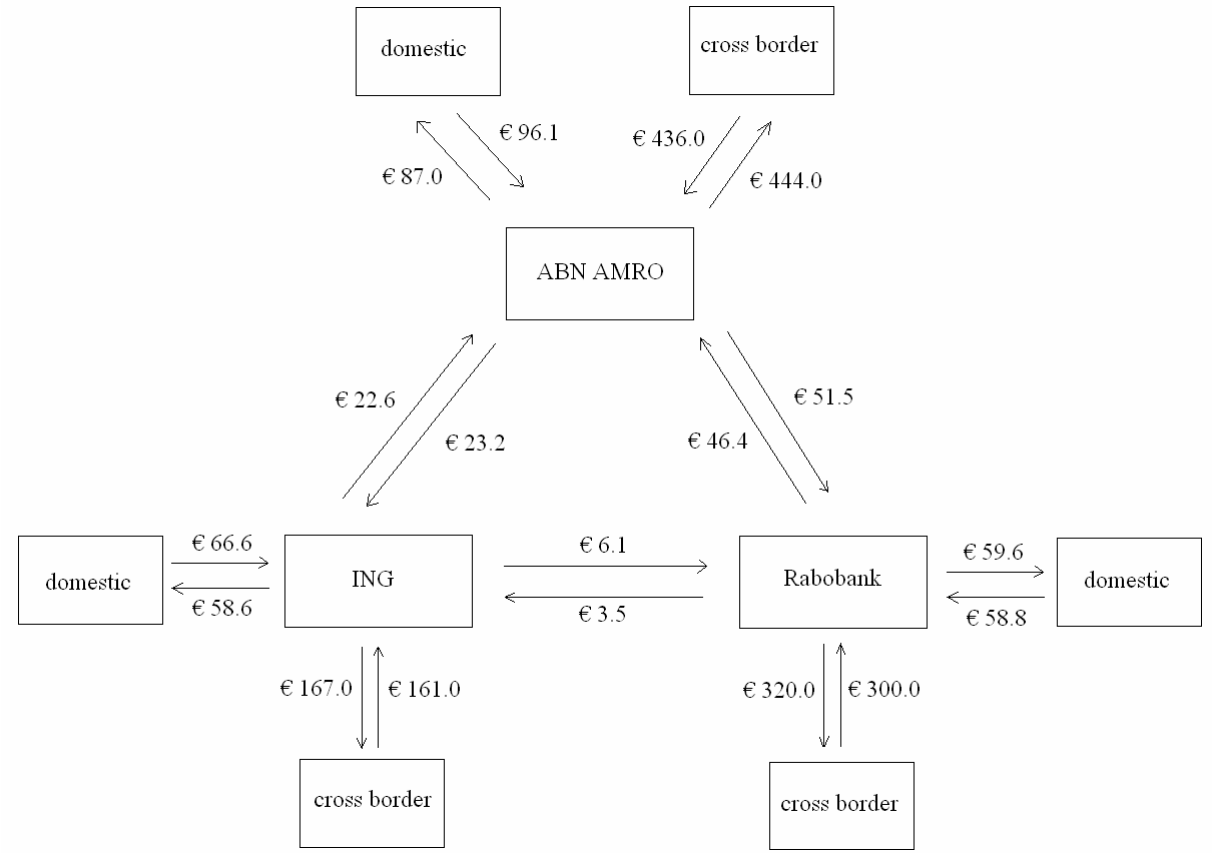
border TARGET participants the domestic market might face shortage of liquidity as a result of the increased outflow to cross border participants. The cross border participants absorb the liquidity of the domestic market.

Figure 2 shows the total payment flows of the month December 2005 of the three large banks. An interesting characteristic is the net payment flow between participants. This can be seen i.e. from the payment flow from ING to Rabobank. ING pays Rabobank EUR 2.6 billion more than it receives. Given the fact that in the long run there can not be net payers or receivers in the system, this extra flow between the two participant has to come back from other participants (domestic or cross border), see i.e. Pröpper et al (2007) on network characteristics.

Table 2 showed the domestic and cross border payment statistics of a whole month. Figure 2 showed the payment flows of a whole month of the three large participants. They both give information on monthly values.

Figure 3 shows the daily balance of the three large banks for the three large banks for December 2005. The daily balances of ABN AMRO i.e. vary between EUR -9 and EUR +7 billion. The balances for ING and Rabobank are slightly lower than the ones for ABN AMRO.

Figure 2: Payments flows between the three large banks and between the large banks and other domestic participants and cross border payments for December 2005[6]. Payment values are in billions.

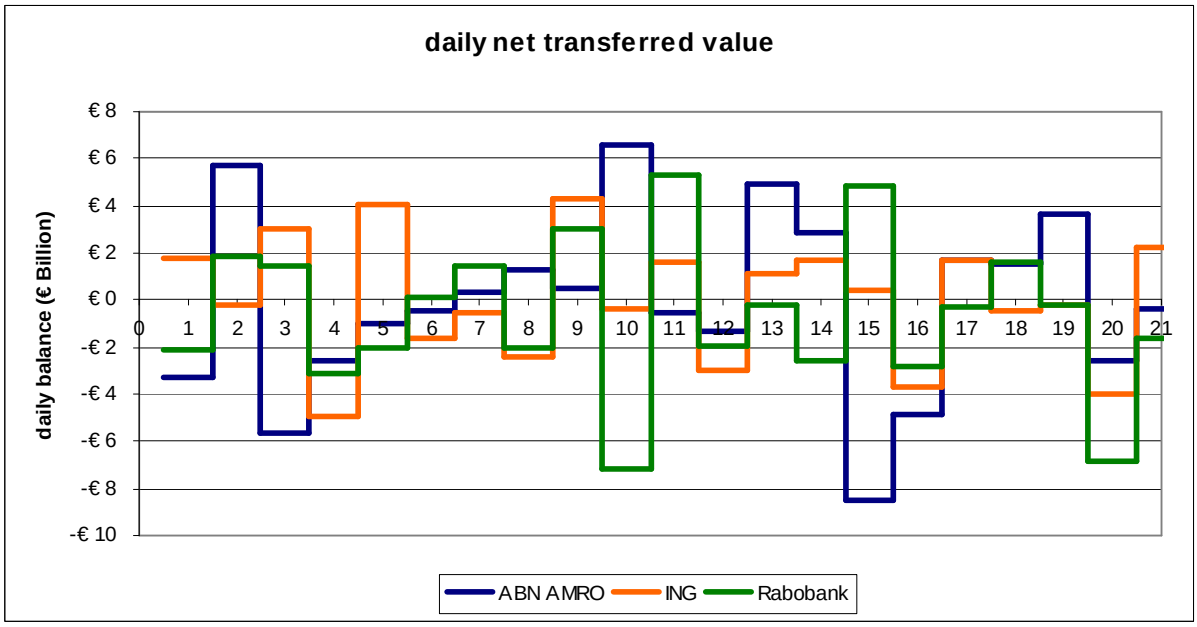


[6] The payment transaction from and to the same participant are not displayed in this figure.

Table 2: Domestic and cross border payments made by ABN AMRO, ING and Rabobank in December 2005 and April 2006 both in value and percentage of the total amount

		Value December 2005		Volume December 2005		Value April 2006		Number April 2006	
Participant		EUR (billion)	%	number	%	EUR (billion)	%	number	%
ABN AMRO	Domestic	250	18.8	45,756	13.9	240	19.4	37,142	12.5
	Cross border	444	36.3	33,436	44.1	420	35.0	28,304	42.8
	Total	694	27.2	79,192	19.6	660	27.1	65,446	18.0
Rabobank	Domestic	180	13.5	18,105	5.5	161	13.0	14,399	4.8
	Cross border	320	26.2	6,134	8.1	292	24.3	6,304	9.5
	Total	501	19.6	24239	6.0	453	18.6	20,703	5.7
ING	Domestic	162	12.1	31,755	9.7	133	10.7	25,817	8.7
	Cross border	166	13.6	4,382	5.8	155	13.0	4,546	6.9
	Total	329	12.9	36,137	8.9	288	11.8	30,363	8.3
3 participants	Domestic	593	44.5	95,616	29.1	534	43.1	77,358	26.0
	Cross border	931	76.1	43,952	58.0	867	72.3	39,154	59.2
	Total	1,524	59.6	139,568	34.5	1,400	57.5	116,512	32.0
Total all participants	Domestic	1,332	100	328,921	100	1,238	100	297,836	100
	Cross border	1,224	100	75,760	100	1,198	100	66,132	100
	Total	2,556	100	404,681	100	2,436	100	363,968	100

Figure 3: Daily net transferred values for the three large banks for December 2005.



3.4 COLLATERAL VALUES

Simulations have been made using four different values of collateral, see Section 3.1. The HC collateral level shows the maximum level of intraday credit a participant can obtain when it has not used a part of its collateral for open market operations. Because many of the (large) banks use a part of their collateral for open market operations the HCex collateral level is also used. In fact the banks would only be able to use the HCex for intraday credit. The UB and LB are theoretically calculated levels of collateral. In reality it will be difficult to determine these levels prior to the start of a new business day because it is not (exactly) known at what time and how many payments will be paid and received that day. In case of a disruption it is likely that the collateral level is insufficient to execute all payment immediately in case of the UB or by the end of the day in case of the LB. If the disruption is large enough there will even be unsettled payments at the end of the day when the UB collateral level is used.

Figure 4 to Figure 7 show the four different collateral values of ABN AMRO, ING, Rabobank and all participants together for December 2005. The figures show that the HC (orange line) is relatively constant for all three banks. The HCex (green line) shows more fluctuation in the values, which means that these banks have participated in open market operations during the month. The upper bound (brown line) fluctuations vary for the three large banks. ABN AMRO bank shows values between EUR 6 billion and EUR 14 billion. The Rabobank shows values between EUR 0 and EUR 6 billion. A value of EUR 0 for the upper bound means that the banks did not need any collateral these days to settle all their payments immediately. The value for Rabobank has the largest fluctuations with values between EUR 2 billion and EUR 14 billion. A few days of this month the value of the upper bound is higher than or close to their maximum collateral value. This suggests that Rabobank actively uses its collateral. The lower bound is zero for the three banks and almost zero for all participants. This is due to the fact that all banks have an obligation to hold a certain level of credit on their account for their minimum reserve requirement. These funds can be used to settle payments intraday while at the end of the day their balance has been levelled to meet their requirements.

The total value of collateral (HC) available varies between EUR 65 billion and EUR 69 billion, see Figure 7. The HCex varies between EUR 44 billion and EUR 59 billion. The HCex is variation is larger than for the HC. The variation of the UB, between EUR 20 billion and EUR 36 billion, is in absolute value comparable to the HCex but in relative terms it varies more. The LB on the other hand shows values close to zero most of the time. Only on the 15th business day it goes up to EUR 0.5 billion.

Figure 4: Collateral values for ABN AMRO, December 2005

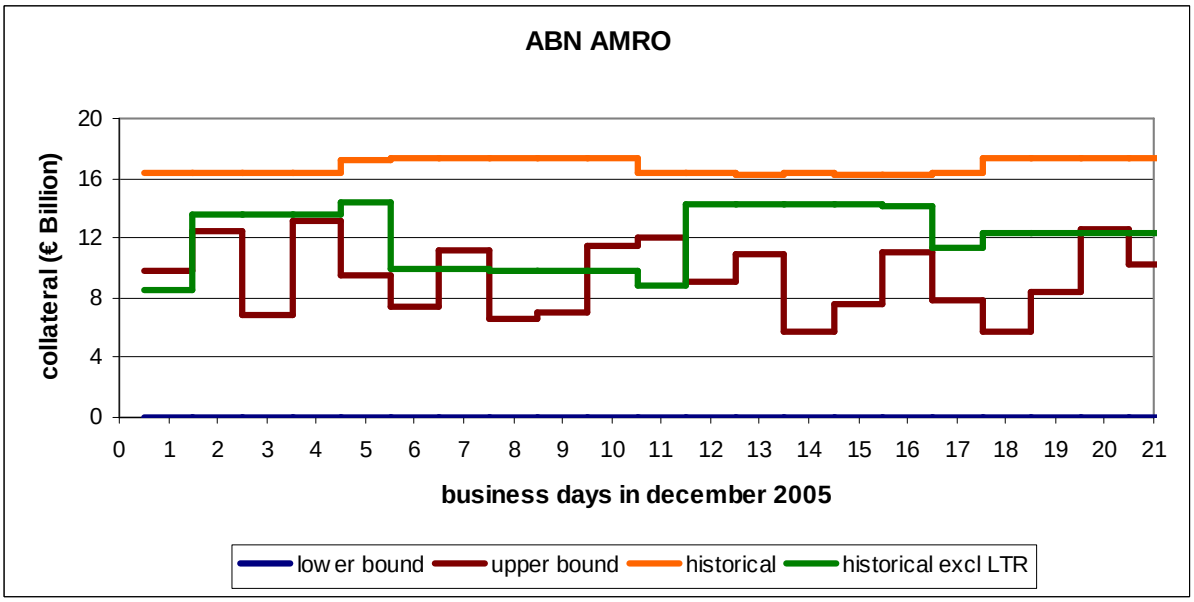
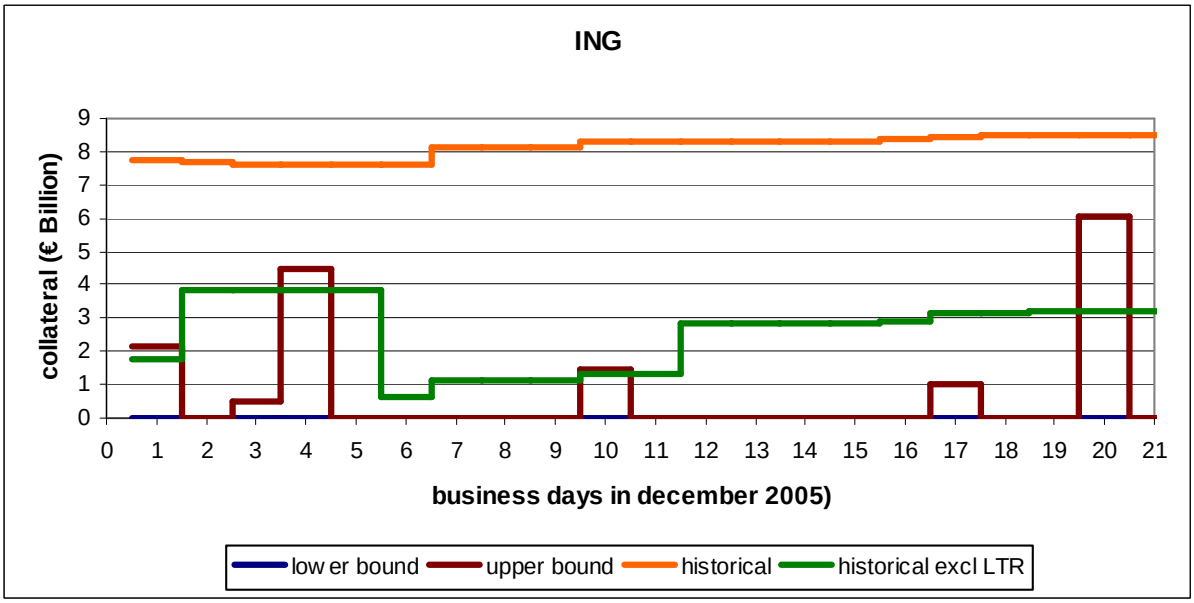


Figure 5: Collateral values for ING, December 2005



From Figure 7 it can be concluded that there is more collateral available in the payment system than the participants require on the basis of the collateral indications used. However, the distribution of the available collateral over the participants is not optimised for each individual participant. Some participants have much more than they need and others have less than they need. This can be seen in Figure 6, which shows that the collateral value of Rabobank for the UB is higher than the HC and HCex for several days. This means that this participant had queued payments as a result of insufficient collateral.

Figure 6: Collateral values for Rabobank, December 2005

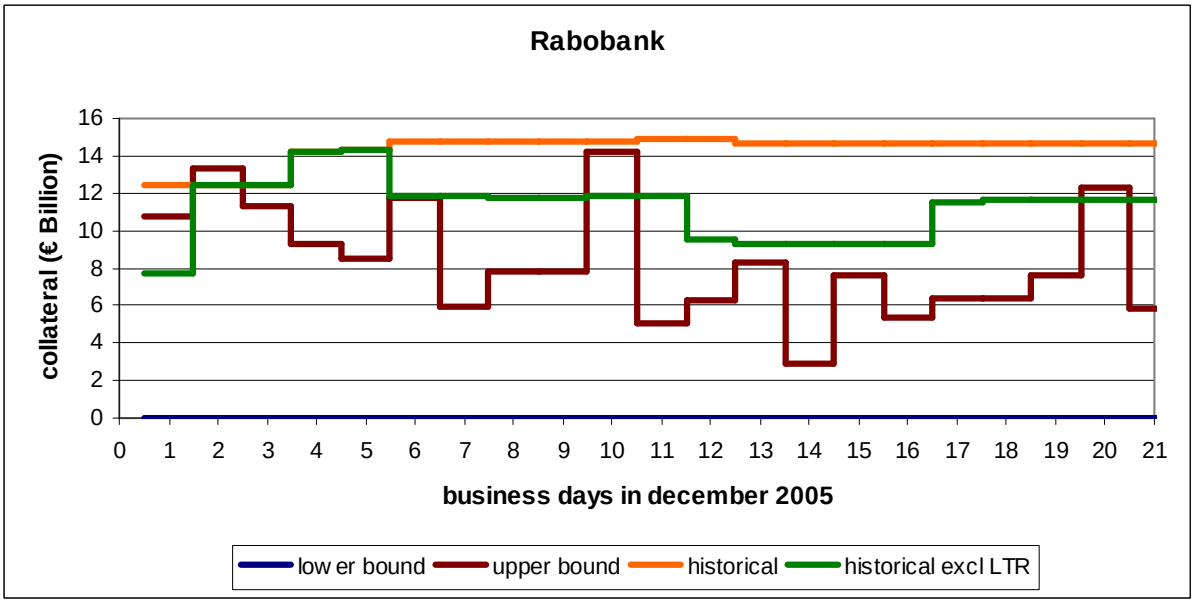
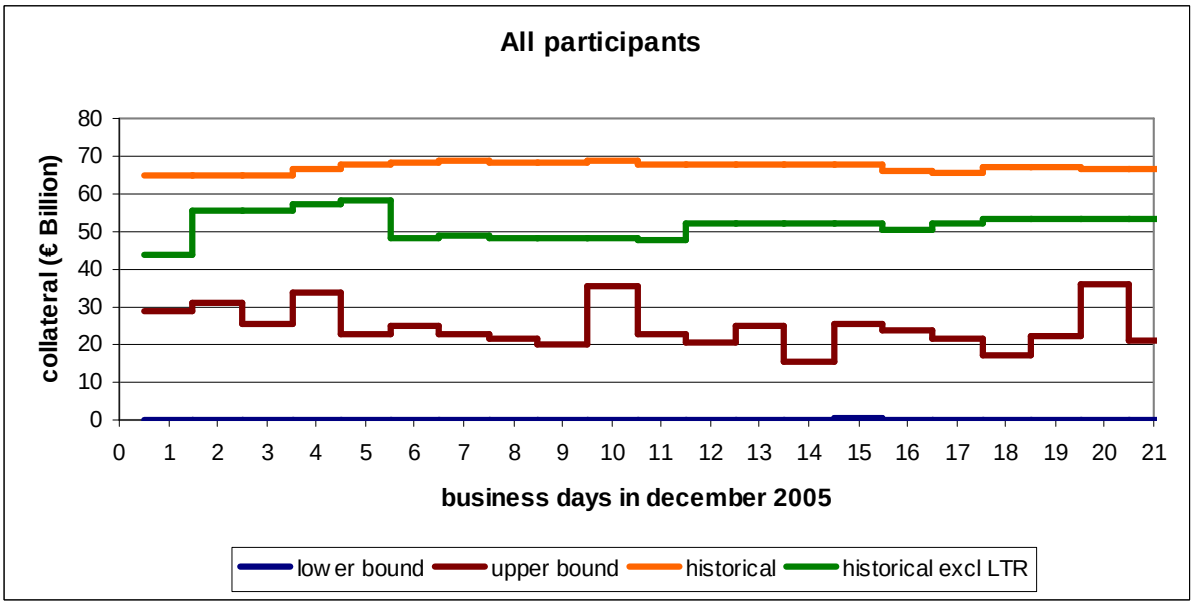


Figure 7: Sum of collateral values for all participants, December 2005



3.5 SIMULATIONS AND ASSUMPTIONS

The scenarios described in section 3.2 are based on a few assumptions. These assumptions do not necessarily reflect what happens in reality. They are required however to study the potential impact of a disruption given a certain stress scenario. The assumptions are:

- Participants cannot obtain extra liquidity from other accounts in TARGET. Also no additional collateral can be pledged in this analysis to obtain extra intraday or overnight credit.

- It is not possible for a participant to take a loan from another participant. In practice a participant who has not levelled its balance or has not fulfilled its cash reserve requirements will often take a loan from another participant.
- Participants do not react in any way to the stress situation. Even though this might not be realistic, the goal of this paper is to look at the potential effect of a stress situation on the whole payment system and not to study reaction patterns in these situations. Besides, reaction patterns also require assumption on these patterns.
- Every participant is treated equally. The simulations do not distinguish between a commercial bank, an ancillary system or a Central Bank. There are also participants who are completely funded by another participant (usually a large bank). These participants are relatively small in both volume and value.
- The accounts of the DNB, accounts of EU central banks and the treasury department have no check on their collateral, which means that they have access to an unlimited amount of intraday credit.
- Participants in TOP do not have to fulfil their minimum reserve requirement in this analysis.

4 Results: number of banks affected

4.1 INTRODUCTION

This section gives the results of the simulations with respect to the number of banks affected by the disruption. The figures presented in this section will refer to December 2005 unless stated otherwise. In this paper affected means that a bank has unsettled transactions at the end of the day. Also banks which do not have unsettled payments will face the effect of the disruption, but that is still within their possibility to "absorb" the shock and to fulfil their own obligations. The number of banks affected gives insight in how the disruption spreads out over the payment system. This does not say anything about the value of unsettled payments, which will be described in section 5. In section 4.2, 4.3 and 4.4 the number of affected banks is given when ABN AMRO, ING and Rabobank is disrupted respectively. The description of the different scenarios was given in section 3.

4.2 ABN AMRO

This subsection describes the number of banks affected by the disruption of ABN AMRO. A comparison is made between the different scenarios.

4.2.1 Scenario: Single Day, Historical Collateral, December 2005 and April 2006

Figure 8 and Figure 9 show the number of banks affected as a result of a disruption of ABN AMRO for each business day of the month December 2005 and April 2006. The disruption in these figures is a decrease of its outgoing payments (to 50%, 75%, 90% and 95% of its historical payment values). The amount of collateral in this scenario is the HC. This decrease in payments by ABN AMRO leads to less liquidity for the other participants in TOP. For the cross border TARGET participants this will have no effect because by assumption these cross border TARGET participant have unlimited liquidity, see section 3.5. The domestic participants on the other hand might face payment difficulties as a result of this decrease in payments of ABN AMRO. The separate bars in the figures show the number of banks affected on each business day of the relevant month. There are no spill over effects to the next business day, which means that unsettled payments at the end of the day will be removed from the queue before going to the next business day.

From Figure 8 it can be seen that in the 50% case 4 to 10 participants will be affected by the disruption. In the 95% case this is 3 to 7 participants. The number of affected banks does not decrease much when the disruption becomes smaller. The reason for this is that most of the affected participants are relatively small. Many of these small participants do not have much or any collateral and quite often have (almost) zero beginning of day balances. The result is that when such a participant does not receive a few payments this will lead to unsettled payments at the end of the day. Most of the small

Figure 8: **Number of banks affected when ABN AMRO pays 50%, 75%, 90% and 95% of its payments, when each day is treated individually.**

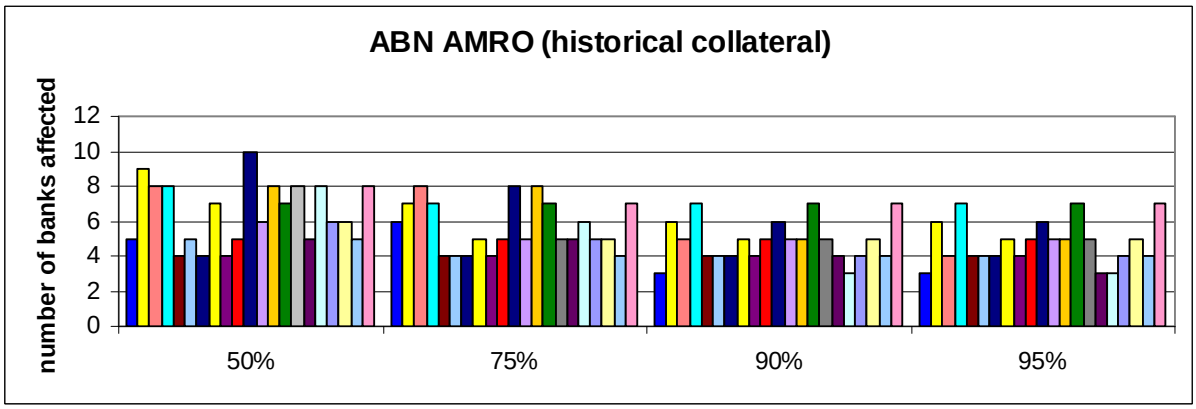
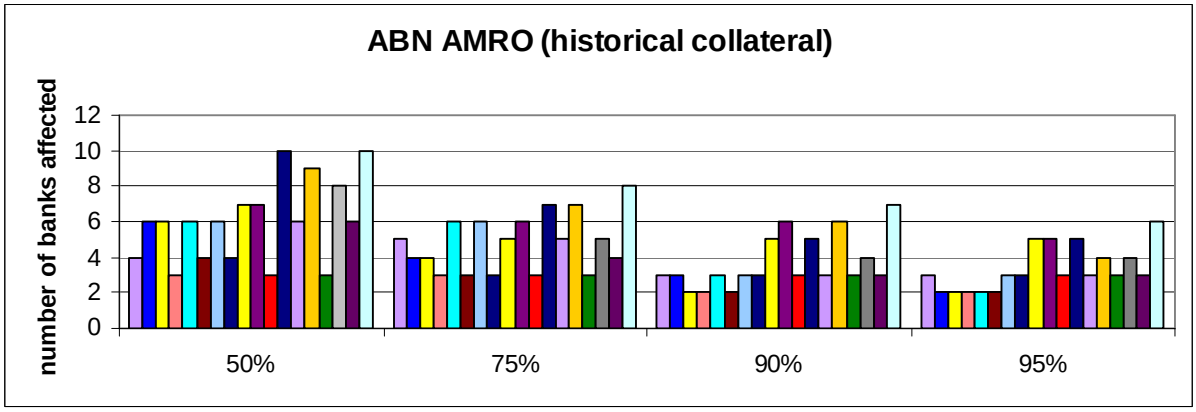


Figure 9: **Number of banks affected when ABN AMRO pays 50%, 75%, 90% and 95% of its payments for the month April 2006, when each day is treated individually.**



affected participants are controlled by large participants. The large participant funds the account of the small participant in the morning and the remaining liquidity at the end of the day is transferred back to the large participant. Other participants which have unsettled payment at the end of the day are Equens, Euroclear and Kasbank (Trade for Trade (TfT) account). These participants also have no collateral on these accounts. Also the accounts of HSBC and Citibank show some unsettled values. The results for April 2006 are similar to the ones for December 2005. The figures also show that the number of banks affected given a certain disruption varies between the business days. This is the result of the large daily net transferred value, see Figure 3. A large negative net transferred value has a larger impact on the other domestic participants than a large positive net transferred value. In the first situation the bank pays much more than it receives, which makes the other participants more dependent on the disrupted bank, in this case ABN AMRO.

Figure 10 and Figure 11 show the number of banks affected as result of a disruption of ABN AMRO. In this disruption ABN AMRO pays 110%, 125%, 150% and 200% of the historical values for December 2005 and April 2006 respectively. There are no spill over effects to the next business day.

Figure 10: Number of banks affected when ABN AMRO pays 110%, 125%, 150% and 200% of its payments, when each day is treated individually.

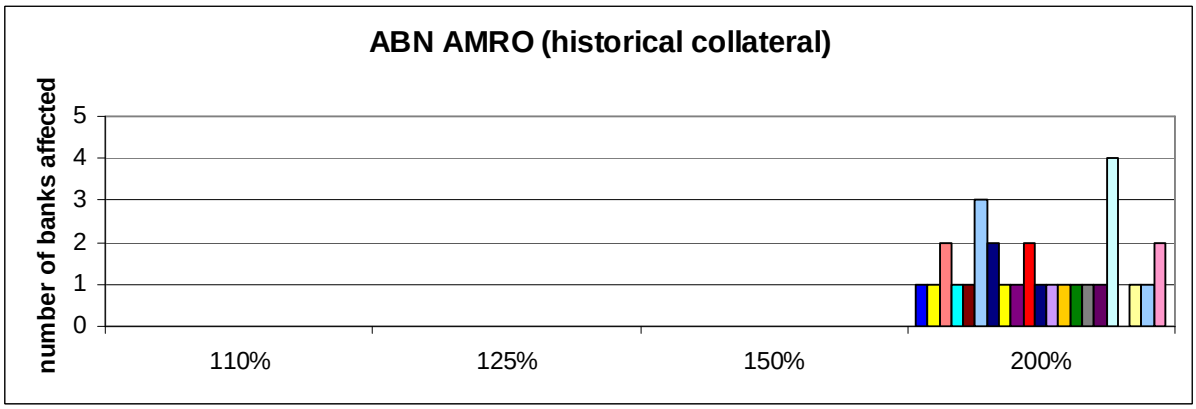
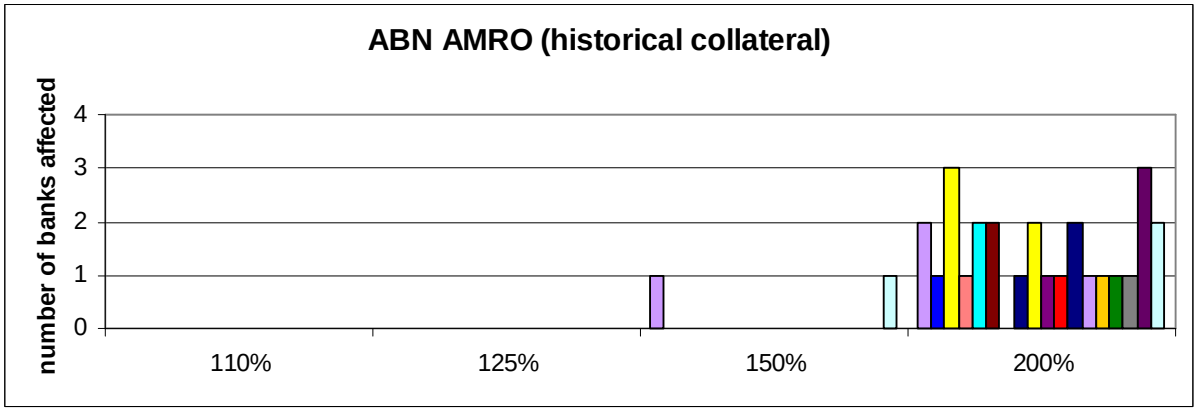


Figure 11: Number of banks affected when ABN AMRO pays 110%, 125%, 150% and 200% of its payments for April 2006, when each day is treated individually.



There are no participants affected for the 110% to 150% cases for December 2005. This means that ABN AMRO is able to absorb its increased payments by means of its credit balance and collateral. There is one participant affected for the 150% case for April 2006, which is ABN AMRO itself. Even though ABN AMRO is able to fulfil its obligations it does not say anything about potential delays during the day. For the 200% case on the other hand there are 0 to 4 participants affected for December 2005 and 0 to 3 participants for April 2006. When there are one ore more banks affected, this is at least ABN AMRO, or in general the disrupted bank, because it has run out of liquidity.

It is interesting to see that not only ABN AMRO itself is affected. ABN AMRO provides the system with extra liquidity as a result of its increased amount of outgoing payments. You might expect only ABN AMRO to obtain payment problems when it runs out of its liquidity. The first reason that not only ABN AMRO is affected is that most of the transferred values from ABN AMRO go cross border. This means that a lot of liquidity leaves the domestic market to cross border TARGET participants. A second reason could be that the payments are not distributed homogeneously over the domestic participants in time. The result of a heterogeneous distribution in time could be that participants, who expect early payments from ABN AMRO, will still receive them while others who expect payments at the end of the day will not because ABN AMRO has run out of liquidity in the mean time. Especially

participants with little or no collateral will face payment problems when they do not receive a few payments.

4.2.2 Scenario: multiple day, historical collateral, December 2005 and April 2006

In section 4.2.1 the results of the simulations were shown when there are no spill over effects to the next day. This section shows the results for the situation in which the disruption continues the whole month. The unsettled payments at the end of the day are transferred to the beginning of the next business day. Even though it is not likely that a disruption will continue the whole month, it gives insight to what extend the disruption of a large participant, in this case ABN AMRO, can continue without causing a total gridlock of the payment system. The more time there is before having a total gridlock the more time other participants and central banks have, to take countermeasures.

Figure 12 and Figure 13 show the number of banks affected when the shock continues the whole month for the month December 2005 and April 2006 respectively. The shock starts at the first day of the month. The number of banks affected in the 50% case is up to 33 for December 2005 and 34 and 35 for April 2006. It is clear from both figures that there is an increasing trend for the 50%, 75% and 90% cases is increasing, but not continuously increasing. The number of banks affected decreases slightly on many days. This is due to the fact that some participants remain with unsettled payments at the end of the day because they are only short of liquidity by a small amount. Obtaining some liquidity from a payment can make them fulfill their obligations. The number of banks affected for the 95% case goes up to 12 for December 2005. The average is just below 10 banks during the month. There is no clear increasing trend for this case. For April 2006 the number of banks affected is around 5 most of the month to have an increase at the last five days up to 13 banks.

Figure 14 and Figure 15 show the number of banks affected for the 110% to 200% cases for December 2005 and April 2006. In the 110% case for both months there are no banks affected by the shock. ABN AMRO is able to transfer the increased payment value by use of its collateral. After 7 to 8 days ABN AMRO reaches its credit limits and will have unsettled payments at the end of the day. The 125%, 150% and 200% cases show an increase of the number of banks affected which goes up to 21 banks for the 200% case. The reason why many banks will be affected even though ABN AMRO is providing the payment system with extra liquidity is that most of this liquidity goes to cross border TARGET participants and therefore will not reach other Dutch participants. A second reason could be that the distribution of the payments within the domestic payment system is heterogeneous.

Figure 12: Number of banks affected when ABN AMRO pays 50%, 75%, 90% and 95% of its payments, when the shock continues the whole month.

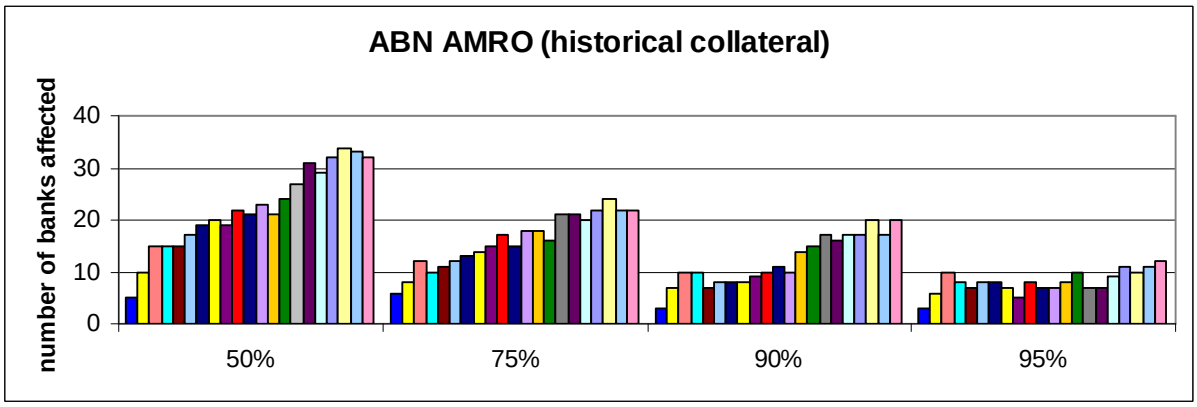


Figure 13: Number of banks affected when ABN AMRO pays 50%, 75%, 90% and 95% of its payments for the month April 2006, when the shock continues the whole month.

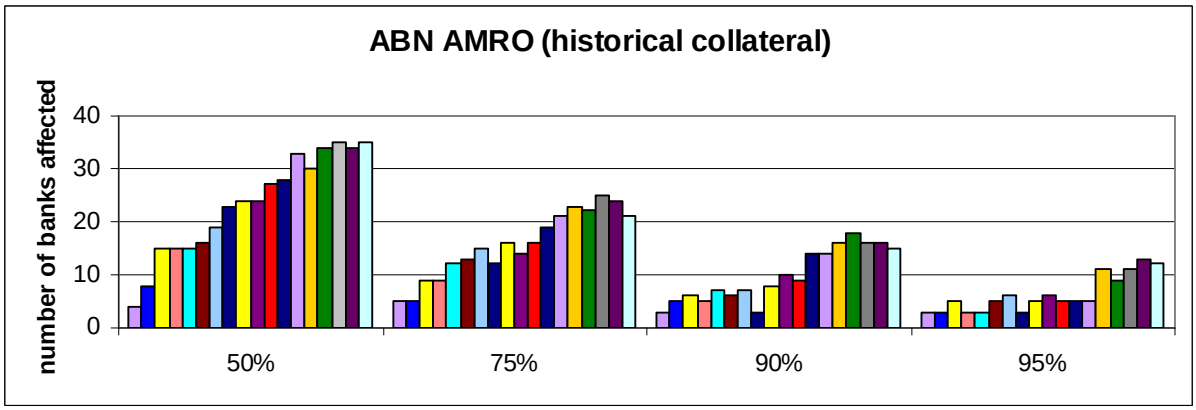
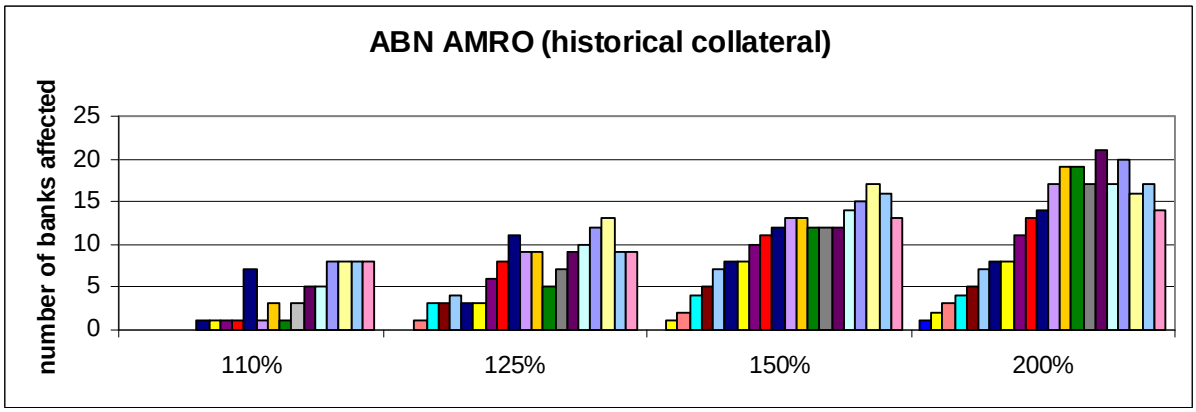


Figure 14: Number of banks affected when ABN AMRO pays 110%, 125%, 150% and 200% of its payments, when the shock continues the whole month.



4.2.3 Scenario: single day and multiple day, historical collateral exclusive open market operations, December 2005

Figure 16 and Figure 17 show the number of banks affected for the 50% to 95% and 110% to 200% cases for December 2005. The difference with section 4.2.1 is that the collateral value used in the simulation equals the HCex, see Figure 4. This means that due to the lower value of available

Figure 15: Number of banks affected when ABN AMRO pays 110%, 125%, 150% and 200% of its payments for the month April 2006, when the shock continues the whole month.

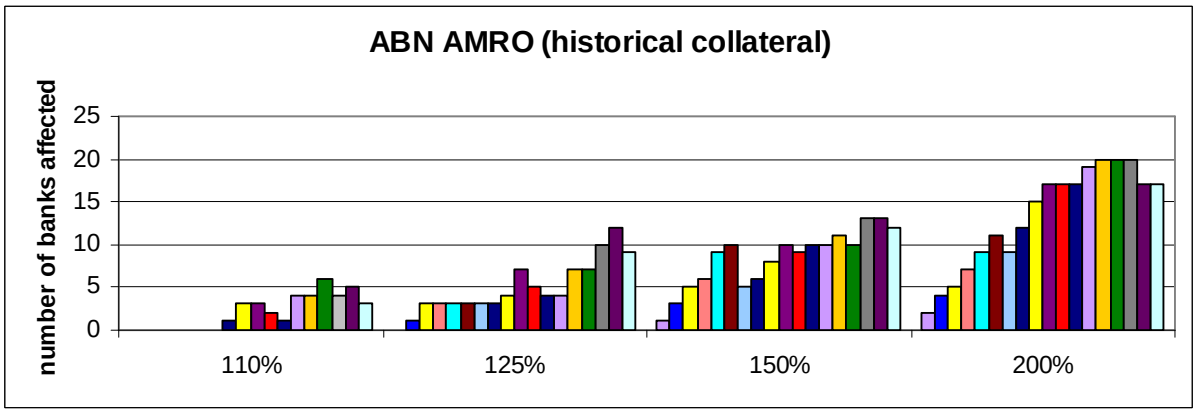


Figure 16: Number of banks affected when ABN AMRO pays 110%, 125%, 150% and 200% of its payments, when each day is treated individually.

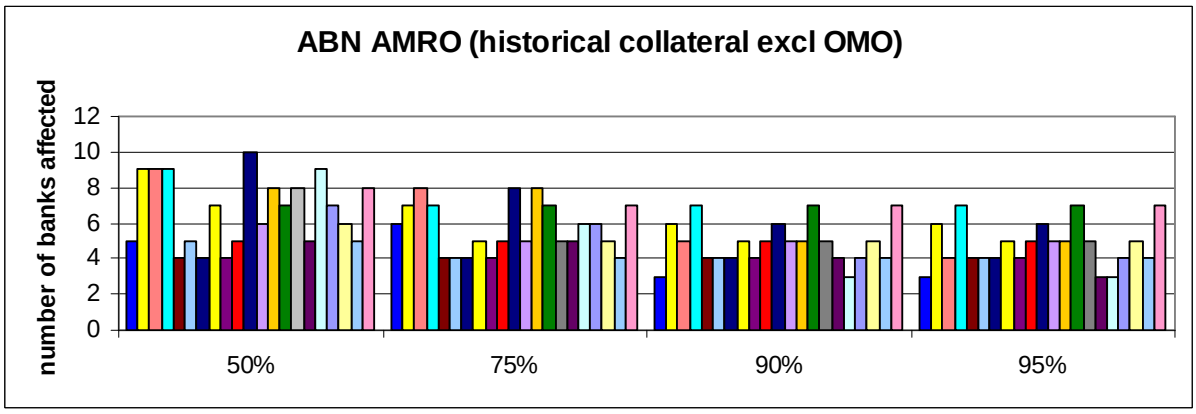
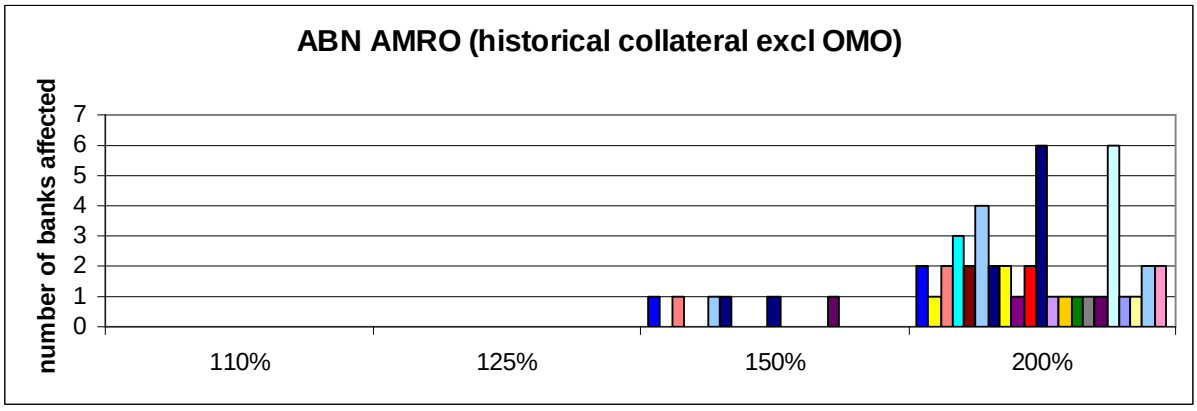


Figure 17: Number of banks affected when ABN AMRO pays 110%, 125%, 150% and 200% of its payments, when each day is treated individually.



collateral the maximum level of intraday credit is also lower. The difference in collateral value between the HC and HCex for ABN AMRO varies between EUR 2 and EUR 6 billion for the different business days, see Figure 4. The minimum and maximum number of banks affected is the same for the HC and HCex collateral scenarios. The average number of affected banks is slightly higher for the HCex. The number of banks affected equals zero for the 110% and 125% cases. The 150% case shows

that ABN AMRO is affected more often than in the HC case of section 4.2.1. For the 200% case the number of banks affected goes up to 6, which were 4 banks for the HC scenario.

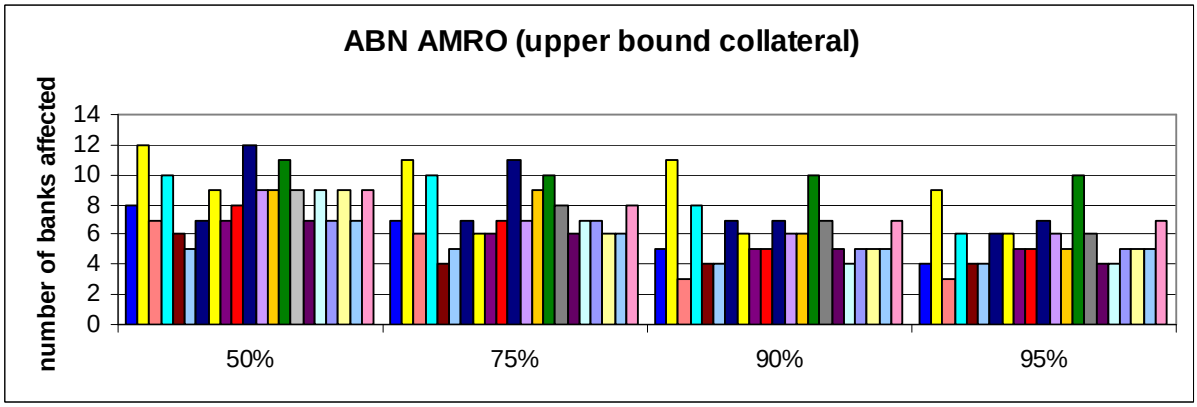
The maximum number of banks affected in the multiple day scenario simulated with HC and HCex shows similar results. The number of banks affected as a result of a given shock is slightly higher on average for the HCex. In the 110% and 125% case the number of banks affected show higher values. This is the result of the fact that ABN AMRO will run out of its liquidity sooner than in the HC scenario.

4.2.4 Scenario: single and multiple day, upper bound collateral, December 2005

Figure 18 and Figure 19 show the number of banks affected for the 50% to 95% and 110% to 200% cases respectively. The amount of collateral used represented in these figures is the UB, see Figure 4. This is the value which would be needed to process all the payments without any delay in case there was no disruption. The difference between UB and HC varies between € 2.5 and € 11 billion and between UB and HCex between EUR -3 and EUR 8.5 billion. Section 4.2.3 showed that the number of banks affected for the HCex was only slightly higher on average than for the HC. The number of banks affected for the UB scenario is between 5 and 12 for the 50% case and 3 and 10 for the 95% case. The average number of banks affected is higher than in the HC scenario. Besides the banks mentioned at the HC scenario the TfT account of ABN AMRO and Staal bank have unsettled payments at the end of the day.

Figure 19 shows that the ABN AMRO will have unsettled values at the end of the day in the 110% to 150% cases, which is in contrast with the HC scenario. This means that ABN AMRO UB collateral is insufficient to absorb the shock by the end of the day. In the 150% case there are 3 days with up to 3 other banks affected as a result of the shock. The 200% case shows an increase of banks affected of most days.

Figure 18: Number of banks affected when ABN AMRO pays 50%, 75%, 90% and 95% of its payments, when each day is treated individually.



The multiple day scenario using the UB shows an increase of banks affected at almost all days for all cases (95% to 200%). The maximum number of banks affected for the 50% case goes up to 46 and for the 95% case to 22, which is 34 and 12 banks for the HC scenario respectively. This will be up to 11 banks for the 110% case and 26 for the 200% case, which are 7 and 11 banks for the HC scenario.

4.2.5 Scenario: single and multiple day, lower bound collateral, December 2005:

The LB collateral is for almost all participants in the TOP system equal to zero, see Figure 7. This is the result of positive beginning of day balances for almost all participants. These beginning of day balances can be used to start making payments without having the need to use intraday credit which is secured by collateral.

Figure 20 and Figure 21 show the number of banks affected for the 50% to 95% cases and 110% to 200% cases respectively for December 2005 simulated with the LB collateral value. The number of banks affected in both figures is clearly higher than in the previous collateral cases. For the 50% case the number of banks affected range from 11 to 22 banks and for 200% case this 3 to 18 banks. For the HC scenario the number of banks is 4 to 10 for the 50% case and 1 to 4 for the 200% case.

Figure 19: Number of banks affected when ABN AMRO pays 110%, 125%, 150% and 200% of its payments, when each day is treated individually.

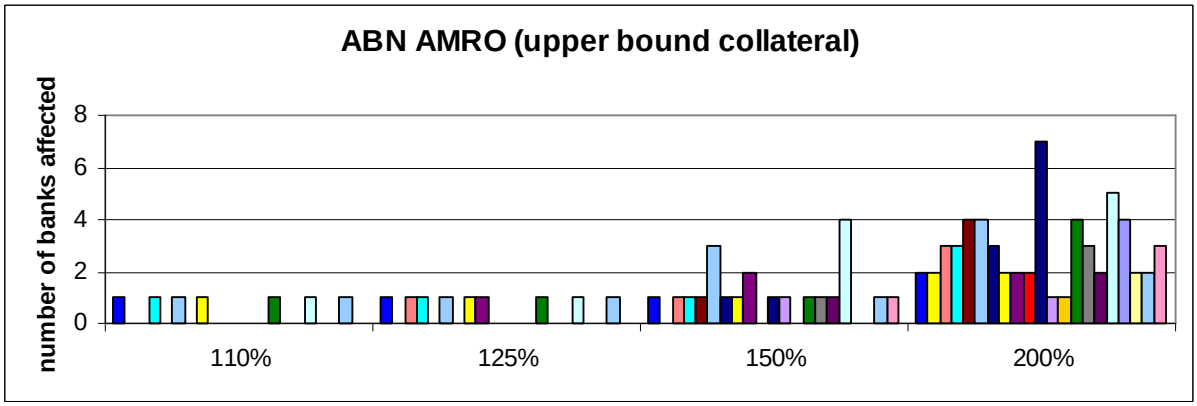


Figure 20: Number of banks affected when ABN AMRO pays 50%, 75%, 90% and 95% of its payments, when each day is treated individually.

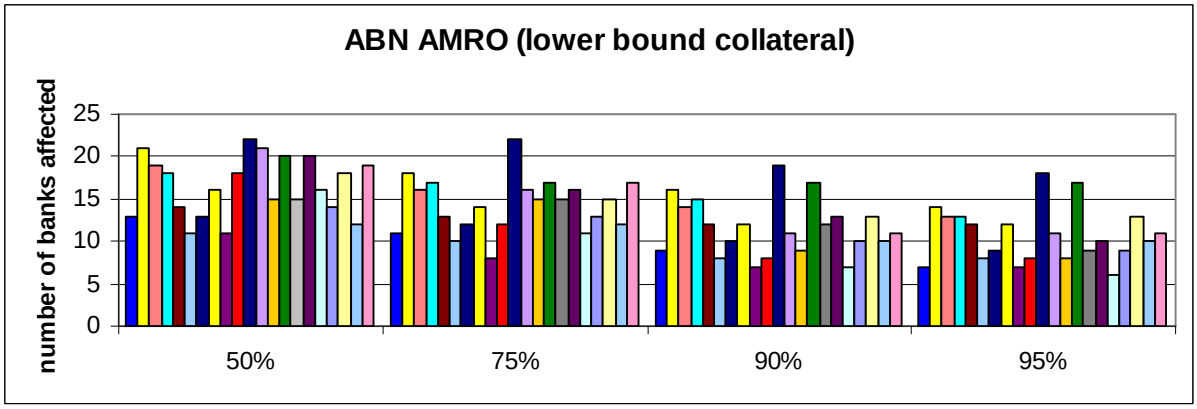
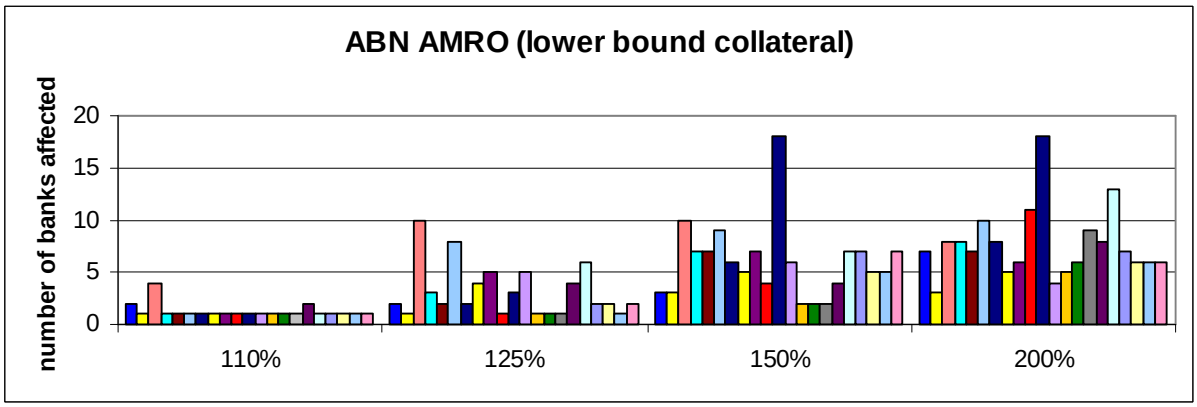


Figure 21: Number of banks affected when ABN AMRO pays 110%, 125%, 150% and 200% of its payments, when each day is treated individually.



The 95% case shows that when there is no collateral available for intraday credit, the number of banks affected goes up to 18 banks. For the HC scenario this was up to 8 banks. Besides the participants mentioned at the HC and UB scenarios BNP Paribas and Mendes Gans are participants with larger unsettled values for the 50% case. The 110% case shows that there is always one bank, ABN AMRO, which has unsettled values at the end of the day. This means that when there is no collateral available the banks can settle their payments by the end of the day, but when there is a small disruption by one of the large participants, this can result in a disruption for many other participants. For the multiple day scenario the number of banks affected goes up to 52 banks for the 50% case and up to 33 for the 200% case.

4.3 ING Bank

This section describes the results of the simulations when the disruption is caused by ING Bank. ING is one of the large participants in the TOP system, but is smaller in both value and volume than ABN AMRO, see Table 2. The results shown for ING will be compared with the ones found for ABN AMRO in section 4.2.

4.3.1 Scenario: single and multiple day, historical collateral, December 2005:

Figure 22 and Figure 23 show the number of banks affected when the outgoing payments of ING are decreased or increased respectively. The number of banks affected for the 50% case is 4 to 8 banks, which is 4 to 10 for ABN AMRO. Like for ABN AMRO scenario Euroclear, Equens and the TfT account of Kasbank have (larger amounts of) unsettled payments but also Bank of America shows these larger amounts.

For the 200% case the number is 1 to 3 banks which is 1 to 4 for ABN AMRO. For the 125% case and 150% there are days in which ING has unsettled values at the end of the day. This means that the impact of ING compared to ABN AMRO is smaller but that ING will run out of its liquidity sooner than ABN AMRO. The number of banks affected for the multiple day scenario shows similar trends to

Figure 22: Number of banks affected when ING pays 50%, 75%, 90% and 95% of its payments, when each day is treated individually.

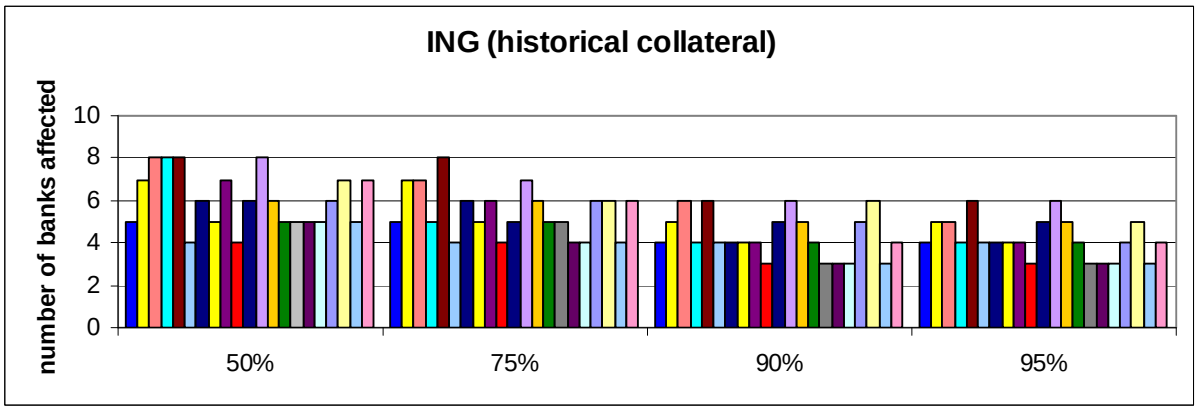
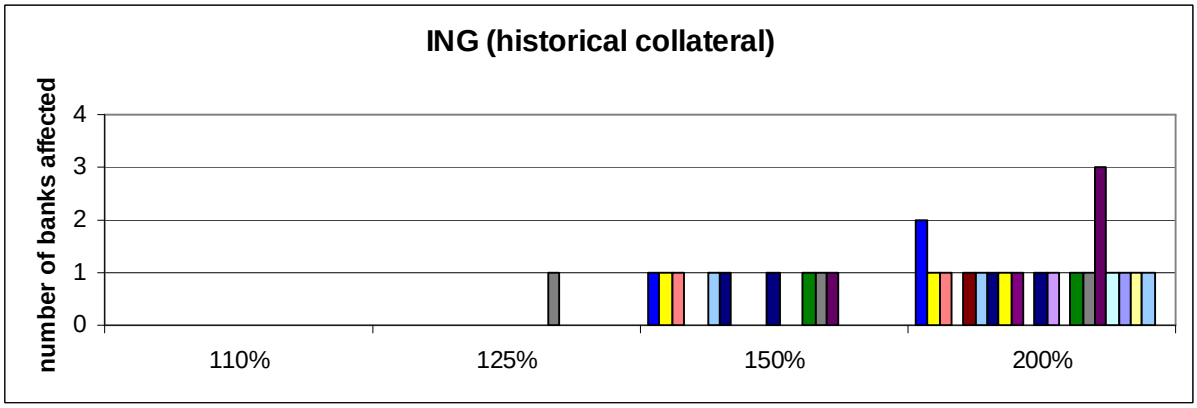


Figure 23: Number of banks affected when ING pays 110%, 125%, 150% and 200% of its payments, when each day is treated individually.



the ones found by ABN AMRO, however the number of banks is up to 25 banks, instead of 33 banks for the ABN AMRO scenario.

4.3.3 Scenario: single and multiple day, historical collateral excluding open market operations, December 2005

The maximum value of the historical collateral value excluding the open market operations is 50% of the historical value. This means that ING used a larger percentage of its collateral for open market operations than ABN AMRO. It has to be mentioned that this has changed over the last two years.

Figure 24 and Figure 25 show the number of banks affected for the 50% to 95% and 110% to 200% cases. For the 50% case there are 4 to 8 banks affected by the shock. The average number of banks affected is lower than for the same type of shock by ABN AMRO. This is due to the smaller daily payment values by ING.

When ING increases its outgoing values (110% to 200% cases) there will be more banks affected on average compared to the ABN AMRO. Even though ABN AMRO has a larger daily payment value than ING, the HCex is relatively lower for ING than ABN AMRO compared to the HC. As a result of

this ING will run out of its liquidity sooner and therefore will be able to affect other participants than itself as well.

Figure 24: Number of banks affected when ING pays 50%, 75%, 90% and 95% of its payments , when each day is treated individually.

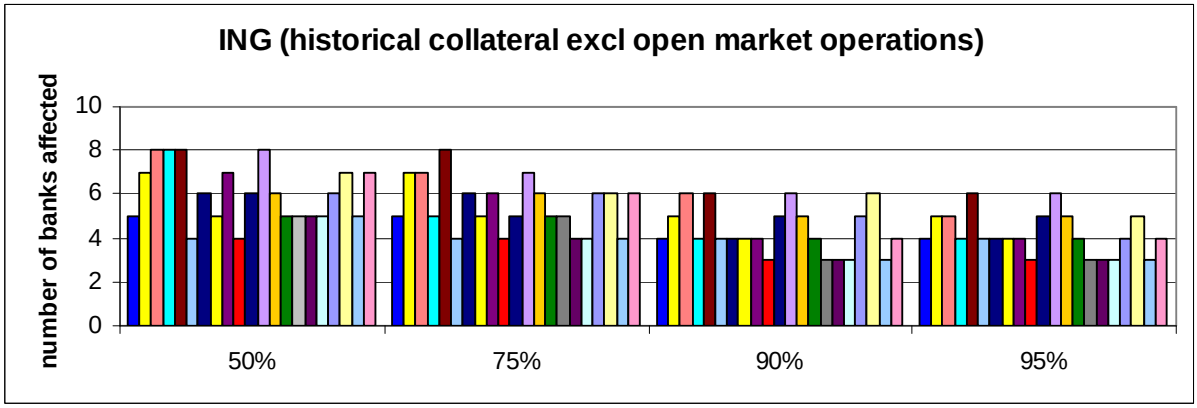


Figure 25: Number of banks affected when ING pays 110%, 125%, 150% and 200% of its payments, when each day is treated individually.

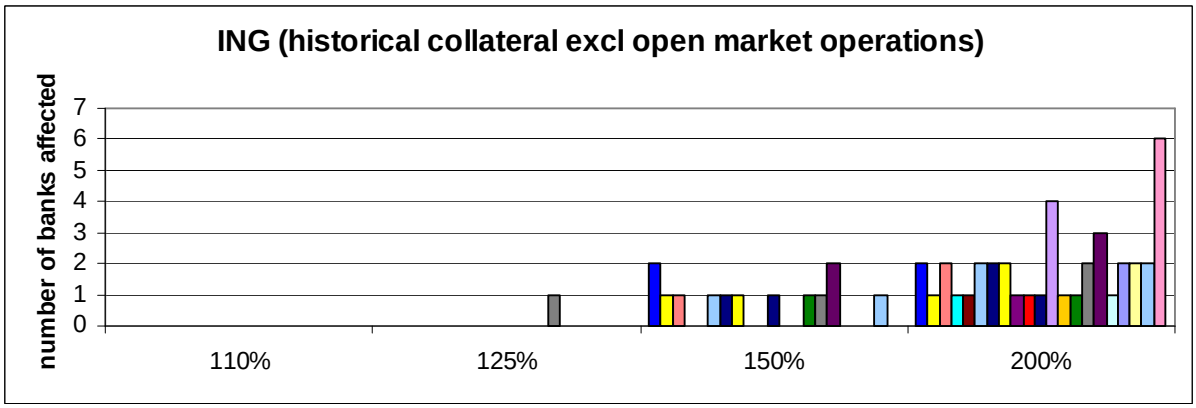


Figure 26: Number of banks affected when ING pays 50%, 75%, 90% and 95% of its payments, when each day is treated individually.

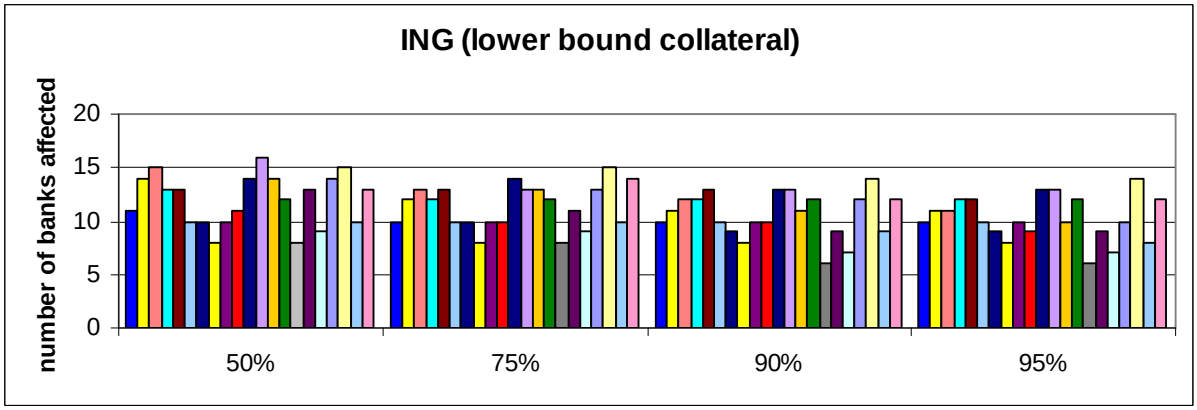
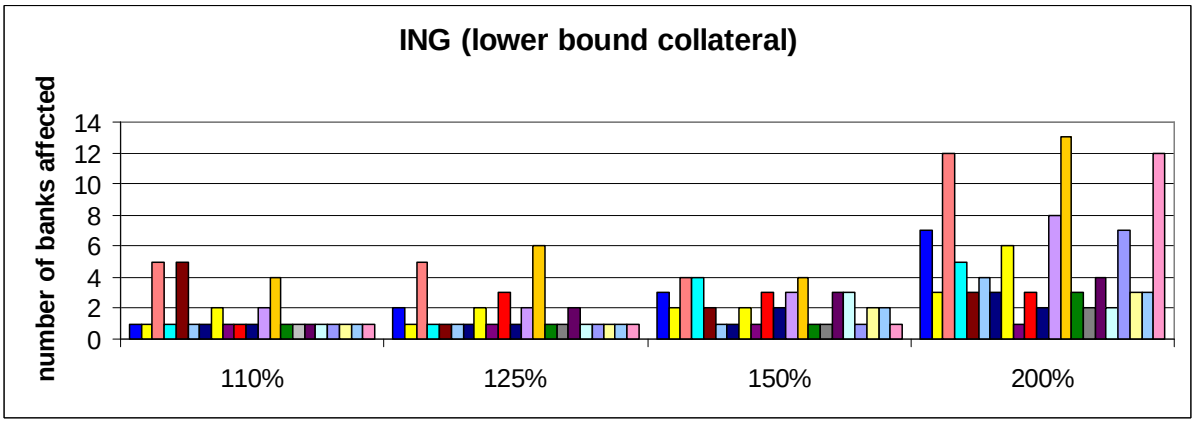


Figure 27: Number of banks affected when ING pays 110%, 125%, 150% and 200% of its payments, when each day is treated individually.



4.3.4 Scenario: single day and multiple day, lower and upper bound collateral, December 2005

The LB collateral is zero for all days and the upper bound collateral is zero for most of the business days, see Figure 5. However, two of the days have collateral values of EUR 4.5 and EUR 6 billion. The number of banks affected for the single day scenario is 8 to 16 banks for the 50% case, see Figure 26, which is approximately twice the number for the HC collateral scenario. Besides the small banks which are controlled by other banks, in the 50% case, BNP Paribas, Citibank, Euroclear and Kasbank (both TfT and regular account) Mendes Gans and Bank of America show larger amounts of unsettled payments. The multiple day scenario goes up to 43 banks for the 50% case 24 banks for the 95% case. For the 200% case the number of banks affected goes up to 35. The reason for this is that liquidity leaves the domestic market and flows to cross border TARGET participants.

4.4 Rabobank

This section shows the number of banks affected for the Rabobank given a certain collateral level and disruption. A comparison with both ABN AMRO and ING is made.

4.4.1 Scenario: single and multiple day, historical collateral, December 2005:

The historical collateral value for Rabobank during December 2005 varies between approximately € 12.5 and € 15 billion, see Figure 6. Figure 28 and Figure 29 show the 50% to 95% and the 110% to 200% cases for Rabobank for December 2005. Each day is treated separately, such that there are no spill over effects to the next business day. The number of banks affected for the 50% case is 1 to 7 and 1 to 3 banks for the 200% case. This is 4 to 10 and 1 to 4 banks for ABN AMRO and 4 to 8 and 1 to 3 banks for ING. The affected banks with the largest amount of unsettled values are the same ones as for ABN AMRO and ING.

Figure 28: Number of banks affected when Rabobank pays 50%, 75%, 90% and 95% of its payments, when each day is treated individually.

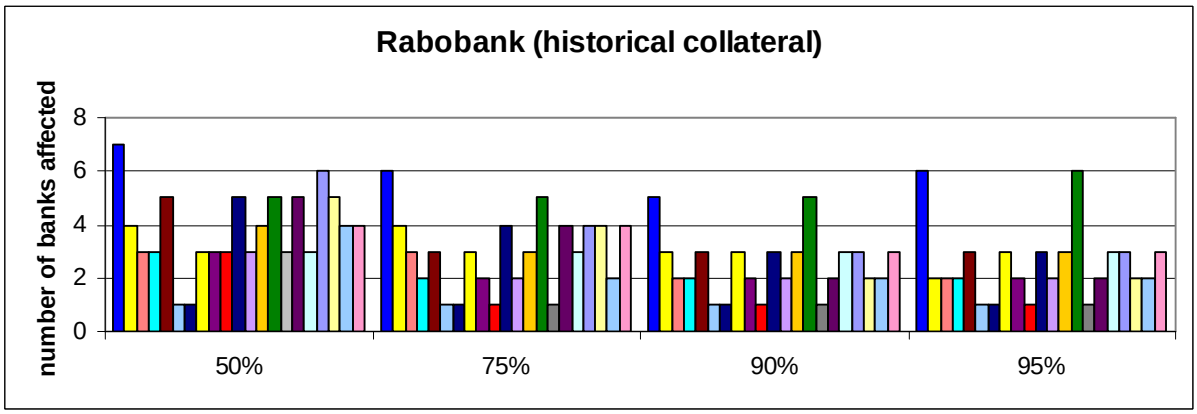


Figure 29: Number of banks affected when Rabobank pays 110%, 125%, 150% and 200% of its payments, when each day is treated individually.

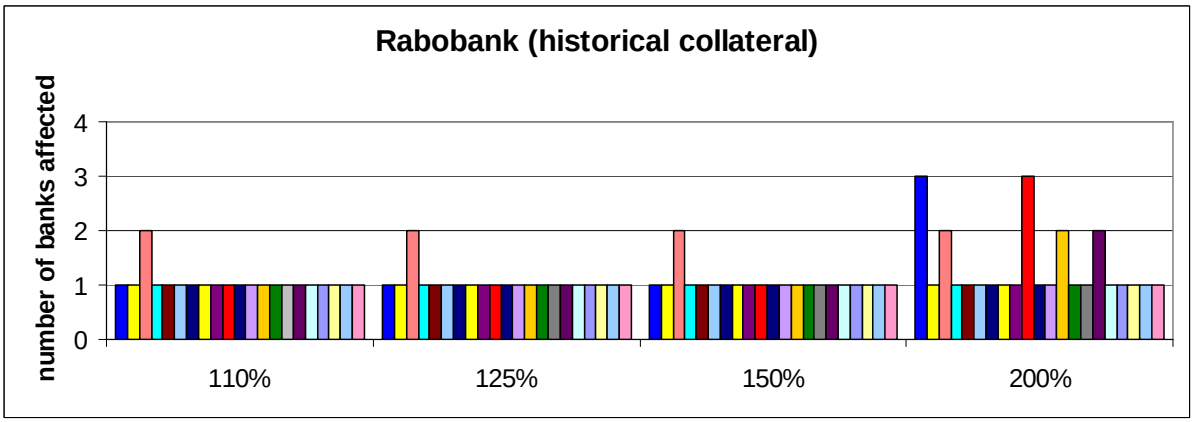
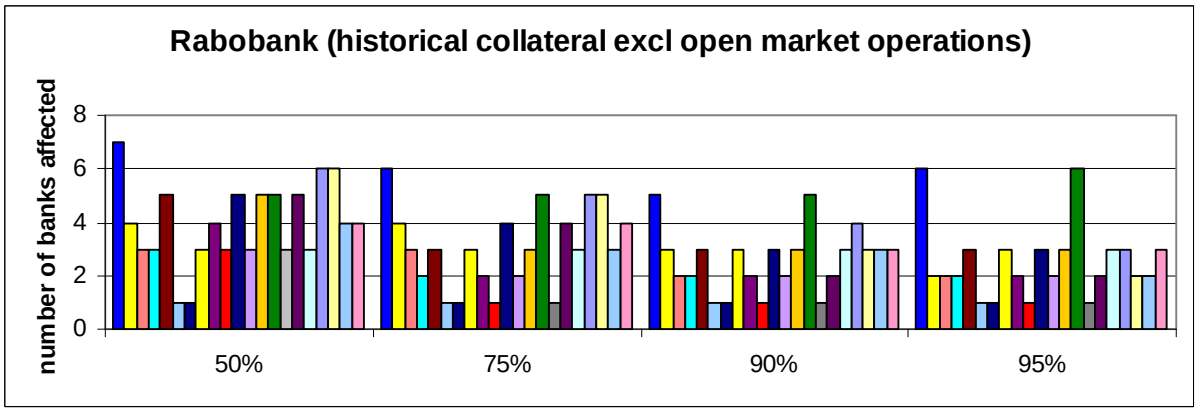


Figure 30: Number of banks affected when Rabobank pays 50%, 75%, 90% and 95% of its payments, when each day is treated individually.



4.4.2 Scenario: single and multiple day, historical collateral excluding the open market operations, December 2005

The value of HCex shows differences with HC of EUR 0 to EUR 5 billion. The differences for most days are within EUR 2.5 billion on a maximum value of EUR 15 billion, see Figure 6. This means that the impact of a shock is similar to the one described for the HC scenario. This can be seen by

comparing Figure 30 with Figure 28 of the HC scenario. Only at a few days the number of banks affected is slightly higher.

4.4.3 Scenario: single day and multiple day, upper bound collateral, December 2005:

The upper bound collateral value shows strong variation between the different business days. It is sometimes even higher than the HC and HCex. On other days it is up to EUR 7 billion lower than HCex and EUR 12 billion than HC. This means that the collateral need for Rabobank varies strongly during the business days. Figure 31 shows the number of banks affected for the 50% to 95% case for December2005. The number of banks affected varies between 2 and 9 for the 50% case. The variation in number of banks is higher than for the ING case, which shows values between 4 and 8. The variation for ABN AMRO shows values between 5 and 12.

4.4.4 Scenario: single day and multiple day, lower bound collateral, December 2005

The lower bound collateral value is zero for all days, like the lower bound for ABN AMRO and ING. Figure 33 shows the number of banks affected for the 50% to 95% case for December 2005. The number of banks affected for the 50% case is 4 to 17.

Figure 31: Number of banks affected when Rabobank pays 50%, 75%, 90% and 95% of its payments, when each day is treated individually.

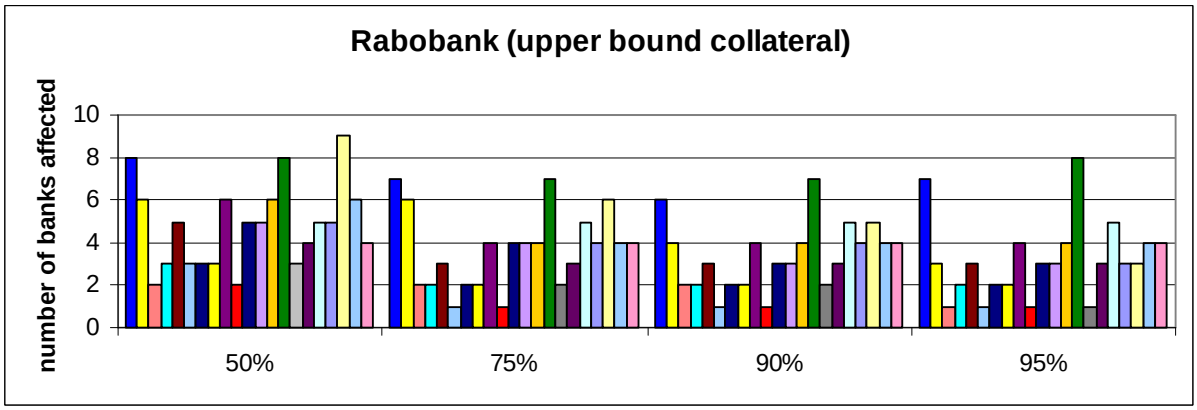
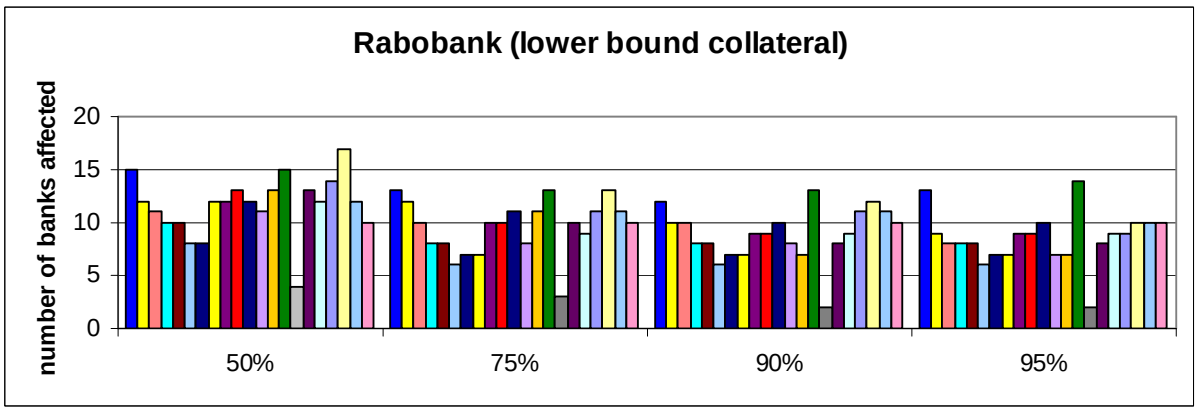


Figure 32: Number of banks affected when Rabobank pays 50%, 75%, 90% and 95% of its payments, when each day is treated individually.



4.5 Summary and general findings

This section has shown the number of banks affected given a certain disruption. All disruptions are simulated for each of the three large banks, ABN AMRO, ING and Rabobank. The simulations show some general characteristics.

Single day scenarios:

- The variation in number of banks affected varies from day to day as a result of the variation in daily net value transferred, see Figure 3. This makes it difficult to make a general prediction.
- The affected banks are usually small banks with little or no collateral. The accounts of Euroclear, Equens and Kasbank (TfT) are often affected. This is because these participants (accounts) do not have any collateral. The main accounts of the other two large banks are never affected by the disrupted large bank. It sometimes happens that a sub account of one of the two other large banks is affected. There is however sufficient liquidity available on the main account to solve the liquidity shortage on the sub account.
- The number of banks affected does not decrease much going from 50% to 95% cases.
- For the 110%, 125% and 150% cases the number of banks affected is zero or one. This is due to the fact that the large bank affected can absorb the extra payment value with its own collateral. If in one of these three cases a bank is affected it is the disrupted bank itself, but usually not the main account of the bank.
- The 200% case shows in quite some situations that more than one bank are affected. This is in all cases at least the disrupted banks itself. Even though more liquidity is provided to the system this is not done homogeneously. Also a lot of liquidity will leave the domestic market to cross border TARGET participants.
- The differences in number of banks affected between the HC and HCex scenario are not very large for the 50% to 95% cases. The reason for this is that the effected banks do not have large or any differences between their HC and HCex, which makes the cases relatively similar. The differences in the 110% to 200% cases are generally slightly larger because the disrupted bank runs out of its liquidity sooner. This is because the HCex is smaller in value than the HC.
- The UB shows larger number of banks affected in most cases. This is due to the lower values of collateral for almost all situations. The LB scenario shows much larger number of banks affected than the HC. This is the result of the collateral values which are zero for most banks, including the large banks.
- ING has for the 50% to 95% cases lower number of banks affected than ABN AMRO, but larger numbers for the 110% to 200%. In the first cases the impact of ING is smaller, due to its lower

total payment values. Rabobank has the lowest number of banks affected for the 50% to 95% case. For the 110% to 200% case they are similar compared to ABN AMRO and ING. The number of banks affected for the 110% to 150% cases one of the accounts of Rabobank is affected in many situations but this is not the main account.

Multiple day scenario:

- For both the 50% to 95% and the 110% to 200% cases there are increasing trends in the number of banks affected, but not continuously increasing. There are days in which there are fewer banks affected than the day before.
- The number of banks affected for ABN AMRO is larger than for ING and Rabobank. The increase in the number of banks affected for the 110% to 200% cases is the result of the liquidity going to cross border TARGET participants. During the month more and more liquidity goes to these cross border participants, but only the “historical amount” comes back to the domestic market.

5 Results: unsettled values

5.1 Introduction

The previous section showed the number of banks affected for the different scenarios. The number of banks affected shows how a certain disruption spreads out over the whole payment system. When only a few (small) banks are affected by the disruption the impact on the payment system is very limited. However, when many banks are affected, especially large banks, the impact of the disruption on the whole payment system becomes larger.

The number of banks affected does not say anything about the unsettled value and negative end of day balances which correspond with this number. In a hypothetical case a bank is EUR 0.01 or EUR 100 billion short to make a payment and this bank will be "affected" according to the definition in section 4. The first case however will be much easier to resolve than the latter one. This shortage of money can be resolved by e.g. an incoming payment or bringing in fresh collateral. The effect of bringing in extra collateral is not investigated in this paper, see the assumptions in section 3.5.

This section describes three different values as a result of the disruption:

- the value of unsettled payments at the end of the day,
- the total amount of collateral the banks with unsettled payments at the end of the day have available,
- the total negative end of day balances of all participants without unsettled values

The value of unsettled payments gives the direct impact of the disruption on the payment system. The amount of collateral gives information on the type of bank affected by the disruption. The banks with large values of collateral are relatively large ones while banks with little collateral are usually relatively small. There are also participants which do not have any collateral at all. Most of these are funded by a large bank (mother company). But also ancillary systems, like Euroclear and Equens do not have any collateral on the settlement accounts. When these banks are affected by the disruption the mother company will be able to provide sufficient funds to resolve the disruption for this bank. The total negative end of day balance of banks without unsettled payments shows the impact of the disruption on the other participants. Even though they do not have unsettled values they do face the negative results of the disruption by decreasing account balances.

The setup of this section is straightforward. The figures in the next section will show three different values for ABN AMRO, ING or Rabobank in one graph: unsettled values (red bar), amount of collateral used by the participants with unsettled values (yellow bar) and negative end of day balances of participants without unsettled values (blue bar). The sum of these three values gives the total impact on the payment system as a result of the disruption. In this section will be referred to these three values

as “the values”.The results of April 2006 are not shown separately because they are similar to the December 2005 scenarios, like for the number of banks affected. The peaks are however at different business days during the month. This means that the effect of a shock is not very much dependent on the month of the year but it depends on the day of the month. The figures presented in this section will refer to December 2005 unless stated otherwise.

5.2 ABN AMRO

5.2.1 Scenario: single day, historical collateral, December 2005:

Figure 33 and Figure 34 show the unsettled values at the end of the day (red bar), the total value of collateral used by the participants with unsettled values (yellow bar) and total negative end of day balance of participants without unsettled values (blue bar) for the 50% to 95% case and 110% to 200% for December 2005 respectively.

From Figure 33 it can be seen that the values vary throughout the month. Especially the unsettled values at the end of the day show strong variation. The amount of collateral of the participants with unsettled values is zero for many of the days. Cases in which a participant is funded by the mother company the amount of unsettled values could be lower, because the mother company might be willing to fund the daughter bank in case of disruptions. Comparing Figure 33 with Figure 8, which shows the number of participant affected by the disruption, shows that a peak in the latter figure does not automatically correspond with a peak in Figure 33. A peak in Figure 33 seems to correspond, however, with a larger number of banks affected in Figure 8.

The amount of unsettled values at the end of the day for the 50% case varies between € 0.3 and € 7.9 billion. The collateral values are between € 0 and € 0.4 billion and the negative end of day balances between € 0.1 and € 1.3 billion. The 75% to 95 % case show lower values for the sum of the three values in most cases. It is possible that the sum of the three values in e.g. the 75% case is larger than in the 50% case. This happens when a daughter bank of ABN AMRO obtains funds from ABN AMRO in the morning and is normally set to zero at the end of the day. The amount of outgoing payments from ABN AMRO to its daughter is in this case 75% of the total historical value instead of 50%. When the daughter is affected by the disruption of ABN AMRO and has the obligations to send a payment to ABN AMRO by the end of the day, ABN AMRO will not receive liquidity from its daughter but did have the higher obligation itself in the morning. Even though these situations do happen in this analysis, they are relatively rare.

Figure 34 shows that in the 110% to 150% cases there are no unsettled values. This is consistent with the fact that there are no banks affected in theses cases, see Figure 10. The negative end of day balances in these three cases are only of the disrupted bank ABN AMRO. The 200% case shows for all days but one unsettled payments at the end of the day. Most but not all of these unsettled payments

Figure 33: Unsettled values at the end of the day, amount of collateral used by participants with unsettled values and negative end of day balance when ABN AMRO pays 50%, 75%, 90% and 95% of its payments, when each day is treated individually.

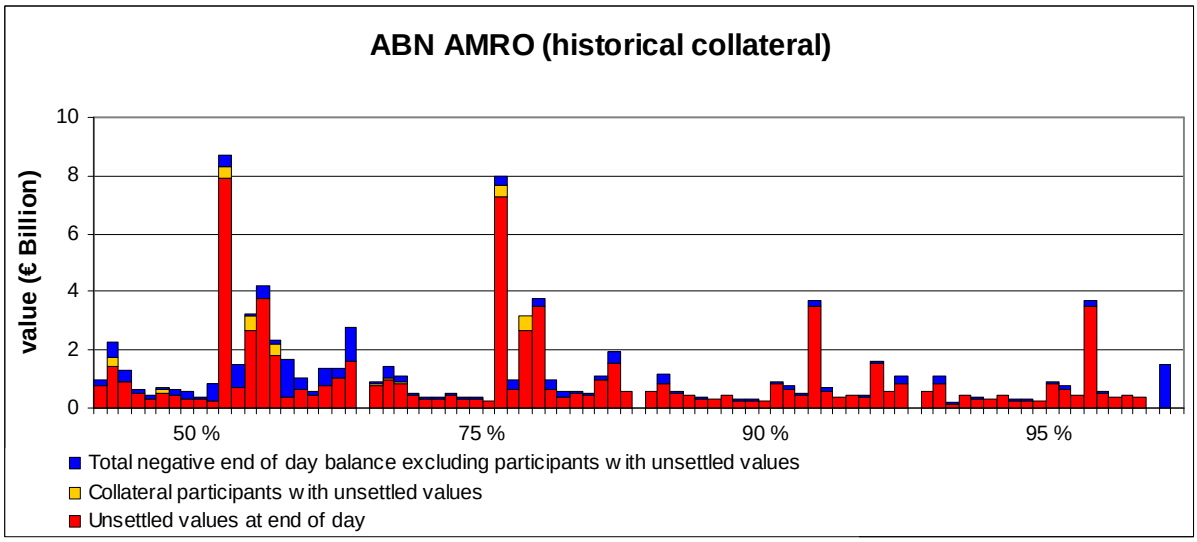
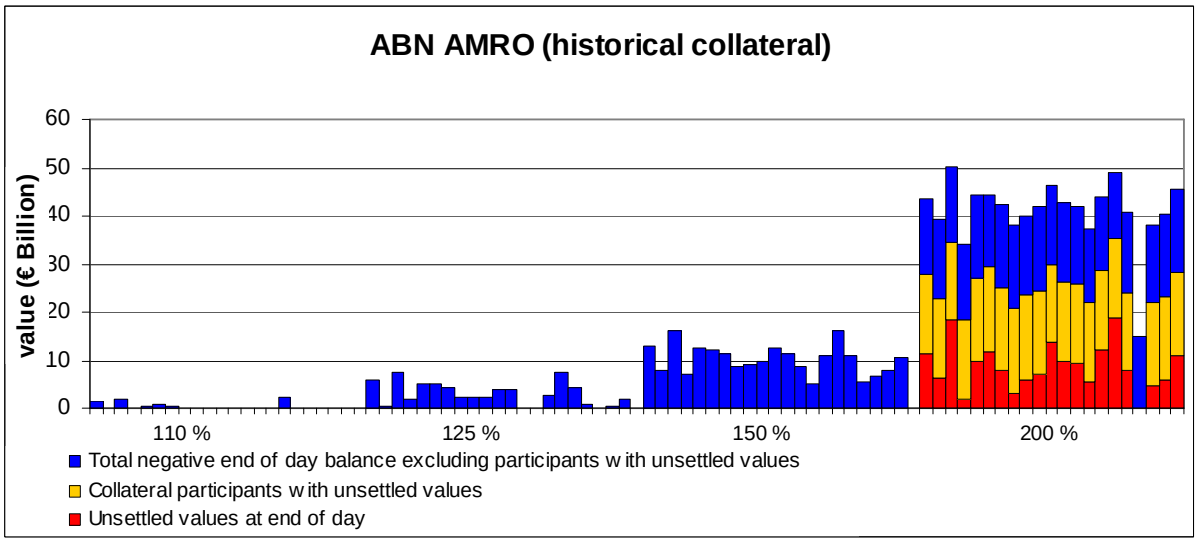


Figure 34: Unsettled values at the end of the day, amount of collateral used by participants with unsettled values and negative end of day balance when ABN AMRO pays 110%, 125%, 150% and 200% of its payments, when each day is treated individually.



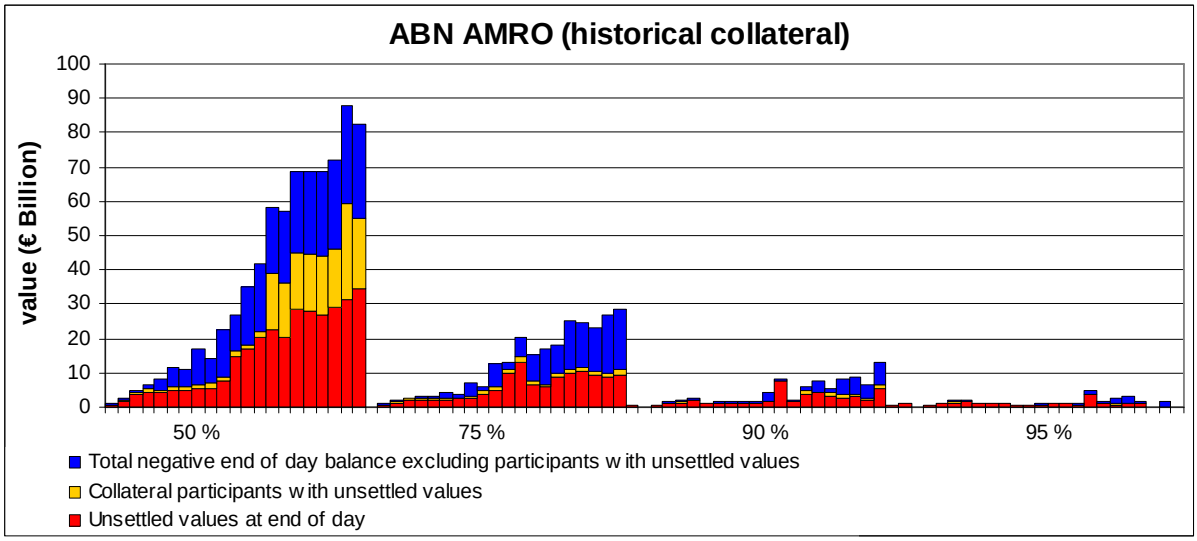
are linked to ABN AMRO. This can be seen by Figure 10, which shows several days with more than one and up to four banks affected. The collateral value of ABN AMRO is approximately € 17 billion. The amount of used collateral listed in the figure varies between in EUR 13.8 and EUR 17.5 billion. This is lower than the maximum available collateral of approximately EUR 17 billion. This is because when a large payment of e.g. EUR 2.5 billion is doubled in the 200% case, which can not be executed as a result of insufficient liquidity on the account, could `block´ up to EUR 5 billion of collateral. This collateral could have been used to execute payments which are behind this payment in the queue.

5.2.2 Scenario: multiple day, historical collateral, December 2005:

Figure 35 shows the values of the 50% to 95% cases for December 2005 for the multiple day HCex scenario. From the 50% case can be seen that the sum of the values shows an increasing trend if the shock continues the whole month. The maximum potential impact for this case is EUR 88 billion (the sum of the three bars) if the peak is not at the last day but the day before the last day of the month. From the 14th day the sum of the three values makes a jump. This is mainly due to the used collateral which increases by a factor 10 to EUR 16.2 billion. A large part of this collateral is from Rabobank, which has for the first time this month unsettled values at its main account. The increasing trend is also visible for the 75% and 90% cases but not as strong as the 50% case. For the 95% case this trend cannot be observed. The maximum amount of used collateral used by the 75% to 95% cases is EUR 1.4 billion which is significantly less than for the 50% case. This means that the main accounts of ING and Rabobank as a result of a disruption of ABN AMRO will not have unsettled values at the end of the day for these three cases.

The 110% to 200% cases show increasing trends for all cases. For the first few days of the 110% and 125% cases all values will be settled by the end of the day. This can also be seen by Figure 14, which shows the number of banks affected by the disruption. This is also zero for the first days for the 110% and 125% cases. The trend for the number of banks affected is not the same as for the values. There is both an increase and a decrease in number of banks affected at the end of the month. This means that even though the maximum potential impact increases in value, the number of banks affected does not increase. Most of the unsettled values belong to ABN AMRO. However, an increasing amount is linked to other participants. This can be seen by the increasing amount of used collateral. This increases from EUR 15.9 to EUR 30.9 billion for the 200% case. Initially it is only ABN AMRO,

Figure 35: Unsettled values at the end of the day, amount of collateral used by participants with unsettled values and negative end of day balance when ABN AMRO pays 50%, 75%, 90% and 95% of the value of its payments. The shock continues the whole month.



which is affected by the disruption. The increase in collateral is not linked to ING or Rabobank. Because of the increased payment value of ABN AMRO a lot of the liquidity leaves the domestic market to cross border participants.

The 110% to 200% cases show increasing trends for all four cases and the maximum of the three values at the end of the month go up to EUR 73 billion for the 110% case and EUR 636 billion for the 200% case. An interesting characteristic is that the collateral values (yellow bar) also show an increasing trend, which means that not only the amount of unsettled values increases (mainly linked to ABN AMRO), but also more and more banks (including larger ones) will be affected. This is due to the liquidity going to cross border TARGET participants.

5.2.3 Scenario: single day and multiple day, historical collateral excluding open market operations and upper bound collateral, December 2005

The single day HCex scenario shows almost identical results as the HC scenario for the 50% to 95% cases. This is because the collateral values of most of the affected banks do not change. Like in the HC scenario the collateral value is relatively low, EUR 0.4 billion. The 110% to 200% cases also show many similarities to the HC case. The 200% case shows increased unsettled values and decreased collateral values and negative end of day balances. The sum of the unsettled values and the collateral used is larger for the HCex scenario. This is the result of less liquidity leaving the domestic market.

The multiple day scenario for the 50% to 95% cases also show very similar results compared to the HC scenario. The main difference is that overall the unsettled value is larger for the HCex scenario. This is not surprising because the collateral values are in most cases lower than for the HC scenario which means that a bank will sooner run out of liquidity. A few days (day 16 and 21) in the 75% case the main account of ING is affected.

The figure with the 110% to 200% case for the collateral value HCex is also very similar to the HC scenario. The difference in collateral between HC and HCex scenario is between EUR 2 and EUR 8 billion. The amount of unsettled payments goes up to EUR 43 billion and EUR 600 billion in the 110% and 200% case respectively. The amount of unsettled values in the HCex scenario is slightly higher than in the HC scenario. This is due to the lower available collateral which makes them run out of liquidity sooner. This is especially true for ABN AMRO which is the first participant to run out of liquidity. The amount of negative end of day balances for the HC scenario on the other hand is higher. This is because participants will not use up their collateral as quickly and therefore will face payment problems later then in the HCex scenario and can have larger negative end of day balances. The sum of the three values is larger for the HC scenario because most of the payments go to cross border TARGET participants. By assumption all these cross border TARGET-participants will never face negative end of day balances. This means that due to fact that ABN AMRO cannot process the same amount and value of payments as in the HC scenario it will transfer less liquidity to cross border

TARGET participants. The difference in the sum of the three value is however quite similar i.e. EUR 630 billion for HCex scenario and EUR 636 billion for the last day of the 200% case. For the UB scenario similar result are found.

5.2.4 Scenario: single day, lower bound collateral, December 2005:

The collateral values for the LB scenario are close to zero for all participants including the three large banks, see Figure 4 to Figure 7. This means that the only liquidity available is the positive credit balance on the account. In other words payments will only be executed when sufficient liquidity is available on the account. Therefore the sum of the three values is (almost) equal to the unsettled values at the end of the day value. This sum of the values compared to the HC scenario, Figure 33, is higher for all business days but the figures look similar in shape.

Comparing the 110% to 200% cases of the LB scenario to the HC scenario, see Figure 34, shows that the total value unsettled is higher in the LB scenario than for the HC scenario. In the situations that ABN AMRO is running out of its collateral, the total amount of the three values is larger in the HC scenario than the LB scenario because a large part of the liquidity goes to cross border TARGET participants. This liquidity does not leave the payment system in the LB scenario because there is not enough liquidity to execute the payments. These payments will be send to the queue of unsettled payments. This means that the end of day unsettled payment list is different for the LB scenario compared to the HC scenario.

5.3 ING Bank

5.3.1 Scenario: single day and multiple day, historical collateral and historical collateral excluding open market operations, December 2005:

Figure 36 and Figure 37 show the three values for the 50% to 95% cases and 110% to 200% cases for December 2005 respectively for the single day HC scenario. From Figure 36 it can be seen that there is a variation between the sum of the three values between the different business days. The variation however is not as large as for the ABN AMRO scenario, see Figure 33. The amount of collateral used for the participants, who have unsettled payments at the end of the day is also relatively small, like in the ABN AMRO scenario. The number of banks affected, Figure 22, does not peak at the same days as the peaks in Figure 36. Figure 37 shows that for the 125% and 150% case there are a few days in which there are unsettled values. These unsettled values are connected to only one participant, see Figure 29. If only one bank is affected in the 110% to 200% cases this must be the disrupted bank, which is ING in this section. The amount of collateral used by ING in the 125% and 150% case is not the amount of the main account of ING, which is approximately € 8 billion. For the 200% case the main account of ING is affected by the shock. Figure 38 shows the values for the 50% to 95% case for December 2005. It is clear that when the shock continues more than one day the total impact (the sum of the three values) is significantly lower than in the ABN AMRO scenario, see Figure 34. For the

50% case this was up to EUR 88 billion for ABN AMRO and 19 billion for ING and for the 200% case this was EUR 636 billion for ABN AMRO and EUR 274 billion for ING. This observation is not surprising when looking at the total amount of outgoing payments in December 2005 listed in Table 2, which is EUR 694 billion for ABN AMRO and EUR 329 billion for ING. Secondly the amount of cross border payments is relatively higher for ABN AMRO (36%) than for ING (14%).

The 50% to 95% cases of the HC scenario show an increasing trend. This trend is not as clear as for the ABN AMRO situation. The total value for the 50% case is EUR 19 billion which is significantly lower than the EUR 88 billion of the ABN AMRO situation. This is due to the much lower payment values of ING. ING has 13% of the total payment value and ABN AMRO 27%. The cross border payments of ABN AMRO are relatively larger than for ING. Fewer cross border payments, thus more domestic, increases the potential impact on the domestic payment systems. Neither ABN AMRO nor Rabobank has been affected by the disruption of ING. This contrasts with the same disruption of ABN AMRO in which Rabobank was affected. The 110% to 200% show very similar results in trends compared to ABN AMRO. The maximum value for the three values in the 200% case is EUR 274 billion for ING and EUR 636 billion for ABN AMRO.

The HCex scenario for the 50 to 95% cases shows almost identical results to the HC scenario. This can be explained by the fact that the collateral values between the HC and HCex for small participants are (almost) equal. Because the same payments have to be executed between the two scenarios and the collateral values are the same the results are also similar.

Figure 36: Unsettled values at the end of the day, amount of collateral used by participants with unsettled values and negative end of day balance when ING pays 50%, 75%, 90% and 95% of the value of its payments, when each day is treated individually.

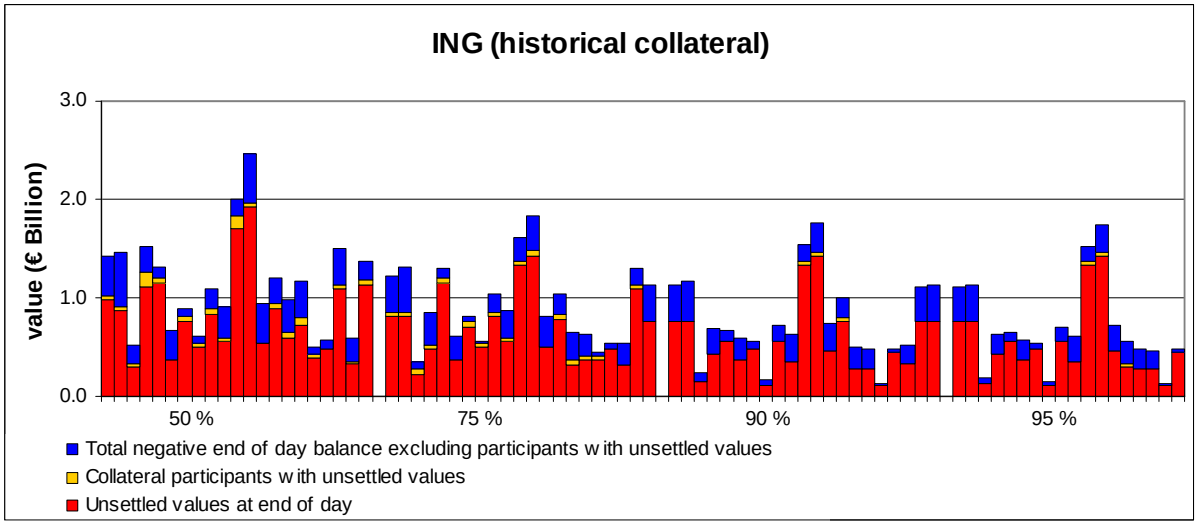


Figure 37: Unsettled values at the end of the day, amount of collateral used by participants with unsettled values and negative end of day balance when ING pays 110%, 125%, 150% and 200% of the value of its payments, when each day is treated individually.

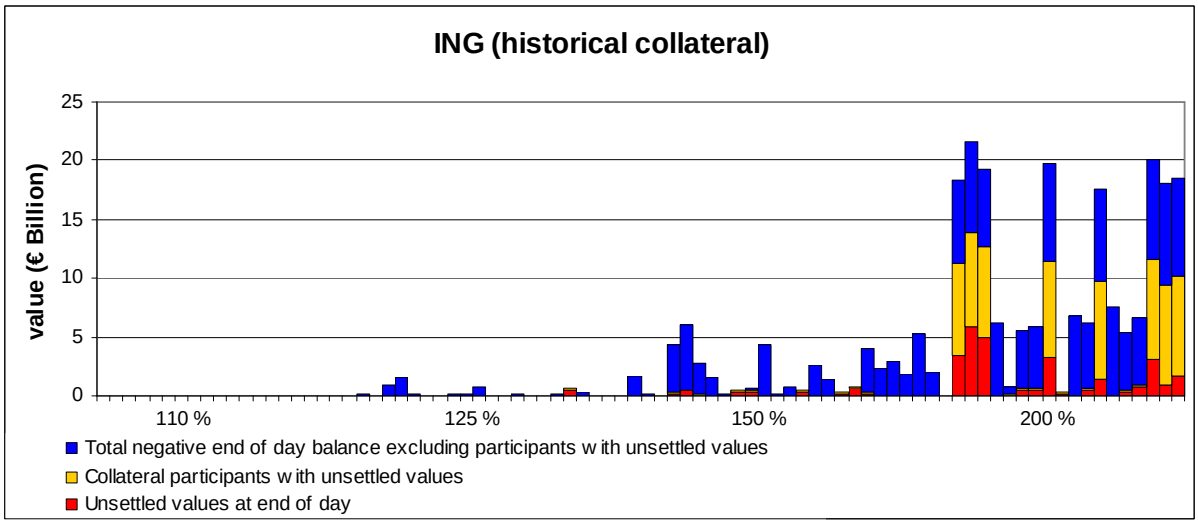
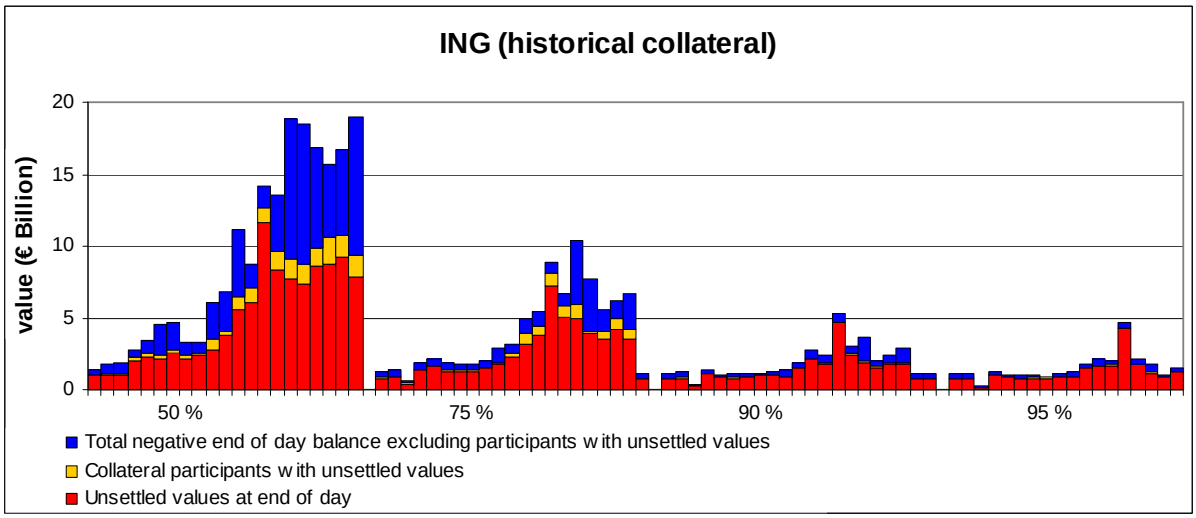


Figure 38: Unsettled values at the end of the day, amount of collateral used by participants with unsettled values and negative end of day balance when ING pays 50%, 75%, 90% and 95% of the value of its payments. The shock continues the whole month.



The 110% and 125% cases do not show unsettled values of the main account of ING. There are, however, some unsettled payments which are very low. These are unsettled payments of ING of accounts with no collateral. These values are not significant. The 150% case shows similar results for most of the days. For a few days the HCex collateral is insufficient for ING to settle all the payments. The 200% case for the HCex scenario shows more days with unsettled values than the HC scenario. The unsettled values (red bars) are higher for the HCex, but the total of the three values is higher for the HC scenario for the cases in which the main account of ING has insufficient funds to settle their payments. The HC scenario has a maximum peak of EUR 21.5 billion and HCex one of 17.

5.3.2 Scenario: single day and multiple day, lower and upper bound collateral, December 2005:

Given the fact that almost all participants have a lower bound of zero it is not possible to absorb a (temporary) shock by means of intraday credit. The effect of the shock is similar to what happened in the ABN AMRO scenario. The values are however lower (approximately 50%). Max EUR 6.5 billion for the 50% case. The maximum value of the unsettled values does not decrease much going from 50% to 95%.

5.4 Rabobank

The total payment value of Rabobank is smaller than ABN AMRO but larger than ING see Table 2. The average value of the payment of Rabobank is however much higher than the other two, EUR 21 billion compared to EUR 9 billion for ABN and ING. This is an important characteristic in case of a disruption. In situations in which there is not al lot of liquidity available on accounts a large value becomes more difficult to settle than smaller ones. This will be especially important in the 200% case because payments are double and therefore become even larger.

5.4.1 Scenario: single day and multiple day, historical collateral and historical collateral excluding open market operations, December 2005:

Figure 39 show the values for Rabobank for the 50% to 95% cases for December 2005 for the single day HC scenario. The values for Rabobank are lower than for the ABN AMRO scenario, see Figure 33, and comparable to the values for ING, see Figure 36. The domestic value for December 2005 is € 180 billion for Rabobank. This is EUR 250 billion and EUR 162 billion for ABN AMRO and ING respectively. The value of Rabobank and ING for the domestic part of the payment system are almost equal while the value for ABN AMRO is significantly larger. This explains why the impact of Rabobank and ING show similar results for the 50% to 95% cases. For the decreased value cases only the domestic payments are relevant because the cross border TARGET participant will never face payment problems by assumption.

The 110% to 200% show different results than the ING case. The maximum of the three values for Rabobank for the 200% case EUR 42 billion, for ING EUR 22 billion and for ABN AMRO € 50 billion. This is due to the different collateral values and different total payment values including the cross border payments. The cross border TARGET participants can absorb lots of liquidity. Rabobank has relative to ING much more cross border payments, but less than ABN AMRO.

The HCex scenario shows almost identical results for the 50% to 95% cases. This is due to the low collateral values of the banks which have been affected. Most of these banks do not have any collateral which can be used. This is also true for the 110% and 125% cases. The 150% and 200% cases show more days in which Rabobank will run out of its available collateral. The unsettled values show an increase in these two cases in the HCex scenario. The UB scenario for the single days show similar results compared to the HC and HCex scenario.

For the LB scenario, like for the ABN AMRO and ING LB scenarios, there will be hardly any collateral available to absorb a part of the shock. This means that also for Rabobank there are unsettled values at the end of the day without the use of collateral. The values of unsettled payments at the end of the day are lower than in the case of the ABN AMRO scenario, and comparable to ING scenario, see Figure 22 for ING. The latter can be explained by the relative amount of cross border payments. The unsettled value for the 50% to 95% cases is larger than for the HC scenario. The maximum value for the 50% case goes up to EUR 6.5 billion, which was EUR 3.4 billion for the HC scenario. The 200% case for the multiple day situation shows unsettled values up to EUR 474 billion.

Figure 39: Unsettled values at the end of the day, amount of collateral used by participants with unsettled values and negative end of day balance when Rabobank pays 50%, 75%, 90% and 95% of its payments, when each day is treated individually.

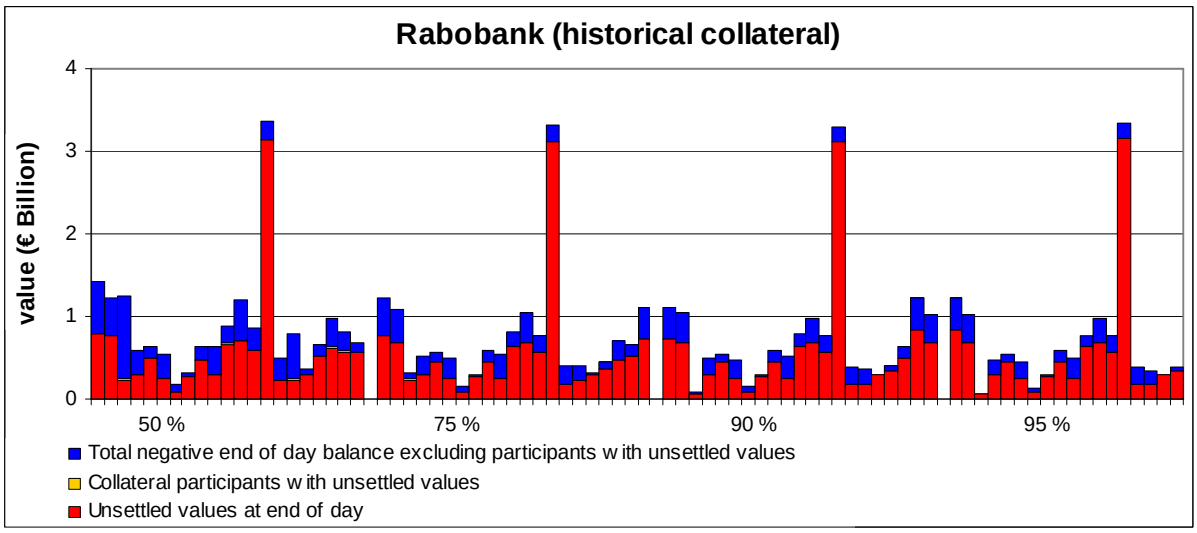
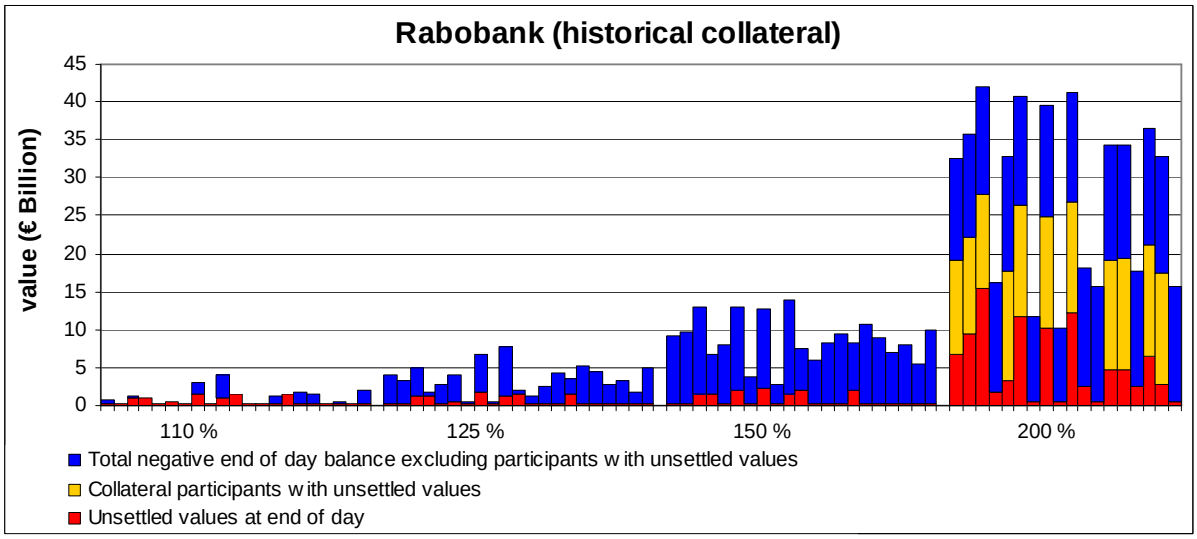


Figure 40: Unsettled values at the end of the day, amount of collateral used by participants with unsettled values and negative end of day balance when Rabobank pays 50%, 75%, 90% and 95% of its payments, when each day is treated individually.



5.5 Summary and general findings

This section has shown the value of the unsettled payments, the used collateral and the total negative end of day balances of the banks without unsettled payments by the end of the day for the different stress scenarios.

Single day scenarios:

- Like for the number of banks affected, the values also vary from day to day, which makes it difficult to make a general prediction.
- As can be seen from the number of banks affected, the values for the 200% case are significantly larger than for the 110% to 150%. This is the result of liquidity leaving the domestic market going to cross border participants.
- The differences between the HC and HCex scenario are small for the 50% to 95%. This is due to the fact that most of the affected banks have (almost) equal collateral values of the HC and HCex. The values for the 110% to 200% cases are slightly higher for the HCex scenario. The UB scenario also shows similar values to both HC and HCex. The LB scenario shows larger values on average, but the peak values are similar.
- ING and Rabobank have similar characteristics but the values are lower than for the ABN AMRO case. This is the result of the lower payment values of both banks compared to ABN AMRO.

Multiple day scenario:

- For both the 50% and 75% there is an increasing trend in the total values. However there are also days in which the total values are lower than in the day before. This is the result of the fluctuating daily net value transferred, see Figure 3. This increasing trend is not so visible in the 90% case and not visible for the 95% case.
- For the 110% to 200% cases there are increasing trends in the number of banks affected. There are few days in which there are fewer banks affected than the day before. The results between the four collateral values for the 110% to 200% are similar. This is the result of the impact of the disruption which is much larger than the "shock absorption capacity" of one single bank.
- ING and Rabobank show very similar trends. The values are lower for both banks than for ABN AMRO. The values of ING are lower than the values of Rabobank.

6 Summary and conclusions

General figures

This paper investigated the potential impact of a disruption of a large bank in the Dutch interbank payment system in terms of both number of banks affected and the corresponding unsettled values of the participants at the end of the day. The unsettled values in the simulations are deleted at the end of the day (single day scenarios) or transferred to the next day to be settled (multiple day scenarios). In general it can be said that the more (larger) banks affected, the more widespread the impact is and the larger both the unsettled values and the negative end of day balances are, the deeper the impact is.

The simulations in this paper were limited to disruptions of ABN AMRO, ING and Rabobank, which are the three largest banks of the Netherlands. These three participants have almost 60% of the total value of the payments. Differentiating between cross border and domestic payments they are responsible for approximately 75% of the cross border and 45% of the domestic payments value. The impact of an operational disruption on the domestic market is smaller when the stricken participant has a larger amount of cross border payments. Another important characteristic is the amount of collateral available to obtain intraday credit. The more collateral a participant has, the better it is able to absorb a temporary shock. The relative amount of collateral is 58% of the total collateral of all banks, which is approximately equal to the relative total amount of outgoing payment value. The analysis focused on 4 different collateral levels[7]

Number of banks affected and unsettled values

Section 4 showed the number of banks affected given a certain disruption. Many of the affected banks are relatively small ones. The amount of available collateral of these banks is often (almost) zero. The banks with no collateral at all are quite often controlled by the mother company. This means that the number of banks affected (and the amount of unsettled payments) could be lower because the mother company is able to fund the daughter in case of liquidity shortage. Other participants which are often affected are the ancillary systems Equens and Euroclear and the TfT account of both Kasbank and ABN AMRO.

For the single day scenarios the differences between the HC and the HCex are relatively small. This is the result of the small difference between the collateral levels of the banks affected in the HC and HCex. The LB shows the largest number of banks affected of all four collateral levels. The only available liquidity, in the LB to execute payments, is the positive credit balance on the accounts. In the

[7] HC: Historical collateral (the amount of collateral pledged at DNB), HCex: Historical collateral excluding the amount used for open market operations, UB: Upper Bound (the amount of collateral needed to execute payments without any delay, LB: Lower Bound (the amount of collateral needed to execute payments by the end of the day, allowing intraday queues)

200% case there will be more banks affected in many cases than the bank itself. This is due to liquidity leaving the domestic market to cross border TARGET participants.

The number of participants affected, for the multiple day scenarios, shows an increasing trend for most cases. However, for the first days in the 110% to 150% cases this trend is quite often not observed because the disrupted bank is able to absorb the disruption. The increasing trend also shows sometimes fewer banks affected compared to the previous day. This is the result of the strong variation in net daily balances. The disruption has to continue quite some days to affect the main account of the other two large participants, but this is usually solved again within a few days. This means that the "shock absorption power" of the large banks among each other is large and that a disruption mainly affects the smaller participants.

In section 5 the corresponding value of the disruption has been addressed. It is interesting that a large number of banks affected, does not mean a large value of unsettled payments. A large value of unsettled payments however quite often corresponds with a larger number of banks affected, but certainly not in all cases. This can be explained by the fact that it does not matter how much liquidity a bank is short to execute a payment. A small amount of liquidity shortage is "sufficient" to block the payment. This is especially true for the daughter companies which have zero beginning and end of day balances and no collateral. This means that they do not have the possibility to absorb any shock.

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