Operational Risk and Contagion in the Austrian Large-Value Payment System ARTIS

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The objective of this paper is to quantify the contagion effect of an operational incident occurring at one ARTIS participant's site on the payment activity of the other ARTIS participants. We used model simulations to focus on operational problems occurring at one of the participants, not an operational failure of the ARTIS platform itself. The scenarios are designed according to an ex-ante estimation of potential risk concentrations based on actual data for the sample period (Schmitz et al., 2006). The main conclusion from the simulations was that the contagion effect in ARTIS is low on condition that the existing business continuity arrangements prove effective. However, this is a very restrictive assumption. Without the use of business continuity arrangements or if they turn out to be not fully effective, the contagion effect on the smooth functioning of the payment system was substantial in all three scenarios. In contrast to the most common approach described in the literature, we used actual (instead of simulated) liquidity data to study the contagion effect at the individual bank level as well as at the aggregate level of unsettled payments. A non-negligible number of banks failed to settle payments in all three scenarios. The paper also provides results on two features of large-value payment systems that have hitherto gone unstudied in the literature: the stop-sending rule and debit authorization.

JEL classification: E 50, G 10

1 Introduction

The objective of this paper is to quantify, by use of simulations, the degree to which an operational incident occurring at one of the ARTIS[2] participants affects the ability of the other participants to settle transactions. The Committee on Payment and Settlement Systems defines operational risk as "the risk that operational factors such as technical malfunctions or operational mistakes will cause or exacerbate credit or liquidity risk" (CPSS, 2001, p. 5). Our analysis focuses on operational problems occurring at one of the participants, not on an operational failure of the ARTIS platform itself. The simulations use real data for the sample period November 2004 (a typical month of ARTIS operation). The basic functionalities of ARTIS are mapped onto the simulation tool as closely as possible. The scenarios are designed according to an ex-ante estimation of potential risk concentration based on actual data for the sample period. Nevertheless, one must bear in mind that the reported results are the outcome of simulation experiments based on stylized operational failures rather than historical events. Actual operational incidents at ARTIS participants causing disruptions over several hours have occurred too rarely and they had too little impact on payment activity to provide a reliable data basis for the empirical assessment of operational risk.

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[2] *ARTIS (which stands for Austrian Real Time Interbank Settlement system) is the Austrian component of the Trans-European Automated Real-time Gross settlement Express Transfer system TARGET.*

This study was motivated by the OeNB's mandate to oversee ARTIS and its Austrian participants pursuant to Article 44a of the Federal Act on the Oesterreichische Nationalbank of 1984 (Nationalbankgesetz), which empowers the OeNB to perform payment systems oversight, and Article 82a of this Act, which defines the sanctions the OeNB can impose in the area of payment systems oversight.

The paper is structured as follows: section 2 very briefly outlines the main descriptive statistics of ARTIS. In section 3, we introduce the scenarios, present the results obtained and compare them across scenarios. Section 4 discusses the implications of the results and section 5 summarizes them.

2 Descriptive Statistics of ARTIS – Participation and Transactions

In November 2004 ARTIS comprised a total of 575 accounts, which were held by credit institutions, the Austrian federal government, non-financial corporations and by the OeNB itself.[3] A large number of these accounts were offset accounts (e.g. accounts of GSA, the OeNB's subsidiary in charge of cash services in Austria) and transfer accounts (e.g. those which link ARTIS to the other national TARGET components[4]). The other 234 were transaction accounts held by Austrian and international banks; they are the main focus of this analysis. Nevertheless, the simulations – and the aggregate data calculated on their basis – must include all accounts in order to ensure that the system is closed.

In November 2004 the average daily value of payments submitted in ARTIS totaled EUR 32.61 billion; with a standard deviation of EUR 7.7 billion, this value was, however, quite volatile. The total value of transactions settled in the period under review came to EUR 717.39 billion, which equals about three times nominal GDP in 2004. Most daily values were within the range of the mean plus/minus one standard deviation with three notable exceptions: On November 1 (public holiday in Austria) as well as on November 11 and 25 (U.S. bank holidays), the daily transaction values were significantly below the mean.

3 Simulations

What does the simulation data reveal about the contagion risk within the system with respect to an operational failure at one of the participants? We can distinguish two channels via which operational incidents at one of the participants can have contagious effects on other participants: the payment concentration channel and

[3] *For more detailed descriptive statistics of ARTIS, please refer to Schmitz et al. (2006).*

[4] *Transfer accounts are ARTIS accounts of other ESCB central banks held at the OeNB. It is via them that all transactions with the respective country and Austria are routed. If e.g. an operational problem occurred at the Deutsche Bundesbank, it would not be able to forward the payments of German banks accumulating on the Austrian transfer account at RTGSplus to ARTIS. Some of the transfer accounts are very active owing to the large volume of foreign trade as well as the large volume of capital market and money market transactions with the respective countries. Transfer accounts do neither hold beginning-of-day balances nor collateral, as they are operated by ESCB central banks. At the end of the trading day all bilateral net positions are consolidated into single net positions for each central bank vis-à-vis the ECB (netting by novation).*

the liquidity concentration channel.[5] While the former focuses on the number of payments a participant is involved in as sender or receiver, the latter concentrates on the participant's share of liquidity (beginning-of-day balances plus collateral[6]) in total liquidity at the beginning of the day.

To quantify these two risks and their adverse effects, we conducted a large number of simulations based on three different scenarios for all transaction days in November 2004, using the Bank of Finland's simulation tool BoF-PSS2. This payment system simulator recalculates the transactions of each day by adding incoming payments to and subtracting outgoing payments from the participants' respective accounts. As transactions in the input data set come with time-stamps, the simulator recalculates the balances of all participants' accounts throughout the day depending on the institutional features of the system (e.g. settlement algorithm, queue release mechanism). We included many of these features directly via the parameterization of the BoF-PSS2. However, some of the system's institutional features could not be accounted for in the simulator and had to be mapped into the input data set. In addition, it is not possible to take into account behavioral reactions of system participants. Consequently, they had to be determined exogenously and mapped into the input data set. Nevertheless, this tool is widely used to determine operational risk – Bedford et al. (2004), for example, show that the contagion effect of operational shocks in the U.K.'s system CHAPS Sterling is quite low. While most studies in this field are based on simulated aggregate liquidity levels, our study uses actual liquidity data, analyzing the impact of operational risk on the system as a whole as well as on individual banks.

3.1 Scenarios

The scenario design was based on an analysis of actual payment flows in ARTIS. The objective of the simulations is to estimate the contagion effect of an operational incident at one (or several) of the system's participants on the liquidity of the other participants and the functioning of the system as a whole. We designed the scenarios in the following four steps.

First, we defined the impact of an operational failure: It is the incapacitation of the affected participant to process outgoing payments, i.e. the inability to submit transactions.[7]

Second, we selected the node(s) of the network of payment flows to be affected by the operational failure. We chose the most active nodes in the network in terms of liquidity (liquidity concentration channel), number and value of payments submitted and received (payment concentration channel) and Herfindahl index of

[5] *An operational incident at a participant who processes transactions with many other participants is expected to have a larger contagious impact, as it is likely to lead to a larger withdrawal of liquidity from the system. For the same reason, an operational incident at a participant who holds a large share of aggregate liquidity is likely to have a large contagious impact. See Bedford et al. (2004).*

[6] *Strictly speaking, there is a difference between collateral and liquidity; the former must be liquidized by applying for intraday credit. However, the pecuniary and non-pecuniary costs to do so are negligible. Therefore, we regard collateral (rather than actual intraday credit) as the relevant constraint for participants to settle payments.*

[7] *In this context, we assumed that the resulting illiquidity of the affected participant is not interpreted as potential insolvency by the other participants of the payment system and the financial system at large.*

concentration of payment flows (based on the number and value of payments received and submitted).[8]

Third, we specified the duration of the operational failure, that is, for how many hours the affected participant was incapacitated by the incident. We conducted the simulations on the assumption of a one-day failure[9] to submit payments. Scenario design was guided by the principle that the shocks to the system should be exceptional but still plausible. ARTIS also provides for business continuity arrangements: in the case of operational failures, ARTIS participants can submit payments by phone, fax, physical messenger services or eKonto,[10] on condition that their internal systems remain fully functional.[11] As these methods to submit payments are more costly, they are only employed for critical and/or large-value payments. In order to assess the impact of such backup facilities, we reran the simulations under the assumption that backup facilities were employed before the end of the business day, i.e. after ten hours of operational failure. The reruns are based on the (very restrictive) assumption that even very large numbers of payments can be processed with these methods in a timely manner, i.e. before the end of the business day, and that the affected bank's internal systems are fully functional.[12]

Forth, since the simulator cannot account for the reactions of other system participants or the system operator to the operational incident, two types of behavioral reactions must be included exogenously. (1) Other participants may want to stop submitting payments to the affected participant. When an operational problem occurs at a central bank's transfer account, a stop-sending rule applies in TARGET. This means that no further payments are transferred to the affected transfer account. However, when an operational problem occurs at a bank, no stop-sending rule is applied in ARTIS; the other participants usually continue to submit payments to the affected participants, even if the latter cannot submit payments themselves for many hours. This is a restrictive assumption, but it is well supported by anecdotal evidence supplied by ARTIS operators. According to them, banks explicitly prefer to submit payments to "stricken" banks, because they want to fulfill their obligations with respect to these banks in a timely manner irrespective of the latters' operational problems. We are not aware of any evidence suggesting that banks impose bilateral sending limits. Our scenarios were designed in line with this assumption; the simulations are thus limited to operational incidents with a duration of up to one day – in the case of a longer operational failure, the other participants are more likely to discontinue submitting payments to the participants with operational problems. (2) Participants

[8] For the underlying data on the network structure in ARTIS, see Schmitz et al. (2006).

[9] See also Bedford et al. (2004).

[10] This is an alternative access mode to the ARTIS operating desk that is available to some but not all participants, in which payments are submitted manually and are further processed manually by the ARTIS operating desk.

[11] Otherwise, the affected participants would have no access to the information on their respective payment obligations.

[12] A delayed closing is (in principle) possible with the ECB's approval.

can react to possible operational incidents by increasing available collateral. Anecdotal evidence suggests that participants already hold large shares of their assets that qualify as collateral on accounts at the OeNB. After all, depositing eligible assets with the OeNB is no more costly for system participants than depositing them with the Austrian central securities depository; doing so can be even cheaper than depositing international assets with the respective foreign central securities depository. By contrast, providing additional eligible collateral is likely to involve portfolio readjustments, thus possibly incurring greater costs. Therefore, we assumed that system participants would not increase collateral for a one-day operational incident, which again limits the simulations to operational failures with a duration of up to one day.

Finally, we defined three scenarios with the highest expected impact and the highest expected contagion effects in accordance with the parameters defined in step 2: In scenario 1 the most active transfer account cannot submit payments to the system, while in scenario 2 the most active bank is affected by the same problem, and in scenario 3 the three most active banks simultaneously cannot submit payments to the system owing to operational problems (e.g. owing to a breakdown of the communications infrastructure). In all three scenarios we assumed that the operational incident would last for one day or ten hours, respectively, in accordance with step 3 of the scenario design procedure. Furthermore, we assumed that the other participants would continue to submit payments to the affected participants with the exception of scenario 1, in which payments to the affected participant could still be submitted but not sent (stop-sending rule in accordance with the basic functionalities of ARTIS/TARGET). The simulations are based on actual collateral data for November 2004, which are interpreted as binding liquidity constraints for the banks.

3.2 Scenario 1 – Failure at the Top Transfer Account

In scenario 1, the national TARGET operator in charge of the most active transfer account is affected by an operational incident at 07:15 a.m. It cannot submit or settle payments until the end of the business day at 06:00 p.m. In response to the operational incident, a stop-sending status is declared at 08:00 a.m. in line with ARTIS/TARGET business continuity arrangements.[13]

3.2.1 Impact on Aggregate Liquidity and on the Smooth Functioning of the Payment System

In scenario 1, aggregate liquidity is equal to actual aggregate liquidity at the beginning of the day, as the transfer account holds neither beginning-of-day balance nor collateral. Consequently, the operational problems at this account do not cause a liquidity drain (i.e. they do not reduce aggregate liquidity owing to the fact that the affected participant's liquidity re-

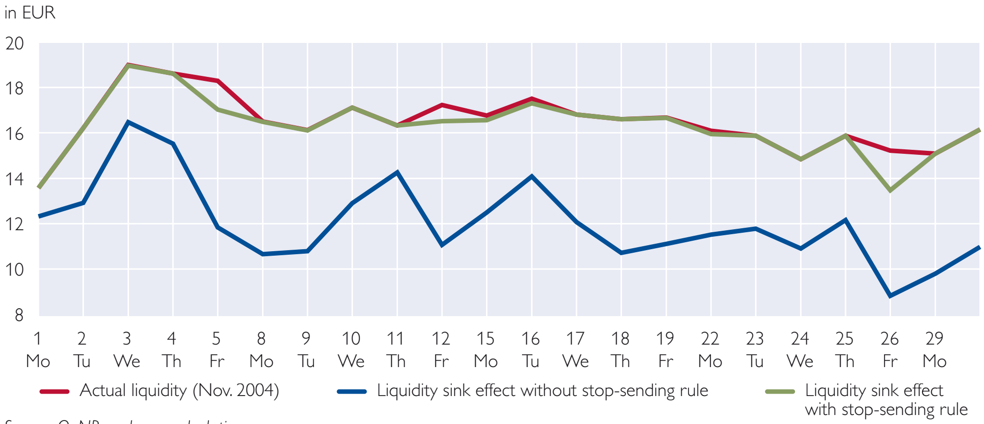
[13] *After about 30 minutes, the national TARGET operators exchange information on the operational incident at the affected central bank in a conference call and decide whether to apply the stop-sending status. It is therefore sensible to assume that it takes about 45 minutes in total until the stop-sending rule is actually applied.*

serves are not available for circulation in the system). Instead, the account's central position in the network structure of payment flows in ARTIS can lead to a "liquidity sink" effect (also referred to as liquidity trap). It denotes a reduction of aggregate liquidity available for circulation in the system that occurs when liquidity is transferred to the stricken account and discontinues circulating as a result of the account's operational problems. The higher the value transferred to the stricken account, the higher the liquidity sink effect is. The stop-sending rule was designed to mitigate this effect. As a result, available aggregate daily liquidity decreased by no more than 1.19% on average owing to transactions that were settled after the operational failure had occurred but before the stop-sending rule was applied (see chart 1). The changes in aggregate liquidity in scenario 1 were, however, quite volatile, with a standard deviation of about 240% of the mean. The source of volatility was the liquidity sink effect, which differed substantially from day to day. As the analysis suggested that the stop-sending rule would limit the contagion effect within the system to operational risk outside the ARTIS platform, we reran the simulations for all 22 days in the sample without the stop-sending rule. The results are presented below in section 3.2.4.

The value of payments submitted to the system in scenario 1 totaled EUR 22.4 billion on average, with a standard deviation of EUR 5.8 billion. This represented a 31.5% decrease relative to the unstressed system, which is attributable to two factors: (1) the stricken account's node risk (defined as an individual bank's share in the total value of submitted and received transactions, in this scenario 18.8%), and (2) the stop-sending rule (which accounted for a decrease by 12.7%). The average daily value of settled transactions totaled EUR 21.6 billion (with a standard deviation of EUR 5.5 billion), which corresponds to a reduction by 33.8% relative to the unstressed scenario. The number of payments submitted shrank by 16.3% to a daily average of 12,832 during the sample period. This reduction is once more substantially higher than the node risk of the transfer account in terms of the number of payments (9.7% of the total number of payments submitted or

Chart 1

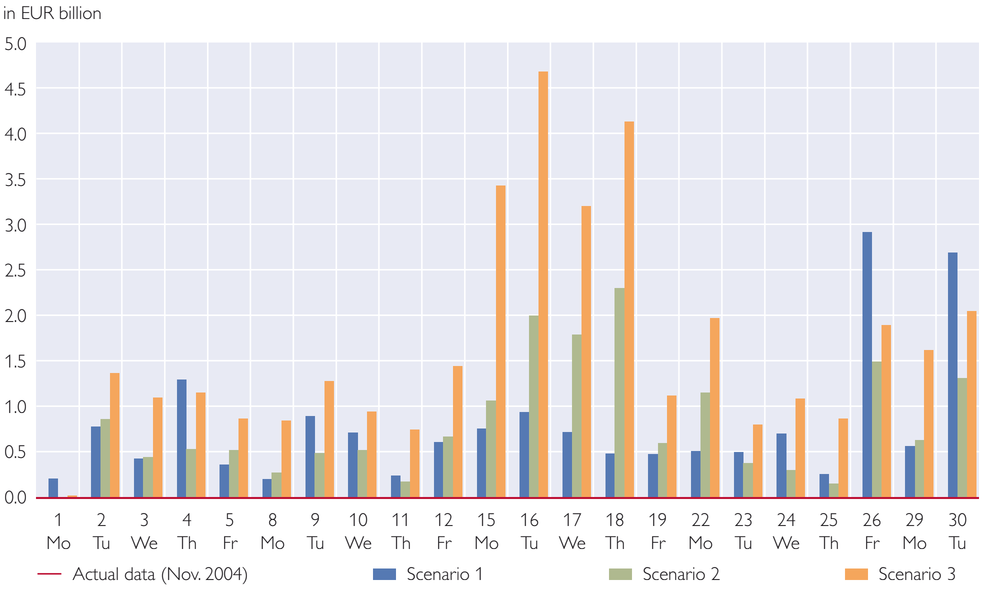
Actual and Stressed Liquidity With and Without the Stop-Sending Rule (Scenario 1)



Source: OeNB and own calculations.

Chart 2

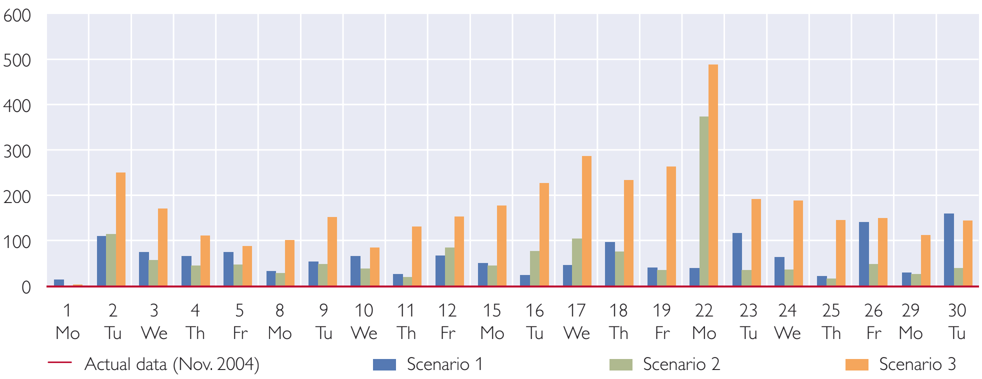
Value of Unsettled Payments



Source: OeNB and own calculations.

Chart 3

Number of Unsettled Payments



Source: OeNB and own calculations.

received). The difference is again attributable to the impact of the stop-sending rule.

In scenario 1, the contagion effect on the other participants of the payment system was significant in terms of the aggregate value of unsettled transactions. This value came to EUR 780 million on average per day or 3.5% of the average value submitted in the unstressed system, in which all payments were settled (see chart 2). The value of unsettled transactions refers only to the payments submitted by the other participants (including those to the stricken transfer account), but not to payments of the stricken transfer account itself. It was rather volatile with a standard deviation of EUR 710 million in a range from EUR 200 million to EUR 2.9 billion. On average, the number of payments submitted but not settled amounted to 64 per day in a range

Table 1

Number of Banks with Unsettled Payments

	Actual	Scenario 1	Scenario 2	Scenario 3
Daily average	0	12.1	8.7	22.8
Minimum	0	8	0	1
Maximum	0	18	12	30
Standard Deviation	0	2.4	2.8	5.9
Total	0	36	38	56

Source: OeNB and own calculations.

from 14 to 159 (see chart 3). The large variations in the value of unsettled transactions demonstrate that the impact of one and the same operational incident on the system can be different on different days.

How much additional liquidity is required to settle all transactions on each day? Even though the value of unsettled transactions provides a first indication, it overstates the need for liquidity assistance, as it fails to take into account the fact that liquidity circulates once it was injected into the system. The indicator for continuous liquidity usage estimates the ratio of submitted payments that was covered by reserves. In scenario 1, this indicator had an average value of 0.37 (compared with 0.30 in the unstressed system). This means that, across all days and participants, on average 37% of the total value submitted was covered by individual participants' liquidity reserves and 63% by payments received. The volume of liquidity assistance that is actually required in the sample period, i.e. taking into account the circulation of liquidity, can be estimated by multiplying daily continuous liquidity usage with the daily value of unsettled transactions. On an average day, EUR 290 million had to be injected into the system to reach the lower bound of additional aggregate liquidity, thus enabling all accounts to settle open transactions.[14] This value corresponds to 1.76% of liquidity available during the sample period. The necessary minimum liquidity assistance ranged from EUR 70 million (or 0.4% of actual aggregate liquidity available on that day) to EUR 1.1 billion (or 7.5% of actual aggregate liquidity available on that day) across the sample period. The average value of daily unsettled payments (EUR 780 million or 4.7% of average aggregate liquidity in the unstressed system) provides an indication of an upper bound – the maximum amount required – of additional liquidity necessary to prevent a contagion effect.

3.2.2 Impact on Individual Banks

In scenario 1, the contagion effect – measured by the number of individual banks that could not settle all transactions – was substantial. Their number averaged 12.1 per day in a range from 8 to 18 out of a total of 234 banks among the 575 accounts (see table 1). The total number of banks that failed to settle submitted transactions on at least one day totaled

[14] *For the lower bound to suffice for the settlement of all transactions, additional liquidity must be provided to those participants in the system who experience problems, i.e. who actually need it. Furthermore, the circulation of additional liquidity must equal the circulation of aggregate liquidity.*

Table 2

Impact of the Stop-Sending Rule – Selected Indicators in Scenario 1
(average daily values across November 2004)

Indicator	Scenario 1 with stop-sending rule (1)	Scenario 1 without stop-sending rule (2)	Difference (1)–(2)
Aggregate liquidity (in EUR billion)	16.3	12.1	4.2 (26%)[1]
Liquidity reduction (in % of aggregate liquidity)	1.2	26.9	–25.7[1]
Value of submitted transactions (in EUR billion)[2]	22.4	26.7	–4.2 (–18.9%)
Value of unsettled transactions (in EUR billion)[3]	0.8	1.3	–0.6 (–71.8%)

Source: OeNB and own calculations.

[1] *Differences in percent of value with stop-sending rule.*
[2] *Value of submitted transactions refers to the value of payments submitted by unaffected participants, i.e. excluding the value of payments that were not submitted by the stricken bank owing to operational problems. If the stop-sending rule applies (column 1), the payments redirected in the queue are not included in the value of payments submitted: the respective liquidity is still available to the banks, who can cancel submissions as long as they are queued.*
[3] *Value of unsettled transactions refers to the payments submitted by those participants who are not affected by operational problems.*

36. Two of them could not settle all transactions on all 22 days, while 10 of them were affected on 11 or more days and 7 accounts failed on one day only. The impact of scenario 1 on the individual banks differed widely among banks.

3.2.3 Impact of Business Continuity Arrangements

In order to assess the impact of backup facilities, we reran the simulations under the assumption that the operational failure lasted until 04:00 p.m. rather than the entire day. We assumed that the available backup facilities were employed in a timely manner so that all payments could be processed before the end of the business day at 06:00 p.m.[15] Furthermore, we assumed that the participant's internal systems were fully operational, so that they knew which payments needed to be processed. Under these assumptions, all submitted payments were actually settled and no adverse effects on the payments of the stricken account or any other participant were recorded.

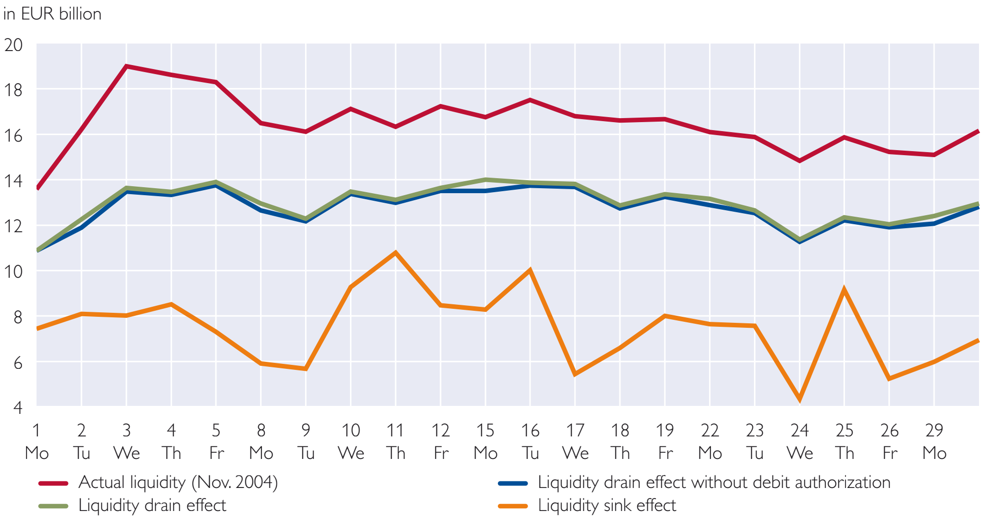
3.2.4 Impact of the Stop-Sending Rule

The stop-sending rule substantially reduced the adverse impact of the operational shock and increased the resilience of the system. In order to assess the relative impact (and thus the efficacy) of the stop-sending rule, we reran scenario 1 without the stop-sending rule, while keeping all other features identical. Without the stop-sending rule, the liquidity sink effect increased from 1.2% to 26.9% of aggregate liquidity in the unstressed system, and the mean value of submitted transactions increased by EUR 4.2 billion or 19.3% on average (see table 2). This implies that the value of payments to the affected transfer account after 08:00 a.m. came to EUR 4.2 billion on average. Without the stop-sending rule, the total value of unsettled transactions increased from EUR 780 million to EUR 1.3 billion on average, while the number of unsettled payments went up from 64.1 to 120.8 on average.

[15] *A delayed closing is (in principle) possible with the ECB's approval.*

Chart 4

Actual and Stressed Liquidity With and Without Debit Authorization (Scenario 2)



Source: OeNB and own calculations.

3.3 Scenario 2 – Failure at the Top Bank

In this scenario, the most active bank cannot submit or settle payments from 06:00 a.m. until 06:00 p.m. owing to an operational incident. The scenario design includes the feature of debit authorization by the stricken bank for a number of other participants in ARTIS.[16] Consequently, many payments by the stricken bank could be submitted (via the participants to whom debit authorization was granted) and settled despite the operational problems. Thus, debit authorization can reduce the liquidity drain effect. In order to assess the impact of debit authorization on the contagion effect within the system, we reran the simulations in a replicated scenario without debit authorization. The results are presented in section 3.3.4.

3.3.1 Impact on Aggregate Liquidity and on the Smooth Functioning of the Payment System

Owing to the operational incident at the most active bank, aggregate liquidity available for circulation in the system (i.e. excluding the liquidity accumulating at the stricken bank) decreased by an average of 54.6% (21.6% were attributable to the liquidity drain effect and 33.2% to the liquidity sink effect) to a daily average of EUR 7.5 billion (see chart 4). Compared with the actual value in November 2004, the average daily value of payments submitted shrank by EUR 5.2 billion to EUR 27.4 billion (with a standard deviation of EUR 6.4 billion). This decrease by 16% corresponds to the stricken bank's usual share in submitted payments (which could not be submitted as a result of the operational incident)

[16] *According to § 9 of the Terms and Conditions governing the OeNB's ARTIS system, participant A can grant debit authorization to participant B. Debit authorization is defined as the right granted to participant B to initiate (certain pre-agreed) payments from the account of participant A. Debit authorizations are granted to a small number of participants for prearranged purposes (very frequently recurring standard operations) and cannot be interpreted as crisis mitigation instruments available on short notice in the case of an operational incident.*

minus the value of payments submitted by debit authorization (which could still be processed). The average value of settled payments was EUR 26.6 billion with a standard deviation of EUR 6.1 billion.

The operational incident had a substantial negative contagion effect on aggregate payment activity, as the daily average value of unsettled transactions amounted to EUR 800 million or 2.9% of the value submitted (see chart 2).[17] The impact of the operational incident, however, varied markedly from day to day – the value of unsettled transactions ranged from EUR 0 to EUR 2.3 billion. The number of unsettled payments rose to 63.3 on average per day, accounting for 0.4% of submitted payments on average (see chart 3). The contagion effect was substantial, as a large share of payments could not be settled by the unaffected participants. According to our estimates, some EUR 320 million (or 1.9% of average aggregate liquidity in the unstressed system) would be required to reach the lower bound of average liquidity and settle all submitted payments, taking into account the circulation of liquidity. The upper bound would be EUR 800 million or 4.9% of average aggregate liquidity in the sample period.

The mean of the continuous liquidity usage came to 40%, which means that 40% of the submitted payments in scenario 2 were settled using liquidity reserves. Compared with the unstressed scenario, this implied an increase by about 10 percentage points. Still, the circulation of liquidity did not come to a complete halt despite a substantial contagion effect.

3.3.2 Impact of Scenario 2 on Individual Banks

The impact on the ability of the other banks to settle submitted payments was substantial in scenario 2, and it varied considerably from day to day. A total of 38 banks (or 16.2% of all banks) were affected by contagion throughout the month (see table 1). On average, 8.7 banks in a range from 0 to 12 banks (or 3.7% of all banks) were unable to settle all submitted payments on each day. While 4 banks could not settle all transactions on 21 days, 7 were affected on 11 or more days, and 14 banks were affected on one day only. This means that the impact of scenario 2 on the different banks was also far from uniform.

3.3.3 Impact of Backup Options

We reran the simulations under the assumption that the business continuity arrangements were invoked at 04:00 p.m. and all payments of the stricken bank were settled before the end of the business day. Under these assumptions, all payments were settled and no contagion effect materialized. However, the resilience of the system rests on the following two conditions: the participant's internal systems must be fully operational, so that he knows which payments need to be processed, and between 534 and 1,655 payments (submitted via phone, fax, messenger service or eKonto) must be processed manually before 06:00 p.m.[18]

[17] *The value of unsettled transactions refers only to payments submitted by the unaffected participants (including payments to the stricken bank); it does not include payments of the stricken bank itself (as these cannot be submitted).*

[18] *As noted above, a delayed closing is possible with the ECB's approval.*

3.3.4 Impact of Debit Authorization

We reran scenario 2 without debit authorization. It turned out that debit authorization slightly attenuated the contagion effect of the operational shock within the system. Debit authorization allowed some payments of the stricken bank to be settled despite the operational failure (provided that its account is sufficiently liquid, which it usually is, as the bank is unable to submit payments). Consequently, the average liquidity drain was lower than in a system without debit authorization. In scenario 2, this feature reduced the liquidity drain from 22.5% to 21.4% of aggregate liquidity, thus accounting for a reduction by EUR 170 million or 1.1 percentage points of aggregate liquidity in the unstressed system. Without debit authorization, the liquidity drain equals the stricken bank's share in aggregate liquidity (22.5%). In scenario 2 with debit authorization, the value of unsettled transactions decreased by EUR 150 million (or 15.6% of the value without debit authorization) from an average of EUR 950 million to EUR 800 million. The number of unsettled payments shrank by 74.1 payments per day on average (or 53.9% of this number without debit authorization) from 137.3 to 63.3. The average number of banks which could not settle all transactions on each day of the sample period decreased from 10.3 in a range from 0 to 14 to 8.7 in a range from 0 to 12 (–15.2%). While the total number of banks affected by contagion was merely reduced from 42 to 38 (–9.5%), debit authorization had a strong impact on the individual participants. Those who had the right to access the stricken bank's account were effectively shielded from any direct effects of the operational incident.

3.4 Scenario 3 – Simultaneous Failure At the Three Most Active Bank Accounts

This scenario assumes that the three most active banks cannot submit payments from 06:00 a.m. until 06:00 p.m. owing to an operational incident. All three stricken banks granted debit authorization to a number of other ARTIS participants. To gauge the impact of this feature on the smooth functioning of the system, we reran the simulations based on a replicated scenario without debit authorization. The results are presented in section 3.4.4.

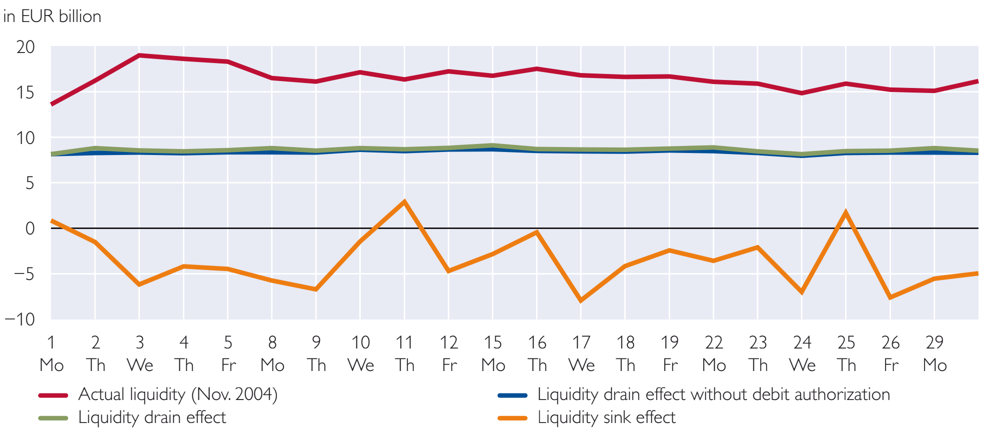
3.4.1 Impact on Aggregate Liquidity and on the Smooth Functioning of the Payment System

In theory, aggregate liquidity available for circulation in the system (i.e. excluding the liquidity accumulating at the stricken banks) decreased by 121.5% compared with the unstressed level, with the liquidity drain accounting for 47.4% and the liquidity sink accounting for 74.1% (see chart 5). If all payments to the three stricken banks had been settled, liquidity would have turned negative. In reality, however, aggregate liquidity available for circulation in the system is bounded below by zero. In scenario 3, the liquidity sink effect basically withdrew all remaining liquidity from circulation, and the adverse impact of the contagion effect on the smooth functioning of the payment system was very strong indeed.

The average value of submitted payments decreased to EUR 20.7 billion (–36.4% relative to the unstressed system). This reduction equaled the three stricken banks' share in the total value of transactions submitted in the unstressed system minus the share of payments submit-

Chart 5

Actual and Stressed Liquidity With and Without Debit Authorization (Scenario 3)



Source: OeNB and own calculations.

ted under debit authorization. On average, the value of settled payments shrank to EUR 19.1 billion (–41.6% compared with the unstressed value). The daily value of unsettled transactions came to EUR 1.7 billion on average in a range from EUR 150 million to EUR 4.7 billion (see chart 2). On average, 175 payments (in a range from 3 to 488) could not be settled (see chart 3). The volume and value of unsettled payments refer only to payments submitted by the other participants (i.e. excluding the stricken banks' payments, which could not be submitted, but possibly including payments made by the other participants to them). According to our estimation, the lower bound of additional liquidity necessary to settle all submitted payments came to around EUR 1.1 billion (in a range from EUR 0.1 billion to EUR 3.2 billion) on an average day, taking into account the circulation of liquidity. This corresponds to 6.8% of aggregate liquidity in the unstressed system. These results also indicate that the impact of the scenario varied substantially across days. The upper bound of additional liquidity came to EUR 1.7 billion (10% of aggregate liquidity in the unstressed system).

The system's participants had to rely much more on their liquidity reserves than on incoming payments to settle outgoing payments. The indicator of continuous liquidity usage increased from 29.9% in the unstressed scenario to 67.8%. This means that the participants covered roughly two-thirds of the value of submitted and settled payments with liquidity reserves and only one-third with incoming payments.

3.4.2 Impact on Individual Banks

On average, 22.8 (in a range between 1 and 30) of the 234 banks failed to settle all payments submitted on each day (see table 1). While 56 banks were unable to settle all payments on at least one day, one bank was affected on all 22 days of the sample period and 24 banks failed to settle all transactions on 11 or more days. 10 banks were affected on a single day only. Thus, the impact of scenario 3 on the individual banks differed across banks.

3.4.3 Impact of Backup Options

In order to assess the impact of alternative submission channels, we reran scenario 3 under the assumption that all payments of the three stricken banks were submitted via alternative channels. Furthermore, we assumed that the stricken banks' internal systems were fully operational, so that they knew about their payment obligations. In this case, all payments were settled and no negative effects on payment activity were observed. On condition that all payments could be processed in time, the system proved to be resilient even to a very strong negative shock. For the business continuity arrangements in place, this implied that between 1,440 and 4,022 payments would have to be processed manually before the end of the business day at 06:00 p.m.[19]

3.4.4 Impact of Debit Authorization

We reran scenario 3 without debit authorization to identify its impact on the financial soundness of the system. Debit authorization reduced the liquidity drain effect by a daily average of EUR 250 million or 1.5% of aggregate liquidity. The value of unsettled payments decreased by an average of EUR 190 million or 10.3% of the value of unsettled payments compared with the scenario without debit authorization, thus declining from about EUR 1.9 billion to EUR 1.7 billion. The number of unsettled payments on average went down from 267 to 175, while the average number of banks affected by contagion was reduced from 24.6 to 22.8. The number of banks with unsettled payments on at least one day in the sample period decreased from 60 to 56. Debit authorization thus slightly decreased the impact of the operational failure on the system in scenario 3. A more substantial impact was recorded for the liquidity position of those participants who had the right to access the accounts of the stricken banks. They were effectively shielded from any direct impact of the operational incident (provided that the stricken banks' accounts were sufficiently liquid).

3.5 Comparison Across Scenarios

In the scenarios including business continuity arrangements, no adverse impact was recorded on the smooth functioning of the payment system. Given the very restrictive assumptions underlying the efficacy of the business continuity arrangements, we compared the impact of the operational incidents in the three scenarios without business continuity arrangements. The strongest impact on aggregate liquidity, on the value of unsettled payments and on the number of banks with unsettled payments as well as on the frequency of settlement failure was recorded for scenario 3 (see table 3). However, one must bear in mind that it was designed as a worst-case scenario. The value and number of unsettled payments and the total number of banks with unsettled payments were very similar in scenarios 1 and 2. This similarity is quite surprising, taking into account the large differences in liquidity reduction (1.2% of aggregate liquidity in scenario 1 compared with 54.8% in scenario 2). In addition, the stop-sending rule was only applied in scenario 1.

[19] *As noted above, a delayed closing is possible with the ECB's approval.*

Table 3

Comparing Selected Indicators
(daily values/ averages across November 2004)

Indicator	Actual	Scenario 1	Scenario 2	Scenario 3
Aggregate liquidity (in EUR billion)	16.5	16.3	7.3	–3.8
Liquidity reduction (in % of aggregate liquidity)	0	1.2	54.8	121.5
of which: Liquidity drain (in percentage points)	*0*	*0*	*21.6*	*47.4*
Liquidity sink (in percentage points)	*0*	*1.2*[1]	*33.2*	*74.1*
Value submitted (in EUR billion)	32.6	22.4	27.4	20.7
Without business continuity arrangements				
Value of unsettled payments (in EUR billion)	0	0.8	0.8	1.7
Value of unsettled payments (in % of value submitted)	0	3.3	2.7	7.7
Number of unsettled payments	0	64.1	63.3	175
With business continuity arrangements[2]				
Value of unsettled payments (in EUR billion)	0	0	0	0
Value of unsettled payments (in % of value submitted)	0	0	0	0
Number of unsettled payments	0	0	0	0

Source: OeNB and own calculations.

[1] *With stop-sending rule – without it, the respective value would be 26.9%.*

[2] *The assumption that the stricken bank submits all payments via backup facilities and that ARTIS operators manually process them all in time is rather restrictive.*

4 Implications

Any measures taken on the basis of these results in the field of payment system design and payment system oversight need to conform to the guiding principles of practicability and efficiency for payment systems as stipulated in Core Principle VIII.[20] The marginal cost of implementing additional security features and business continuity arrangements must not outweigh the marginal (pecuniary and non-pecuniary) return from increased reliability.

The simulations account for the available business continuity arrangements by reopening the submission channel for the stricken bank(s) at 04:00 p.m. Many transactions were queued until that time and settled between 04:00 p.m. and 06:00 p.m. However, this means that for business continuity measures to be effective – i.e. for service levels to be met even under stress – some 1,500 to 3,400 payments (depending on the scenario) or even around 4,000 payments (on peak days in the worst-case scenario) would have to be processed manually. This assumption is very restrictive and unlikely to hold in practice. The time available to complete this task depends on when exactly the stricken bank switches to alternative submission procedures, while the time required to do so depends on the processing capacities available at the central platform. Assuming that about 30 payments per hour can be processed manually by one staff member, substantial additional human capital and equipment would be required to reach the required payment throughput before the end of the business day

[20] *"Core Principle VIII – The system should provide a means of making payments which is practical for its users and efficient for the economy."(CPSS, 2001).*

(06:00 p.m.), while maintaining a high level of processing quality.[21]

In order to reduce contagion within the system when it is under stress, the existing contingency procedures could be complemented by a stop-sending function comparable with the one employed in scenario 1. All other participants would then be informed of the fact that a particular account cannot submit payments. Furthermore, they would be given the option to redirect their payments to the stricken bank to a queue. In principle, these queued payments remain available to the sending bank in ARTIS. Once the stricken bank has resolved the operational problems, all payments in the queue are released and settled. A stop-sending function would substantially reduce the liquidity sink effect, and it would be a simple and practical solution as required in Core Principle VII (CPSS 2001, p. 40). Nevertheless, in order to assess the exact impact of a stop-sending function, further simulations based on scenarios 2 and 3 have to be conducted.

From the perspective of payment systems oversight, the findings of this study again emphasize the importance of (regular) testing as a valuable tool for assessing the effectiveness of existing business continuity arrangements, in particular with regard to their workability in practice. In this regard, this study confirms the usefulness of the currently conducted review of the business continuity oversight framework established by CPSS Core Principle VII. With this review, the Eurosystem aims at achieving a sufficiently high level of operational resilience across systemically important payment systems. The implementation of effective testing and regular reviewing processes for business continuity measures, among other aspects, is of particular interest; it will be addressed in the context of TARGET 2 oversight.

5 Summary

The objective of this study was to quantify the contagion effect of an operational incident outside the ARTIS platform on the ability of other, unaffected participants to settle payments. The methods applied were model simulations of operational shocks for the sample period November 2004.

In the unstressed scenario, the smooth functioning of the system was guaranteed by the availability of sufficient aggregate liquidity. All submitted transactions were settled and no account experienced liquidity shortages that would have caused transactions to remain unsettled by the end of the business day (06:00 p.m.) on any day in the sample period.

We conducted simulations based on three different scenarios. Their design took into account the two main sources of contagion risk in payment systems: the payment concentration channel and the liquidity concentration channel. The simulated shocks were exceptional but plausible operational incidents. On condition that the existing business continuity arrangements prove effective, the simulations showed the high opera-

[21] *The Basel Committee on Banking Supervision emphasizes the need to ensure that business continuity plans are effective and to identify necessary modifications through periodic testing (Basel Committee on Banking Supervision, 2005, Principle 6).*

tional reliability of ARTIS. Under the very restrictive assumptions that (1) the stricken bank(s) had access to the information concerning their payment obligations and (2) all payments submitted by the stricken bank(s) could be settled in time via phone, fax, messenger service or eKonto, no adverse effects were recorded for their own or any other participant's payments. The system functioned smoothly even under severe stress.

However, without the use of business continuity arrangements or in case they turned out to be not fully effective, the contagion effect on the smooth functioning of the payment system was substantial in all three scenarios. A non-negligible number of banks failed to settle payments. The simulations revealed large differences in the impact one and the same operational incident had (1) on the system as a whole and (2) on the individual banks as well as (3) in the extent to which it affected them on various days. Therefore, more research is called for to better understand the determinants of the impact of shocks on the system, on its participants, and across days.

Our investigation of the impact of two noteworthy features of ARTIS on the contagion effect – the stop-sending rule and debit authorization – produced the following results: The stop-sending rule substantially reduced the contagion effect of the operational shock and increased the resilience of the system. Currently, the stop-sending rule applies only to operational problems at one of the TARGET central banks. Our findings indicate that a similar rule for operational incidents at commercial banks would strongly increase the resilience of the system. Further research is, however, needed to put this hypothesis to the test. While debit authorization also attenuated the system's reaction to operational shocks, it did so to a much lesser (but still non-negligible) extent. More importantly, it proved effective in shielding those participants who had access to the stricken bank's account via debit authorization from direct adverse effects of the operational incident.

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