Analysis, by simulation, of the impact of a technical default of a payment system participant

An illustration with the PNS system

EMMANUEL MAZARS, GUY WOELFEL
Payment Systems and Market Infrastructure Directorate
Payment Securities Settlement Systems Oversight Division

Payment systems play a very important role in ensuring the safe and efficient transfer of deposits and financial instruments. Consequently, the failure of these systems may have a destabilising impact. Business continuity plans have thus been developed to ensure their robustness. However, their smooth functioning is also contingent on the capacity of participants to submit their payment orders. The Banque de France, in its role of overseer of the French payment systems, conducted a study with a view to enhancing its understanding of the consequences and the impact of the technical default of a participant in such systems.

This study, carried out using a simulator of the functioning of the Paris Net Settlement (PNS) large-value payment system, operated by the CRI (Centrale des Règlements Interbancaires), shows that the technical default of a participant in this system has negative consequences on the smooth running of the system. Indeed, a situation in which a major participant, in the wake of a technical incident, is unable to submit its payment orders in a normal fashion to its counterparties in PNS, could further exacerbate congestion in the system and result in almost 10% of payments being rejected among non-defaulting participants.

The consequences of a technical default could nevertheless be greatly reduced if the participants set their bilateral sender limits at a lower level than that currently observed and if they reacted rapidly to information indicating a technical default by reducing their bilateral limits with the defaulting participant (defaulter).

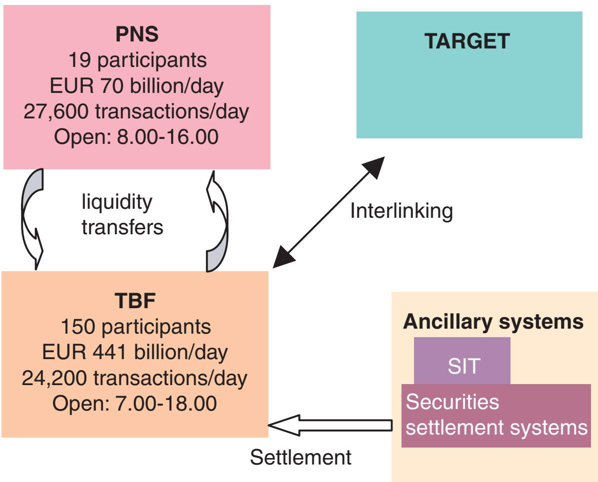
Over the past few years, the various parties concerned (supervisory authorities, financial system operators and users) have stepped up efforts to increase the resilience of critical infrastructures to ensure the smooth functioning of systems in the major financial centres. The different measures taken are part of a single approach that aims notably to ensure that sufficient continuity of service is guaranteed for these infrastructures in the event of a major disruption. Operators of interbank transfer systems (securities settlement systems, payment systems) have undertaken large-scale efforts to improve the soundness of their own infrastructures. However, their smooth functioning is also contingent on the capacity of participants to submit their payments normally.

This study, conducted by the Banque de France, is part of a larger review of operational risk and sets out to better apprehend the consequences and the impact on the functioning of payment systems of the technical default of one of its participants, when it prevents the latter, following an incident (such as the failure of its access platform), from making payments to its counterparties. Analysing such failures is part of the Banque de France's payment systems oversight duties, whose aim is to ensure their security and efficiency in accordance with Article L141-4 of the Monetary and Financial Code.[1] This study focuses on the analysis of the impact of the technical default of a participant in the large-value payment system PNS, using a simulator of the functioning of payment systems developed by the Banque de France. PNS was chosen for this analysis because of its risk management functionalities, which are representative of those of the new generation of large-value payment systems operating on a real-time net settlement basis. The latter are increasingly being used throughout the world. These type of functionalities can be found in TARGET2, for example, which the Eurosystem has scheduled to go live in 2007, to replace its current network of large-value payment systems linked to TARGET. The results obtained highlighted the fact that the technical default of a major participant in the system would have a substantial impact on transfers between the other participants, but that it would also be possible to reduce these consequences under certain conditions.

Sections 1 and 2 of this study describe the main characteristics of the PNS system and the methodology used. Section 3 illustrates the impact of different parameters on its functioning such as the amount of liquidity submitted by participants or the value of the bilateral limits set by them. The consequences of the technical default of the largest debtor in PNS are analysed in Section 4. It shows that the impact of the technical default of a participant may be mitigated if the other participants in the system respond appropriately, in particular by setting apposite bilateral limits with the defaulter.

1| PRESENTATION OF PNS

Paris Net Settlement (PNS) is a large-value payment system operated by the CRI (Centrale des Règlements Interbancaires).[2] It provides real-time settlement of transactions on central bank money accounts that must always remain in credit.



Figures at December 2004

PNS is linked to *Transferts Banque de France* (TBF), the real-time gross settlement system and French component of TARGET operated by the Banque de France. TBF is mainly used for the settlement of monetary policy operations, operations processed by post-market infrastructures (securities clearing and settlement systems), operations processed by SIT (retail payment system), and for urgent payments,

1 *"The Banque de France shall ensure the smooth operation and the security of payment systems within the framework of the tasks of the European System of Central Banks relating to the promotion of the smooth operation of payment systems"*
2 *The CRI is jointly owned by the Banque de France and eight participating commercial banks.*

and payments to other components of TARGET. PNS is mainly used for the settlement of less urgent large-value domestic payments. Participants start and end the day with zero account balances in PNS. The link between TBF and PNS enables participants to transfer, without delay, liquidity from their account in TBF to their account in PNS in the way that best suits their cash flow needs: each participant usually makes an initial injection of liquidity into PNS at the beginning of the day and may then add further sums or return liquidity to TBF depending on the nature of its dealings throughout the day. At the end of the day, participants account balances in PNS are automatically transferred back to their accounts in TBF.

The description of the main characteristics of PNS, in particular the terms and conditions of settlement, sheds light on the factors contributing to the fluidity of payments executed via this system, under normal conditions, and on the tools available to participants for managing the effects of a technical default.

Payment orders in PNS are settled in real time if they satisfy a certain number of criteria (balances must remain positive, and the FIFO rule[3] and bilateral limits must be observed), or are placed in a queue if these criteria are not met. Queued payments are settled using three different processes that observe the constraints of bilateral limits.The first two also observe the FIFO rule:

• queue scanning, which involves, once an account has been credited, the system checking whether any queued transactions on that account can then be settled;

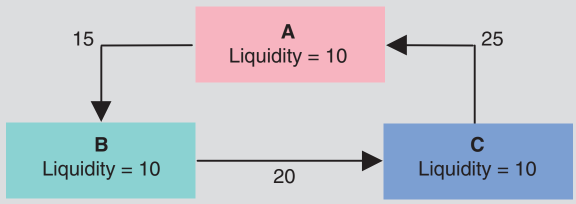
• bilateral optimisation, which is triggered whenever a payment is added to the queue. The system examines all the queued transactions between the sending participant and the receiving participant, and attempts to process some offsetting transactions simultaneously;

• multilateral optimisation, which is automatically launched twice a day as well as on the initiative of the system operator, and makes it possible to resolve gridlock by checking whether a large number of payments can be simultaneously settled.

By simultaneously settling a number of payments that partially offset each other, the last two mechanisms make it possible to significantly reduce the amount of liquidity in central bank money required for the smooth functioning of PNS, compared with a system that only offers gross settlement.

Gridlock

Gridlock is a situation in which several payments cannot be settled individually but can be settled simultaneously. An example of simple gridlock is when three participants A, B, C, all have a liquidity of 10, and A has to make a payment of 15 to B, B a payment of 20 to C and C a payment of 25 to A. In this case, no payment can be settled even though each participant has sufficient liquidity for the simultaneous settlement of all three orders.



Bilateral sender limits are set freely by each participant vis-à-vis its counterparties, thus allowing them to manage liquidity flows and control risks. A bilateral limit is the net amount of money a participant is willing to pay another participant before being paid back. Correct use of such limits enables participants to limit liquidity flows to counterparties withholding payments. There are many reasons why a participant may make late payments. One reason, discussed in this study, would be a technical incident that disrupted the smooth functioning of the participant's access to the system. Another reason could be of a more strategic nature: given that intraday liquidity has a cost, a participant may be tempted to wait to be paid by its counterparties before submitting its payments, so as to benefit from a free ride on the liquidity of others (incoming payments).

[3] *FIFO ("First in First out") means that priority is given to payments according to the order in which they arrive in the system. Nevertheless, a threshold of EUR 1 million exists below which payments bypass the FIFO rule in order to avoid overloading the settlement process. Payments of under EUR 1 million may therefore be settled directly, even if they are submitted after others already in the queue.*

2| METHODOLOGY

This study uses a simulator of TBF and PNS payment systems, developed by the Banque de France in Java script, which almost identically reproduces the functioning of these systems.[4] The simulations are based on 20 actual days of PNS operation[5] in January 2004, and are presented in Microsoft Access tables. The simulator reproduces the actual functioning of PNS by processing payments one by one in the same order in which they actually arrive in the days considered. It produces, at the end of each day, a new table showing each payment simulated, the time of settlement (or, as the case may be, whether it was rejected at the end of the day), if the payment was settled in real time or placed in a queue when it entered the system – and, in this case, the reason for it being placed in the queue (exceeding the bilateral limit, insufficient balance, respecting FIFO), as well as the process that enables settlement of the payment (real-time settlement, queue scanning, bilateral optimisation or multilateral optimisation). By choosing a full month of operation, it was possible to smooth the seasonal effects over the month. Indeed, payment flows may differ significantly over the course of the month (in particular in the run-up to the end of the reserve maintenance period), however they remain almost identical from one month to the next. Moreover, January 2004 can be considered to be characteristic of a "normal" month of operation for the system. In total, over 1,200 simulations were carried out, enabling us to test a large number of parameters.

The impact of technical default of one of its participants on the operation of PNS was tested using different scenarios. Technical default is understood to mean the inability of a participant to make its payments to its counterparties in the system in the wake of a technical incident that affects it. It may however continue to receive payments in a normal manner.[6] There may be many reasons for such an incident including failure of its system access or of upstream applications. In all of the failure scenarios tested, the defaulter could no longer submit payments, but continued to receive them. Consequently, the technical default of a participant is simulated as follows: as of the opening of the system, no payments are submitted by the defaulter but it continues to receive all those made by its counterparties. This is the worst case scenario in terms of the length of the incident and the behaviour of the participants. In terms of length, this scenario assumes that the incident takes place at the opening of the system and is not resolved before the end of the day of transactions. In terms of behaviour, it assumes a maximum "liquidity sink" effect in the system because, in this case, liquidity accumulates on the defaulter's account while the latter is unable to redistribute it in the system by submitting payments. In practice, we observe that in the rare event of the technical default of a participant in PNS, the other participants continued to make payments normally to the defaulter, but no incident has ever lasted the whole day. This assumption differs from that of the Bank of England which, in order to study the consequences of the technical default of a participant in its payment system CHAPS Sterling, assumed that payments to defaulter stop ten minutes after the incident occurs.[7]

For each actual day of transactions and each participant, the following values were calculated.

• Theoretical lower bound of liquidity (LBL). This is the minimum amount of liquidity that a participant must transfer in PNS for all its payments to be settled. The LBL of participant A is calculated as follows:

$$\text{LBL (A)} = \max \left(\sum_X P_{A\rightarrow X} - \sum_X P_{X\rightarrow A} , 0 \right)$$

where X represents the counterparties of A and $P_{A\rightarrow X}$ represents all the payments of A to X.

A participant in credit over the whole day therefore has a LBL of zero.

4 In the current version of the simulator it is not possible to change the bilateral limits set by the participants during the day in PNS. These limits are sometimes raised by participants before the closing of the system so that all the queued payments can be settled.
5 It should be noted, however, that there are minor differences between the bilateral limits used in the simulation and the real ones, as real limits could not be obtained for all days of transactions.
6 Even though it is likely that this participant would not have tools to view and process the payments made by its counterparties.
7 The Bank of England, Assessing operational risk in CHAPS Sterling: a simulation approach, Financial Stability Review: June 2004. Based on this assumption, the Bank of England set out to determine the point at which (date and time) an incident would have the greatest impact by carrying out simulations using actual transaction data from February 2004.

Table 1
Amount of liquidity simulated as a function of α

α	1	0.75	0.50	0.25	0.10	0
Liquidity (in billions of euro)	7.096	6.732	6.370	6.007	5.789	5.644
Liquidity simulated as a % of AL	100	94.87	89.77	84.65	81.58	79.54

Table 2
Value of bilateral limits simulated as a function of β

β	1	0.75	0.50	0.25	0.15	0.10	0.05	0
Bilateral limits simulated as a % of ABL	100	76.37	52.75	29.12	19.67	14.94	10.22	9.58

• Theoretical lower bound of bilateral limits (LBBL). The LBBL of participant A with participant B is the minimum value of the bilateral limit necessary to settle all payments from A to B:

$$\text{LBBL}\ (A \rightarrow B) = \max\ (P_{A \rightarrow B} - P_{B \rightarrow A},\ 0)$$

Simulations with different levels of liquidity injected into PNS[8] and bilateral limits were carried out (simulated liquidity levels and bilateral limits were denoted LS and BLS respectively), by varying their values between their "actual" value (i.e. that observed during the actual days, and denoted AL and ABL respectively) and their theoretical lower bounds. In the rest of this article, the level of liquidity simulated will be represented by an indicator (α), and the level of the bilateral limits simulated by an indicator (β) defined by the following equations:

• level of liquidity simulated (α)

$$LS = LBL + \alpha\ (AL - LBL) \text{ with } \alpha \in [0\ ,\ 1],$$

• level of bilateral limits simulated (β)

$$BLS = LBBL + \beta\ (ABL - LBBL) \text{ with } \beta \in [0.05\ ,\ 1] \cup \{\infty\}.$$

Hence, with α = β = 1, the simulation is based on the functioning of PNS with liquidity levels and bilateral limits equal to their actual values and with α = β = 0, the simulation is based on the functioning of PNS with liquidity levels and bilateral limits equal to their theoretical lower bounds. Lastly, β = ∞ enables us to model the functioning of the system without bilateral limits.

The amount of liquidity simulated in PNS as a function of α is shown in Table 1.

The value of the bilateral limits simulated as a function of β is shown in Table 2 (as a percentage of the actual bilateral limits).

In order to describe the impact of a default on the overall functioning of PNS, the following indicators were used:

• the delay indicator. The delay indicator δ, which describes the fluidity of the system, is defined as follows:[9]

$$\delta = \frac{\sum_i (t_{settled,i} - t_{sent,i})\ m_i}{\sum_i (t_{end} - t_{sent,i})\ m_i}$$

where m_i is the value of the payment i ; $t_{sent,i}$ and $t_{settled,i}$ are the times of submission and settlement of payment i respectively; t_{end} is the time the system closes, i.e. 4pm. Therefore, as the delay indicator decreases, the fluidity of the system increases: δ = 0 when all the payments are settled immediately, and δ = 1 when all the payments are settled at the end

8 *All liquidity transfers between TBF and PNS were reduced by the same percentage, without changing the times of these transfers. For example if a participant has made the liquidity transfers: EUR 100,000 at 8am and EUR 10,000 at 2pm from TBF to PNS, EUR 20,000 at 3.30pm from PNS to TBF, then a simulation with a ratio of 0.9 will be carried out with the following liquidity transfers: EUR 90,000 at 8am and EUR 9,000 at 2pm from TBF to PNS, EUR 18,000 at 3.30pm from PNS to TBF.*

9 *This definition of the delay indicator was introduced by Risto Koponen and Kimmo Soramäki in the Article "Intraday Liquidity Needs in a Modern Interbank Payment System. A Simulation Approach", Bank of Finland, 1998.*

of the day. When modelling a technical default, the delay indicator can be adjusted to solely take account of payments between non-defaulting participants, as we set out to identify the consequences of such a default for the latter. In order to calculate this indicator, the above equation is used, changing only the value range of i, which no longer includes the payments made to the defaulting participants;

• the rejected payments indicator. The number and value of rejected payments provides a better understanding of the risk resulting from the technical default of a participant in the system. A distinction was made between payments rejected between non-defaulting participants and rejections of those made to the defaulter. The number of rejected payments calculated by simulation probably overestimates the outcome of a real case scenario as it is likely that some participants would be able to adjust their level of liquidity accordingly, which was not simulated.

A number of other indicators were also used, such as the percentage of payments settled in real time in value and volume terms and the average time payments spend in the queue. Their values were calculated for each day of the month simulated, but were not systematically analysed. These values provide a complementary insight into the underlying factors that affect the main indicators described above.

3| Normal functioning of PNS

In order to determine, by comparison, the impact of a default, the characteristics of a standard day of transactions in PNS must be ascertained. So as to better apprehend the normal functioning of the system without taking account of defaulting participants, a number of conditions of liquidity and bilateral limits were simulated, varying α from 0 to 1 and β from 0 to infinity.

Charts 1 and 2 show the delay indicator (δ) and the rejected payments for different levels of liquidity (α) and bilateral limits (β). In each of the charts, the delay indicator is given on the left-hand scale. The right-hand scale shows the value of the rejected payments as a percentage of the value of all transactions in the system. In addition, the average number of payments rejected daily is given above each point.

The main observation emerging from these simulations is that the system can function smoothly with significantly lower liquidity levels and bilateral limits than their actual values.

This conclusion is supported by the delay indicator, whose upper bound reached $\delta = 0.165$ (for a value of $\delta = 0.09$ with $\alpha = \beta = 1$). The low values obtained for the delay indicator show that PNS is a system that functions broadly in the same way as a gross settlement system. Indeed, even under the most extreme conditions tested, δ remains very far from $\delta = 1$, which would correspond to the functioning of a deferred net settlement system with a settlement at the end of the day. This observation corroborates the conclusions of a previous study conducted several weeks after the PNS system went live.[10]

These simulations also show that there were almost no rejected payments, even for low values of α and β. Rejected payments only appeared at values below $\beta = 0.50$; they are characteristic of situations of gridlock that are not resolved by optimisation algorithms (a value of $\beta = 0.50$ should theoretically allow all payments to be settled).

However, participants in the system can change their bilateral limits during the day. We can thus assume that the few payments that were rejected in the simulations would have actually been released in reality by raising the bilateral limits.

Lastly, the use of optimisation mechanisms greatly increases when β declines and more moderately when α declines, which shows that these mechanisms are more responsive to a decline in the bilateral limits than to a decline in liquidity. These mechanisms ensure the smooth functioning of the system in conditions of tighter liquidity or limits.

[10] *"Les caractéristiques de fonctionnement des systèmes français de règlement de montant élevé TBF et PNS: quelques enseignements tirés de travaux de modélisation", Gilles Ryckebusch, Jean-François Ducher and Denis Beau, Banque de France Bulletin No. 71, November 1999.*

Chart 1
δ = f(α) with β = 1

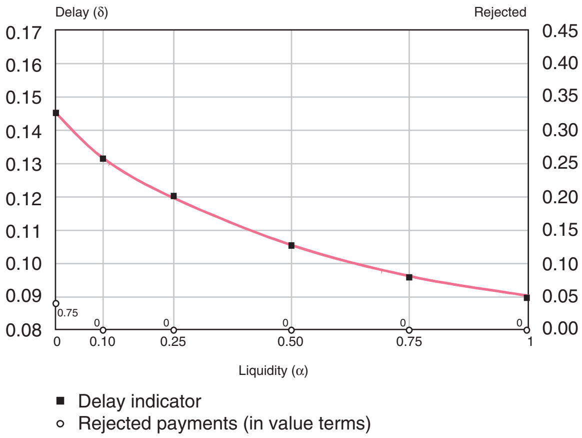
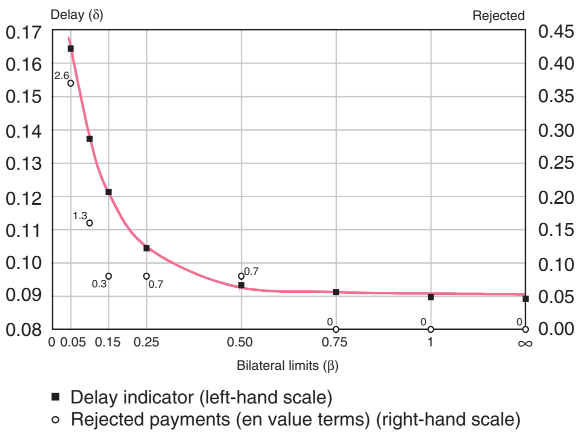


Chart 2
δ = f(β) with α = 1



NB: Charts 1 and 2 show that almost no payments were rejected (right-hand scale), even at much lower levels of liquidity and limits than their actual values.

4| THE DEFAULT OF A PARTICIPANT

4|1 Without varying bilateral limits

The following analysis focuses on the consequences of the default of the largest debtor in the system, i.e. the participant with the highest value of total payments over a given day.

The default of the largest debtor was simulated at the start of the day by initially assuming that non-defaulting participants do not change their behaviour vis-à-vis the defaulter. In the model, non-defaulting participants continue to submit payments normally and do not change their bilateral limits with the defaulter. A number of conditions of liquidity and bilateral limits were tested by varying α from 0.5 to 1 and β from 0.05 to infinity.

These value ranges enable us to test all the conditions of bilateral limits in the system, from the lowest to the highest values. A value of β = ∞ models the functioning of a system that would not be constrained by the existence of bilateral limits.[11]

The value range of α makes it possible to simulate the functioning of the system with an amount of liquidity equal to or below its actual value (i.e. observed during actual transaction days). It is useful to make simulations with an amount of

Table 3
Payments settled using optimisation mechanisms
(as a % of queued payments)

	β = 0.05	β = 0.5	Actual case	α = 0.5	α = 0
Bilateral optimisation	60.71	31.00	29.16	31.48	35.56
Multilateral optimisation	8.34	3.50	3.47	3.36	5.57

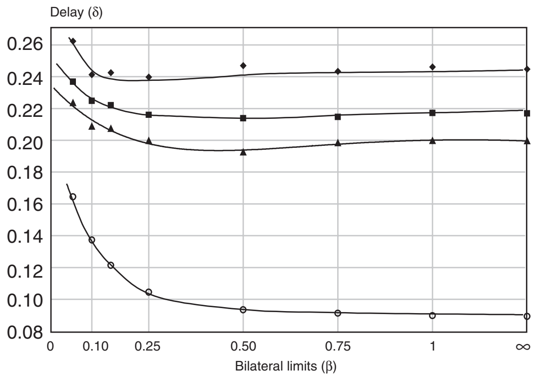
[11] *For technical reasons, due to the simulator's excessively long response time, the value β = 0, which models the functioning of PNS with the bilateral limits set at their lower bound (LBBL), was not able to be tested. Simulations were carried out with values of β sufficiently close (β = 0.05) to be able to extrapolate the functioning of the system at this level of limits.*

liquidity below that of actual liquidity because participants generally use the same technical platform to access TBF and PNS. Consequently, it is likely that a participant in technical default in PNS would also be in technical default in TBF, which could result in tighter liquidity conditions in the system and fewer liquidity transfers on the part of non-defaulting participants to PNS and thus a lower liquidity level α.

The impact of a technical default on the functioning of PNS was measured using the three following indicators: the delay indicator δ, the rejected payments between non-defaulting participants (as a percentage of payments between non-defaulting participants, in value and volume terms) and rejected payments made to the defaulter (as a percentage of payments made to the defaulter, in value and volume terms). Charts 3, 4 and 5 show the value of these indicators for the different conditions of liquidity and bilateral limits considered.

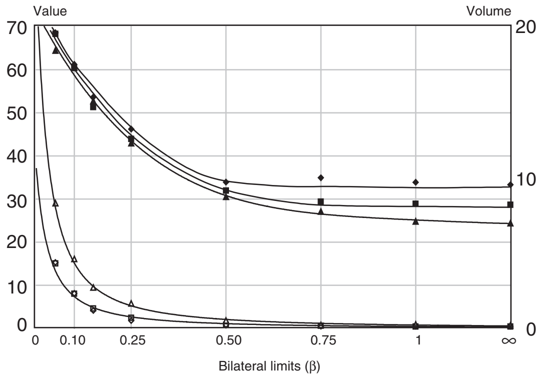
In a preliminary analysis, these indicators show that, irrespective of the level of liquidity in the system and the value of the bilateral limits set by the participants, the impact of the technical default of a participant on the functioning of the system and the consequences for the non-defaulting participants are very significant. Indeed, a technical default leads, in all cases, to a considerable increase in the delay indicator and a substantial number of rejected payments between the non-defaulting participants.

Chart 3
$\delta = f(\alpha,\beta)$



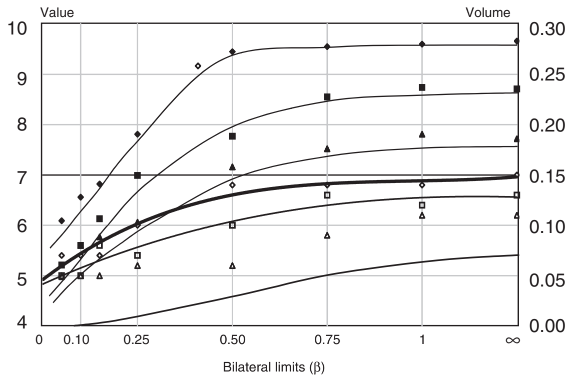
◆ α = 0.50
■ α = 0.75
▲ α = 1
○ Without defaulter

Chart 4
Rejected payments to the defaulter
(as a % of payments to the defaulter)



◆ α = 0.50 (value) (left-hand scale)
◇ α = 0.50 (volume) (right-hand scale)
■ α = 0.75 (value) (left-hand scale)
□ α = 0.75 (volume) (right-hand scale)
▲ α = 1 (value) (left-hand scale)
△ α = 1 (volume) (right-hand scale)

Chart 5
Rejected payments between non-defaulting participants
(as a % of payments)



▲ α = 1 (value) (left-hand scale)
■ α = 0.75 (value) (left-hand scale)
◆ α = 0.50 (value) (left-hand scale)
△ α = 1 (volume) (right-hand scale)
□ α = 0.75 (volume) (right-hand scale)
◇ α = 0.50 (volume) (right-hand scale)

NB: Almost 10% (in value terms) of payments between non-defaulting participants could be rejected in the event of a default. This figure is reduced by half at low values of β.

The delay indicator provides information on how smoothly the system is operating as a whole. It rises sharply in the event of a participant defaulting, which means that a greater number of payments are placed in the queue and remain there for a longer time. It also increases when the amount of liquidity in the system (α) declines. This result is intuitive, because a greater number of payments are queued due to insufficient balances. Moreover, the tighter the liquidity conditions in PNS (low values of α), the less sensitive the delay indicator will be to the value of the bilateral limits. This can mainly be ascribed to the fact that when there are liquidity strains in the system, payments are queued because of insufficient balances before the bilateral limits are reached. Lowering these limits therefore has little impact on the functioning of the system.

Table 4
Queued payment data

Simulations with α = β = 1	Without defaulter	With defaulter
Queued payments (as a % of total payments)	42.90	63.15
Average time spent in the queue (in seconds)	1,850	2,677

Table 5
Delay indicator as a function of β

Delay indicator	Without defaulter	With defaulter
β = 1	δ = 0.090	δ = 0.200
β = 0.05	δ = 0.160	δ = 0.225

From Chart 4, it can also be seen that the number and the value of rejected payments to the defaulter are highly dependent on β (the lower the bilateral limits are, the faster those set with the defaulter are reached as the latter does not submit any payments), but not very dependent on the level of liquidity α. If β falls from 1 to 0.05 the proportion (in value terms) of rejected payments rises from 25% to 65%.

The number and the value of rejected payments between non-defaulting participants are very sensitive to the level of liquidity and value of the bilateral limits β. They increase when α declines, and decrease when β declines. Furthermore, sensitivity to β is much greater for low values of this parameter. The following mechanism can be observed: the lower the bilateral limits are, the higher the number of rejected payments to the defaulter. This results in non-defaulting participants losing less liquidity and reduces the "liquidity sink" effect, as these counterparties would then have more liquidity to settle payments between themselves. Chart 5 illustrates this mechanism: the number of rejected payments between non-defaulting participants is reduced by almost half when β declines from 1 to 0.05.

Moreover, payments rejected between non-defaulting participants are mainly those of large value. The average value of a rejected payment (EUR 76.1 million, where α = 1) is more than 50 times greater than that of the average payment in PNS (EUR 1.5 million).

In the event of a technical default, the value of the bilateral limits has a twofold influence. Firstly, the lower the bilateral limits are, the greater the number of queued payments. This increases the value of the delay indicator and the number of rejected payments. This mechanical effect was highlighted in the first section of the study. However, low bilateral limits contribute to reducing liquidity flows (liquidity sink effect) to the defaulting participant, which increases the amount of liquidity available for the settlement of transactions between non-defaulting participants. This effect results in a reduction in the delay indicator and in the number of rejected payments among non-defaulting participants.

The second effect, whereby the number and the value decline when β decreases, is a determining factor for explaining rejected payments between non-defaulting participants. Moreover, the combination of the two effects gives an optimum value of β (close to 0.50 for α = 1 or 0.75 and close to 0.25 for α = 0.50), above and below which the delay indicator shows a higher value.

Table 6
Payments received by the defaulter as a function of ß
(in EUR billions)

ß	∞	1	0.50	0.25	0.10	0.05
Payments received	6.005	5.972	5.583	4.484	3.113	2.522

4|2 Varying bilateral limits

In order to determine the extent to which changes in the behaviour of a defaulter's counterparties are likely to reduce the negative impact on the functioning of PNS, scenarios were carried out in which the bilateral limits of these counterparties vis-à-vis the defaulter were changed.

In the scenario tested, the bilateral limits of the non-defaulting participants vis-à-vis the defaulter were changed immediately (as of the opening of the system), and set at their theoretical lower bound [12]. This value enables non-defaulting participants to ensure that all payments to the defaulter could be settled if the latter were also able to submit payments (below this level it would not be possible to meet this condition). However, this value also limits liquidity flows to the defaulter that is unable to submit payments.

Several simulations were carried out with a liquidity level $\alpha = 1$ and varying the bilateral limits among non-defaulting participants ($\beta = 0.25; 0.50; 0.75$ and 1). No simulations were conducted with both a selective change in limits vis-à-vis the defaulter and values of β below 0.25. Indeed, these conditions are sufficiently close to those already simulated and presented in Section 4|1 of this article ($\beta = 0.05$; no selective change vis-à-vis the defaulter) for the results from the latter to be extrapolated. Furthermore, given the probability that a technical default may also affect the amount of liquidity transferred between TBF and PNS, the study was supplemented by a series of simulations in which the amount of liquidity α was lower than its actual value, $\alpha = 0.75$. This series was tested with a value of $\beta = 0.50$, which, on the basis of the preliminary results obtained for $\alpha = 1$, appeared to be the most appropriate choice.

Chart 6
$\delta = f(\beta)$

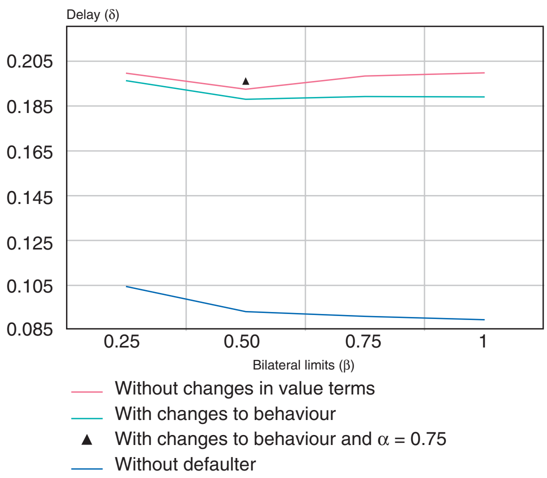
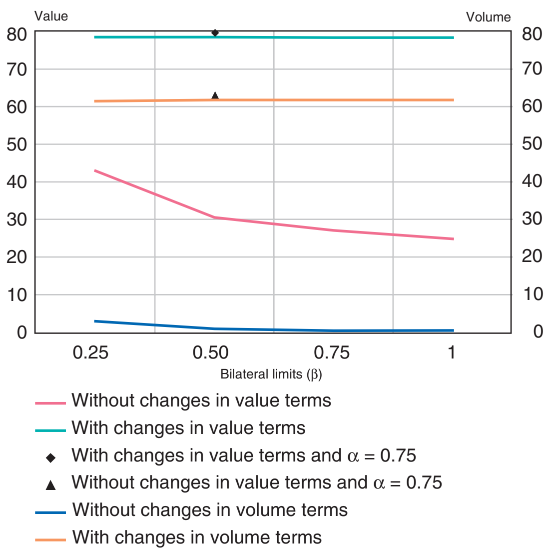


Chart 7
Rejected payments to the defaulter
(as % of payments to the defaults)

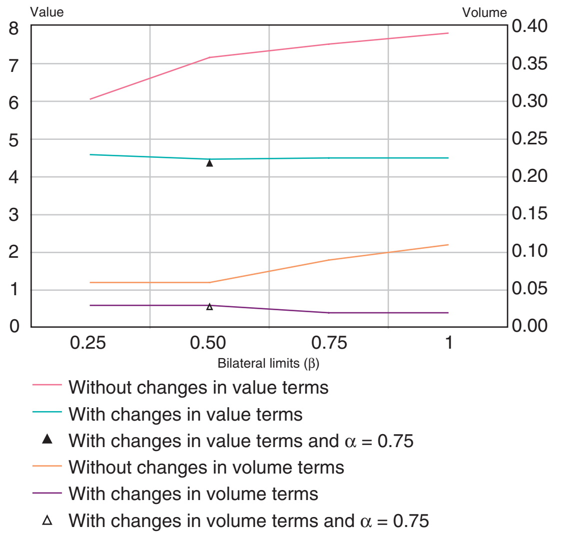


[12] *It should nevertheless be noted that this exercise remains theoretical because this value is not a priori known by the participants, as they are not necessarily aware of all the payments they expect from their counterparties.*

Table 7
Reason for rejected payments to the defaulter and payments received by the latter when β = 0.5
(Rejected payments as a %, payments received in euro)

	Rejected payments due to exceeding limits		Rejected payments due to insufficient balance		Payments received by the defaulter
	In value terms	In volume terms	In value terms	In volume terms	
Without changing behaviour	15.40	33.80	84.60	66.20	5,583,232,111
Changing behaviour	82.30	98.05	17.70	1.95	1,675,232,702

Chart 8
Rejected payments between non-defaulting participants
(as % of payments between non-defaulting participants)



NB: If non-defaulting participants rapidly lower their bilateral limit vis-à-vis the defaulter, the rejected payments of among these participants (in value terms) are reduced by over 40% when α = 1 but remain significant (around 4.5%).

A preliminary analysis of the results obtained (Charts 6, 7 and 8) shows that when non-defaulting participants react rapidly and set their bilateral limit vis-à-vis the defaulter at its theoretical lower bound, the consequences of the default are diminished, but remain significant. In fact, the delay indicator is only marginally reduced and the number of rejected payments between non-defaulting participants, although considerably lessened, remains substantial (around 4.5% in value terms).

The decrease in the delay indicator is indeed very slight irrespective of the value of β (around -2% for β = 0.50), which suggests that setting bilateral limits vis-à-vis the defaulter at their theoretical lower bound only slightly improves the fluidity of the system as a whole.

Furthermore, by a similar mechanism, as when non-defaulting participants do not react selectively, there is an optimum value of β that minimises the delay indicator. This value is close to β = 0.50 for a value of α = 1.

The impact of setting limits at their theoretical lower bound is more pronounced on the number and the value of rejected payments between non-defaulting participants, which decline from 7.2% to 4.5% in value terms and from 2% to 1% in volume terms for a value of β = 0.5. They are also relatively insensitive to variations of β.

Similarly to the observation in Section 4|1 of this article (without varying bilateral limits), the payments rejected between non-defaulting participants are mainly those of large-value. Indeed, the average value of a rejected payment (EUR 166.2 million, where α = 1) is over 110 times greater than that of the average payment in PNS (EUR 1.5 million).

Moreover, the existence of such limits significantly increases the number and the value of rejected payments to the defaulter, as the latter rise from 30% to 80% in value terms and from 2% to 60% in volume terms. These limits therefore result in a substantial reduction of liquidity flows to the defaulter.

The indicators observed are relatively insensitive to small variations in the amount of liquidity α in

Table 8
Impact of the threshold below which payments can bypass the FIFO rule and optimisations
(Rejected payments as a % of the total payments)

Simulations with $\alpha = \beta = 1$	δ	Rejected payments to the defaulter		Rejected payments between non-defaulting participants	
		In value terms	In volume terms	In value terms	In volume terms
Normal case	0.1998	24.80	0.44	7.81	0.11
With 2 additional multilateral optimisations at 9.15am and 2pm	0.2005	25.29	0.45	7.83	0.11
Simulations with a threshold of 500,000	0.1995	24.78	0.45	7.93	0.13
Simulations with a threshold of 100,000,000	0.2100	26.05	0.40	8.64	0.11

the system. On the basis of the results obtained with $\alpha = 0.75$, the delay indicator and rejected payments between non-defaulting participants only increase marginally compared with results obtained with $\alpha = 1$.

Furthermore, for all the indicators concerned, the lower the value of β is, the lower the impact of a selective setting of bilateral limits vis-à-vis the defaulter. This result is intuitive because the lower the value of β, the closer the case observed will be to that observed in Section 4|1 of this article (uniformly low limits).

A number of simulations were also conducted by varying the value of the threshold below which payments can bypass the FIFO rule and by increasing the number of multilateral optimisations. These simulations showed that these two parameters have a relatively low impact on the indicators observed (see Table 8).

The results of the study show that the impact of the technical default of a participant on the fluidity of transactions in the large-value payment system PNS is significant and may disrupt the system's smooth functioning. Such a default results in an almost doubling of the delay indicator and causes payment rejections among non-defaulting participants of up to 10% of total transactions (in value terms). However, an appropriate use of risk management tools enables participants to greatly reduce the impact of a technical default. Preventive actions and a rapid response on the part of the other participants are required. Indeed, as a preventive measure, setting bilateral limits at a lower level than that actually observed in the system makes it possible to reduce liquidity loss in the event of a default, while having an insignificant impact if the system is functioning normally. Moreover, by responding rapidly to information indicating a technical default and adapting their bilateral limits vis-à-vis the defaulter, non-defaulting participants can significantly reduce the impact of such a default on their own transactions. Simulations also showed that there are optimum values for these limits in order to minimise the impact on payments between participants, which are lower than those actually set by participants in the system.

This study confirms the usefulness of the introduction, already planned by the system operator, of a function that makes it possible to submit payments on behalf of the defaulter. This would reduce the risk from such a default by partially redistributing the liquidity "trapped" in the defaulter's account.

These simulations supplement the assessments of PNS carried out by the Banque de France as part of its payment systems oversight duties, in particular by shedding more light on the capacity of the system to function smoothly in the even of "shocks" and highlighting the mechanisms to damp such shocks.

The results obtained for the PNS system make it possible to better understand the consequences that might arise from the technical default of a participant in a system with comparable characteristics, and above all illustrate the importance of the appropriate use of bilateral sender limits in a system with a similar risk management tool. This is the case for TARGET 2, which the Eurosystem has scheduled to go live in 2007, to replace its current network of large-value payment systems linked to TARGET.