# An analysis of systemic risk in alternative securities settlement architectures*


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ABSTRACT

This paper compares securities settlement gross and netting architectures. It studies settlement risk arising from exogenous operational delays and compares settlement failures between the two architectures as functions of the length of the settlement interval. While settlement failures are non-monotonically related to the length of settlement cycles under both architectures, there is no clear cut ranking of which architecture delivers greater stability.


## I. INTRODUCTION

Securities settlement systems (SSSs) are institutional arrangements for confirmation, clearance and settlement of securities trades and safekeeping of securities. The first step in the clearing and settlement process is to ensure that the buyer and the seller agree on the terms of the trade. Following a trade, each party sends an advisory message identifying the counterparty, the security, the quantity of the security, the invoice price, and the settlement date. This process is called trade confirmation. After trades have been confirmed, the next step in the process is clearance, the computation of the obligations of the counterparties to make deliveries or to make payments on the settlement date. Finally settlement are the operations by which securities are transferred from seller to buyer and payments from buyer to seller.

Participants in SSSs face a variety of risks (see Committee on Payment and Settlement Systems (2001)). There is the risk that participants will not settle (credit risk) or that there will be a delay in settlement (liquidity risk). These include the risk that securities are delivered but payment not received and vice-versa (principal risk). Other risks arise from mistakes and deficiencies in information and controls (operational risk), from the safekeeping of securities by third parties (custody risk), or from failures of the legal system that supports the rules and procedures of the settlement system (legal risk). If the failure of one participant renders other participants unable to meet their obligations, the settlement system might be a source of instability for financial markets more generally (systemic risk) (see De Bandt and Hartmann (2002) for a review on systemic risk). The complexity of settlement operations and the varieties of parties involved make SSSs a critical component of the


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infrastructure of global financial markets. A financial or operational problem during the settlement process has the potential to propagate the crisis to other payment systems used by the SSS or that use the SSS to transfer collaterals.

In some markets, a central counterparty (CCP) interposes itself, becoming the buyer to the seller and the seller to the buyer. The use of a CCP reduces credit risk and liquidity risk. Most markets have also established central securities depositories (CSDs) that immobilise physical securities and transfer ownership by means of book entries to electronic accounting systems. Not all buyers and sellers of securities hold accounts at the CSD; instead, they may hold their securities and settle their trades through a custodian (see Holthausen and Tapking (2003) for an analysis of competition between CDS and custodians). The cash leg of the transactions is typically settled through the central bank payment system. The advantage of using central bank funds for payments is that it eliminates credit risks to the selling agent (see Freixas et al (2002) for a comparative analysis of the risks arising from settlement in central bank money or private money).

Delivery versus payment (DVP) is the practice of linking securities transfers to funds transfers to ensures that principal risk is eliminated. The settlement of securities transactions on a DVP basis reduces, but does not eliminate, the risk that the failure of an SSS participant could result in systemic disruptions. A failure to deliver by one party leaves the counterparty needing to replace the transaction at the current market price. The magnitude of replacement cost risk depends on the volatility of the security price and the amount of time that elapses between the trade and the settlement dates. Different methods for achieving DVP can be distinguished according to whether the securities and/or funds transfers are settled on a gross (trade by trade) basis or on a net basis. Further distinctions relate to whether the transactions are settled in real time, (ie throughout the day), in intraday batches, or at the end of the day. Real time gross settlements systems (RTGS), where payments are executed continuously via transfers of central bank funds from the account of the paying bank to the account of the receiving bank, while reducing systemic risk, increase liquidity risk. Participants need to hold for a given volume of transactions, on average more reserves and gridlocks may also occur if the flow of payments is disrupted because participants are waiting to receive payments before sending them[1]. By contrast in netting arrangements each party only delivers its net sale, or receives its net purchase, resulting in very significant reductions in gross exposure. Nonetheless, in net settlement systems a failure to settle results in an unwind, i.e., the deletion of some or all of the provisional transfers involving the defaulting participant and the recalculation of the settlement obligations of the non-defaulting participants. An unwind would have the effect of imposing liquidity pressures and replacement costs on the non-defaulting participants that had delivered securities to, or received securities from, the defaulting participant. Should one or more of the initially non-defaulting participants be unable to cover the shortfalls and default in turn, the system would almost surely fail to settle and it is likely that both the securities markets and the payment system would be disrupted.

Currently there is a given lag between the date of trade and the date of settlement. The longer this lag the greater the risk that one of the parties may default on the trade, and the greater the possibility for security prices to move away from the contract prices, thereby increasing replacement costs risk. Both these risks can be reduced by compressing the time between trade execution and settlement. In 1989, the G30 recommended that final settlement of cash transactions should occur on T+3, i.e., three business days after trade date. The G30 recognised that to minimise

[1]Angelini (1998) studied RTGS systems under payment flow uncertainty and showed in his paper, that uncertainty together with a costly daylight liquidity, may induce participants to postpone payment activities affecting the quality of information available to the counterpart for cash management purpose. This in turn may induce higher than optimal levels of participaints end-of-day reserve holding, relative to the social optimum.

counterparty risk and market exposure same day settlement is the final goal (see also Leinonen (2003)). The International Organization of Securities Commissions (IOSCO) created, in December 1999, the Task Force on Securities Settlement Systems. Amongst other recommendations the Task Force has also recommended that T+3 settlement be retained as a minimum standard. However, T+3 is no longer regarded as best practice. The standard judged appropriate for a market depends on factors such as transaction volume, price volatility and the financial strength of participants. The Task Force recommends that each market assesses whether a shorter cycle than T+3 is appropriate.

In moving from T+n to T+0 liquidity risk becomes particularly important on the payments side because the incoming and outcoming flows of payments are not known in advance by the cash managers. This is true whether settlement is done on a gross basis immediately after the trade or by netting the end of day positions. By contrast, on the securities side liquidity is not a problem because the custodians already have the securities at the execution date. Nonetheless, in some markets the rate of settlement falls significantly short of 100%, because of human errors or operational problems. Errors or delays in transaction processing may result from incomplete or inaccurate transmission of information or documentation, or from system deficiencies or interruptions. A move to a shorter cycle could generate increased settlement failures and generate systemic risk. In fact, while shortening the settlement interval has the advantage of reducing replacement costs following the failure of a participant to settle, it also increases the likelihood of settlement failures.

In this paper we study the effects of increasing the number of intraday settlement batches, when exogenous random delays affect the transfer of securities. For a given distribution of lengths of delays, the likelihood that delays will lead to settlement failure increases as the length of settlement cycles decreases. Thus, we study the interplay between stabilization resulting from reduction in the number of parties involved in a shorter settlement cycle, and destabilization resulting from the effects of delays.

## II. SYSTEMIC RISK

In this section we focus on the securities leg of the transaction and assume that exogenous sources (human mistakes or operational problems) may delay the confirmation of trade and hence the settlement. The inability of a party A to deliver the security to a party B may generate in turn the failure of B to settle, if B has already sold the security to a third party C before the settlement batch.

Mature and liquid securities lending markets (including markets for repurchase agreements and other economically equivalent transactions) could improve the functioning of securities markets, by allowing sellers ready access to securities needed to settle transactions where those securities are not held in inventory. Nonetheless, while securities lending may be a useful tool, these markets are currently not sufficiently liquid (see Fleming and Garbade (2002) for an analysis of the impact of illiquid security lending market in the crisis following the September 11 attack). Hence, in this section we assume that no securities lending market is in place and analyze the systemic effects arising from the failure to settle of one or more participants in the SSS.

We assume that securities are exchanged with a probability $\lambda$ per time unit. A high value of $\lambda$ indicates a very liquid market. We also assume that, with a probability $\mu$, each transaction could experience a random delay $\tau$ to settle. We take $\tau$ to be uniformely distributed in the interval $(0, \tau_M)$, where $\tau_M$ is the maximum delay expected given the specific market available IT infrastructures (we have also analysed normally distributed random delays and the results are qualitatively similar).

We study the dependence of the failure rate on the number $N$ of intraday batches. The length of each settlement interval is $T_i = T_1/N$. Real time settlement is recovered in the limit of $N$ large. While reducing the settlement frequency has the advantage of reducing the number of parties exchanging any given security between two settlement cycles, and hence systemic risk, it also increases the likelihood of such failures to arise when $T_i < \tau_M$.

We compare the performance (measured as the ratio of transactions that fail to settle in a given period over the total number of transactions in the same period) of the gross and netting system under different market conditions, i.e. for different values of $\lambda$ (which is a proxy for liquidity), $\mu$ and $\tau_M$ (which measures the reliability of IT infrastructures) and the number of shares $S$ of the same security traded (which represents the trading volume). We simulate settlement in a system with 1000 participants and take 1 minute as the unit of time. A typical trading day last for 512 minutes (about 8.5 hours). We assume that each trade consists of a single share but $S$ shares (of the same security) are traded in the system and each one is exchanged several times among the participants during a trading cycle. We average the results over 1000 sets of simulations. The values we considered for the other parameters are $\mu = 0.01, 0.1, 1$, $\lambda = 0.01, 0.1, 1$, $\tau_M = 512, 51.2, 5.12$, and $S = 100$.

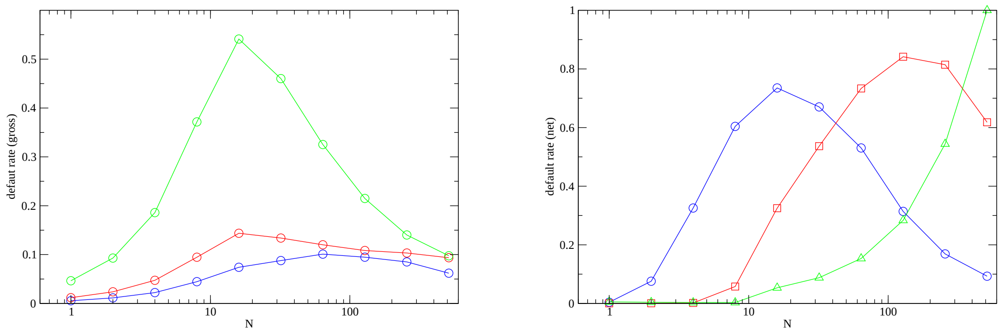


FIG. 1. Default rate in gross (left) and net system (right) as a function of $N$ at various level of $\lambda$: 0.01 (blue), 0.1 (red), 1 (green). In each case $\tau_M = 51.2$, $\mu = 0.1$, $S = 100$.

In gross systems shares are settled independently from each other, so the total number does not play a major role (apart for sharpening the statistical behaviour of the system). But in netting systems the total number of securities does play a crucial role. If a participant fails to settle even one transaction, all its provisional transfers are deleted from the system, and the settlement obligations from the remaining participants are recalculated (unwind). While an increase in the number of traded shares may have the effect of reducing the net exposure of each participant, and hence reduce the number of initial failures to settle, if a failure happens it may generate larger systemic effects as the number of counterparts affected by the unwinding also increases.

Figure 1 shows the default rate for gross (left) and net (right) systems as a function of $N$ and different levels of $\lambda$. In each case $\tau_M = 51.2$, $\mu = 0.1$, $S = 100$. By increasing $\lambda$, the number of exchanges in between to settlement dates increases, and consequently increases the probability that one of the transaction settles with a large delay. This explain the increase of the default rate $r_d$, with $\lambda$, in the gross system. x $\tau_M$ here is chosen to be one tenth of the length of trading day. When increasing $N$, $T_i$ becomes smaller than $\tau_M$ and delays become more likely to last longer than the settlement batch. This explains the initial rise of the default rate with $N$. By increasing $N$ further, the probability that defaults last longer than settlement remains large but almost unchanged. Nonetheless, increasing $N$ has the positive effect of reducing the number of transactions before settlement and, so doing, reduces systemic effects. In the limit of $N$ large trade settles in real time and in all the plots the rate of default converges, as expected, to $\mu = 0.1$. In the netting system the trade off between these two effects is still visible but affects differently the system at various level of $\lambda$. In particular if $\lambda$ is large (green curve) the rate of default increases monotonically with $N$. Furthermore the rate of default initially increases slowly with $N$ but increases faster at high level of $N$. This has the effect of making the system more stable at high $\lambda$ than at low $\lambda$ when $N$ is not too large. This happens because high $\lambda$ generates more opportunities for netting within the settlement period. As long as the settlement period is sufficiently long this effect dominates. As $N$ becomes large enough the likelihood that each trade fails also increases and by reducing $\lambda$, and hence the number of exchanges, the system becomes more stable. Finally we point out that when comparing netting and gross architectures, at $\lambda$ sufficiently large (red and green curves), netting systems are more stable than gross systems (and even more stable the higher the $\lambda$) at sufficiently low $N$ and vice versa.

In figure 2 we show the dependence of the rate of default $r_d$ on $\tau_M$, for $\mu = 0.1$, $\lambda = 0.1$ and $S = 100$.

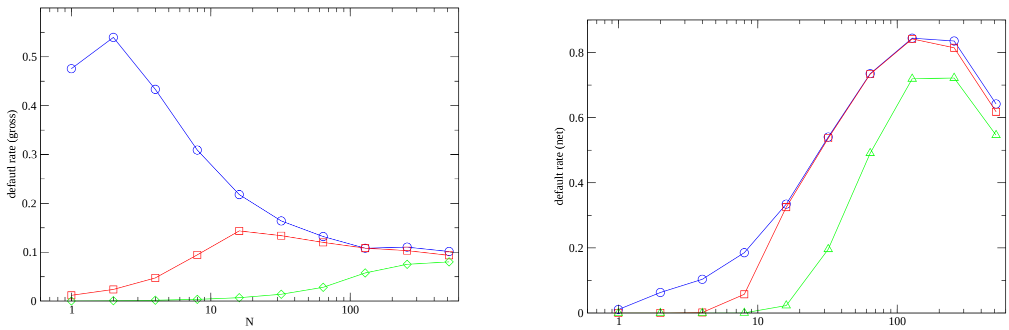


FIG. 2. Default rate in gross (left) and net system (right) as a function of $N$ at various level of $\tau_M$: 5 (green), 51 (red), 512 (blue). In each case $\mu = 0.1$, $\lambda = 0.1$ and $S = 100$.

When $\tau_M$ is small (green curve), and hence delays are short, the default rate increases monotonically with $N$. As $\tau_M$ increases, defaults becomes more and more likely and the rate of default shows a non monotonic behaviour with an initial increase with $N$ and a subsequent decrease with $N$. At very high $N$ few participants exchange the security and the stabilizing effects arising from this are dominant. For $N$ sufficiently small the system is stable again because the reduction in the likelihood of defaults dominates in this case. Of course the region of values of $N$ over which these two effects respectively dominate changes with $\tau_M$. The situation is qualitatively similar in netting systems and again netting systems appear to be more stable than gross systems at low value of $N$.

We also examined the default behaviour of the two systems as a function of $N$ when the values of $\mu$ were changing. The qualitative behaviour as a function of $N$ was simular to that shown in the other experiments and as expected defaults were always greater at higher values of $\mu$.

## III. CONCLUSIONS

In this paper we examined some issues that arise with respect to the performance of different securities settlement architectures at different settlement cycles.

We focused on the securities leg of the transaction under the assumption of exogenous random delays in settlement which could lead to failure of individual transaction and through the unwinding process to systemic settlement failure. In particular we focused on the effects of the length of settlement cycles on settlement failure under different market conditions involving factors such as liquidity, trading volume and the frequency and length of delays. We found that the length of settlement cycles has a non-monotonic effect on failures under both gross and net architectures and that there is no clear-cut ranking of which architecture performs better. Thus which architecture will be less prone to settlement failure depends on a variety of factors which were uncovered by our analysis.

A possible extension of this research is to endogenize the settlement failure decision as a response to movements in securities prices. Although the operator of the SSS can discourage such strategic default by imposing a fine which taxes away potential gain from such behaviour, it would still be interesting to study its effects on different SSSs architectures.

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