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ECB-CFS RESEARCH NETWORK ON CAPITAL MARKETS AND FINANCIAL INTEGRATION IN EUROPE

AN ANALYSIS OF SYSTEMIC RISK IN ALTERNATIVE SECURITIES SETTLEMENT ARCHITECTURES

by Giulia Iori

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In 2004 all publications will carry a motif taken from the €100 banknote.

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ECB-CFS Research Network on
"Capital Markets and Financial Integration in Europe"

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CONTENTS

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 under different market conditions. 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. We show that while, on average, netting systems seem to be more stable than gross systems, rare events may lead to contagious defaults that could affect the all system. Furthermore netting system are very sensitive to the number and initial distribution of traded shares.

JEL classification: C6, D4, G20, O33.

Keywords: Security clearing and settlement, gross and net systems, systemic risk.

NON-TECHNICAL SUMMARY

Securities settlement systems (SSS) are institutional arrangements for confirmation, clearance and settlement of securities trades and safekeeping of securities. Different arrangements for settlement have been devised. In gross settlements systems payments are executed continuously or in batches via transfers of central bank funds from the account of the paying bank to the account of the receiving bank. 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, thus generating contagion and systemic failure.

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 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.

We assume that exogenous sources (human mistakes or operational problems) may delay the confirmation of trade and hence the settlement. We assume that no securities lending market is in place and analyse the systemic effects arising from the failure to settle of one or more participants in the SSS.

We simulate settlement, over a trading day in a system with a large number of participants. We assume that 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 monitor the buyer and seller (if trade happen) of each share at all time steps. We also monitor if an operational delay occurs during any of the transactions. If a trade esperience a delay longer than the remaining time till settlement it will eventually fail to settle. In the case of gross settlement each share is settled independently from the others. If a participant cannot settle the trade for a given share, all the participants that agreed to exchange that share afterwards will also not be able to settle their trades. In the case of netting, the trades of all shares of the same stock are settled together by netting the participant positions. The failure of one or more participants to deliver their net position of shares results in an unwind. Because of the cancellation of some trades when recalculating the net position of the remaining participant is possible that new traders will find themselves unable to settle. This may trigger more failures and unwinding.

We study the effects of the length of settlement cycles on settlement failure under different market conditions involving factors such as liquidity, trading volume, the frequency and length of delays and heterogeneity in the initial distribution of shares.

We find 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. While netting systems seem to be more stable on average (at least in homogeneous conditions), rare events may lead to contagious defaults that affect the all system. Furthermore netting system are very sensitive to the number and initial distribution of traded shares.

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 counterpart, 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 counterparts 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 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 counterparts (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 counterpart 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, (i.e. 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

[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 participants end-of-day reserve holding, relative to the social optimum.

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 counterpart 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. THE MODEL

We 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 analyse the systemic effects arising from the failure to settle of one or more participants in the SSS.

We simulate settlement, over a trading day T in a system with N_a participants. We assume that 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 monitor the buyer and seller (if trade happen) of each share at any time step. We also monitor if an operational delay occurs during any of the transactions, and if the delay lasts longer than the remaining time till settlement. In the case of gross settlement each share is settled independently from the others. If a participant cannot settle the trade for a given share, all the participants that agreed to exchange that share afterwards will also not be able to settle their trades. Hence, if the chain of transaction breaks at one point, all the transaction after the breaking point will result in a default. In the case of netting, the trades of all shares of the same stock are settled together by netting the participant positions. The failure of one or more participants to deliver their net position of shares results in an unwind, i.e., the deletion of all of the trades involving the defaulting participant and the recalculation of the settlement obligations of the non-defaulting participants. Because of the cancellation of some trades when recalculating the net position of the remaining participant is possible that new traders will find themselves unable to settle. This may trigger more failures and unwinding. The settlement process can be completed (possibly after a number of unwinding cycles), when all remaining participants can settle.

We assume in a day there are N intraday batches. The length of each settlement interval is $T_n = T/N$. Real time settlement is recovered in the limit of N large.

We assume here that securities are exchanged with a probability λ per time unit. A high value of λ indicates a very liquid market. The number of trades in an interval (t_1, t_2) is given by m_{t_1,t_2}. On average $\bar{m}(t_1, t_2) = \lambda(t_2 - t_1)$.

We also assume that, with a probability μ, each transaction could experience a random delay τ to settle. We take τ to be uniformly distributed in the interval $(0, \tau_M)$ where τ_M is the maximum delay expected given the specific market available IT infrastructures.[2] A default occurs at time t if $t + \tau > T_n$. For each share γ we record the first time t^*_γ a trader experiences a delay sufficient to generate settlement failure.

If trade experience a delay under gross arrangements, all subsequent trades of the same share will fail to settle. The size of the settlement failure over a settlement cycle is given by $d = \sum_{\gamma=1}^{S} m_{t^*_\gamma, T_n}$. The average default ratio r_d is calculated dividing d by the total number of transactions over the same period, and then averaging over 1000 simulations.

The netting algorithm works as follow:

1. We store all the trades of participants in a common settlement system with each other in a matrix J. The element $J_{i,j}$ gives the number of stocks trader i has sold to trader j. The overall number of sales of participant i is given by $s_i = \sum_{j=1}^{N} J_{i,j}$ and the overall number of purchases is given by $p_i = -\sum_{j=1}^{N} J_{j,i}$.

2. A default occur at time t if $t + \tau > T_n$ as in the gross system. We record the number of trades that participant i fails to settle with participant j in a matrix $F_{i,j}$. The total number of failure of participant i is given by $F_i = \sum_{j=1}^{N} F_{i,j}$.

3. At the settlement date we calculate the net positions n_i of each participants by computing

$$n_i = s_i - p_i.$$

   If n_i is positive trader i has to transfer n_i stock to settle. If n_i is negative trader i has to receive n_i stocks.

[2]This implies that default may only happen for trades that occur sufficiently close to the settlement date. We have tried also normally distributed defaults but our results are qualitatively similar.

4. If a participant net position is positive, he will be able to settle only if

$$s_i - F_i \geq n_i.$$

If the above condition is satisfied by all participant the settlement process can be finalised successfully. All participant for whom this condition is not satisfied fail to settle.

5. We calculate the failure condition in parallel for all participants. If one, or more, participants cannot settle their net positions they are removed from the system, all their trades are cancelled, and the positions of all other participants are recalculated. For example, assume participant k defaults. We first set, for all j, $F_{j,k} = J_{k,j}$ (traders will not be able to deliver the shares they have not received from k) and then we reset $J_{k,j} = J_{j,k} = 0$. We finally recalculate the positions of all remaining participants. The steps 3-5 are repeated iteratively until all participants left in the system can settle (or until all participants have defaulted).

We study the dependence of the failure rate on the number N of intraday batches. 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 rate of failures generated by the random delays.

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 λ (which is a proxy for liquidity), μ and τ_M (which measures the reliability of IT infrastructures, or extend of human mistakes), the number of shares S of the same security traded (which represents the trading volume) and the distribution of shares among market participant (which is a measure of heterogeneity in the market).

III. SIMULATION AND RESULTS

We assume 1 minute to be the shortest time necessary for executing a transaction and we take it as the unit of time. A typical trading day T lasts for 512 minutes (about 8.5 hours). The values we considered initially for the various parameters are $\mu = 0.01, 0.1, 1$, $\lambda = 0.01, 0.1, 1$, $\tau_M = 512, 51.2, 5.12$, $N_a = 100$ and $S = 1000$.

In figure 1 we plot the initial default rate, the total default rate and the ratio between the two for gross systems as a function of N and different levels of λ. In this case $\tau_M = 51.2$, $\mu = 0.1$, $N_a = 1000$ and $S = 100$. In this set of simulations τ_M is chosen to be one tenth of the length of trading day. When increasing N, T_n becomes smaller than τ_M and delays become more likely to last longer than the settlement batch. This explains the initial rise of the default rate with N (with a peak at $T_n \sim \tau_M$). By increasing N further, the probability that defaults last longer than settlement remains large. Nonetheless, increasing N has the positive effect of reducing the number of transactions before settlement (at $N = 512$ only one transaction can possibly be executed) 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 $\mu = 0.1$. By increasing λ, the number of exchanges in between two settlement dates increases, and consequently increases the number of participants which may be affected by a default and systemic effects. This explain the increase of the default rate r_d, with λ, while the initial default rate remains constant (figure 1a).

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 and their distribution play a crucial role. 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 process may also increases.

We compare different initial distributions of shares and assign shares at the beginning according to the rule:

- we pick up an agent i at random
- we assign the agent a number of stock $S(i) = \sigma \epsilon S$ where $\epsilon \sim U(0, 1)$.
- we calculate the number of remaining stocks S_1.
- if there are stocks left to assign we pick up another agent j at random and assign the agent a number of stock accordingly to the rule $S(j) = \min(S_1, \sigma \epsilon S)$.
- we continue the procedure until there are stocks left.

By increasing σ we move from an homogeneous situation with shares equally distributed among many agents to an heterogeneous distribution with shares concentrated in the hands of very few agents.

In the netting system, the trade off between stabilising and destabilising effects when increasing N is still visible. Figure 2a shows that the volume of transactions is considerably lower under netting arrangements. Furthermore in figure 2c, we show that the number of banks initially failing after netting decreases substantially compared to gross architectures, particularly at low N.

In figure 3 and 4 we compare the default rate in netting architectures under different scenarios for λ, S and σ.

We observe that by increasing the number of stocks the system becomes more stable in the homogeneous case (figure 3) and more and more unstable as heterogeneity increases (figure 4). Both the homogeneous and heterogeneous cases are always more stable than the gross system al low N. As heterogeneity increases the net system becomes more and more unstable than the gross system as N increases because of systemic effects.

In the following we study systemic effects in more detail, focusing on the homogeneous case and compare (figure 5,6) the distribution of defaults in net and gross system for $\lambda = 0.01$, $\sigma = 0.01$ and $S = 1000$. In figure 6 we plot the default sizes for each of the 1000 simulations of the experiment. The figure shows that in the net system, when default events start to appear (at $N \geq 8$) they can generate much higher disruption than in the corresponding gross case even if the average default rate is comparable.

In figure 6 we plot the cumulative distribution of defaults size for the gross and net systems for the parameters above and $N = 32$. The average number of transactions (and of possible defaults) in this case is 160. The figure clearly shows that, while the initial distribution of defaults in netting systems is always below the corresponding distribution in gross system, the final distribution of defaults becomes fatter tailed in netting systems. This is a clear evidence of systemic effects taking place. Furthermore the decay of the cumulative distribution function in the netting system seems to be hyperbolic. [3]. This could indicate that the net system goes through a critical phase

[3]The decay only extends over a decade, given the small value of the maximum default size for this choice of the parameters.)

at which no typical scale can be defined and defaults of all size (up to the maximum possible one) are possible.

IV. CONCLUSIONS

In this paper we examined some issues that arise with respect to the performance of different securities settlement architectures under the assumption of exogenous random delays in settlement. 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, the frequency and length of delays and heterogeneity in the initial distribution of shares.

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.

On average, netting systems seem to be more stable (at least in homogeneous conditions) but rare events may lead to contagious defaults that may affect the all system. Furthermore netting system are very sensitive to the number and the distribution of traded shares. In homogeneous conditions (i.e. shares initially equally distributed among participants), as the number of traded stocks increases netting systems are more stable. Under heterogeneous conditions (i.e. participants have different size as measured by the number of shares they trade) increasing the number of stocks traded generates a higher rate of defaults.

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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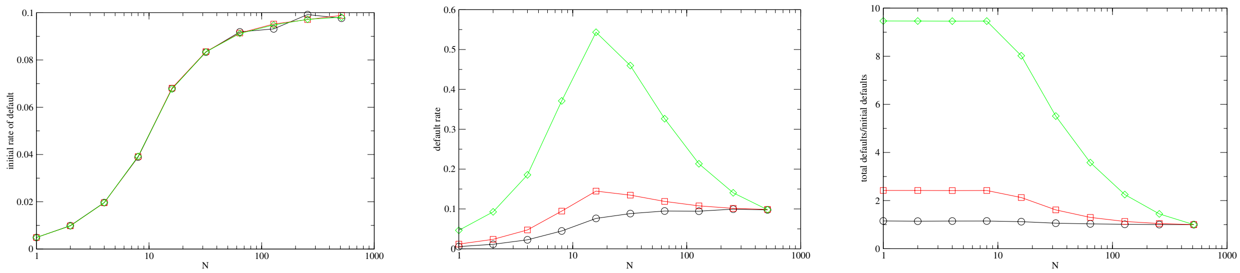

FIG. 1. Initial default rate (left) total default rate (center) and ratio of total defaults over initial defaults in gross systems as a function of N at various levels of λ: 0.01 (black, circles), 0.1 (red, squares), 1 (green, diamonds). In each case $\tau_M = 51.2$, $\mu = 0.1$, $N_a = 100$ and $S = 1000$.

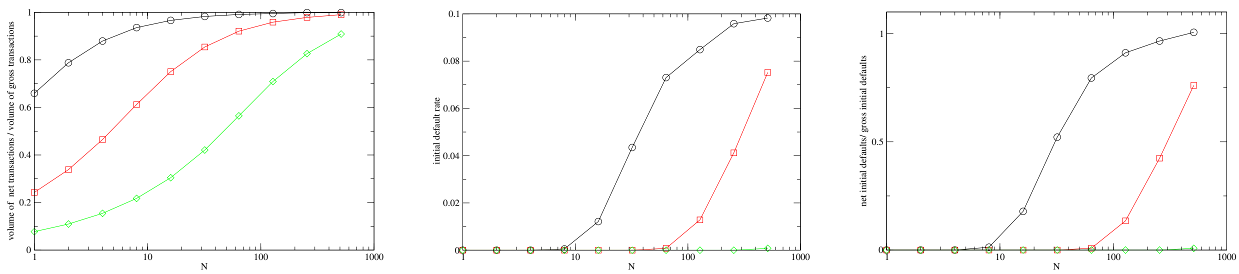

FIG. 2. Ratio between total volume of net transaction and total volume of gross transactions (left) net initial default rate (center) and ratio between initial number of defaults in net and initial number of defaults in gross systems as a function of N at various levels of λ: 0.01 (black, circles), 0.1 (red, squares), 1 (green, diamonds). In each case $\tau_M = 51.2$, $\mu = 0.1$, $N_a = 100$ and $S = 1000$.

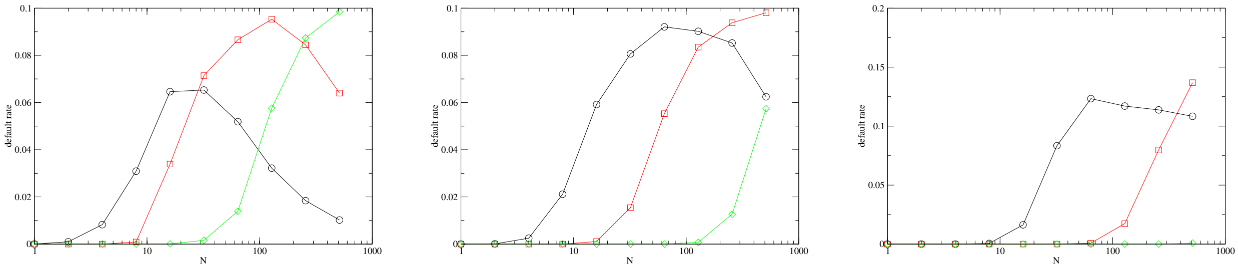

FIG. 3. Default rate in net systems as a function of N at various levels of λ: 0.01 (black, circles), 0.1 (red, squares), 1 (green, diamonds) at different level of S: $S = 10$ (left), $S = 100$ (center), $S = 1000$ (right). In each case $\tau_M = 51.2$, $\mu = 0.1$, $N_a = 100$.

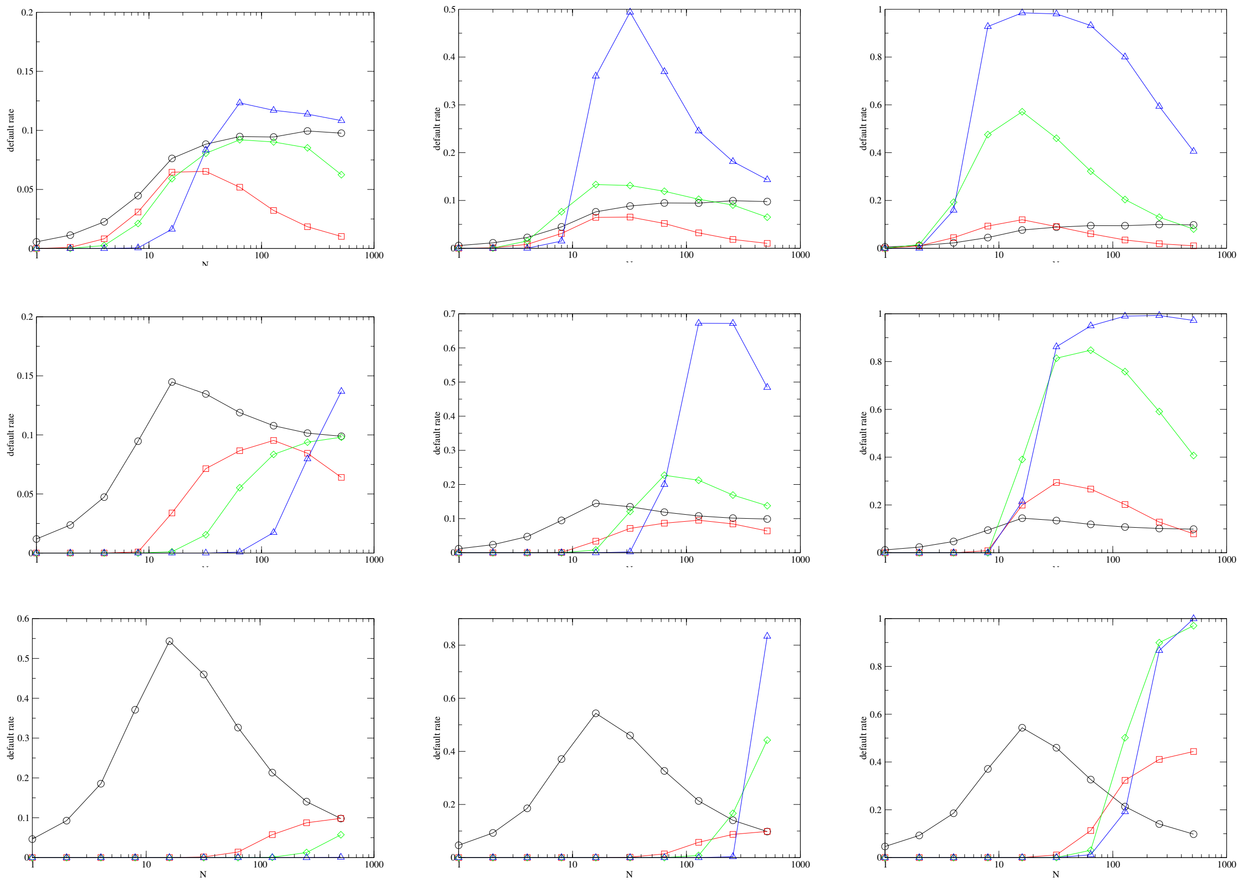

FIG. 4. Default rate in netting systems at different level of λ, S and σ. λ increases from top to bottom: $\lambda = 0.01, 0.1, 1.$ and σ increases from left to right $\sigma = 0.01, 0.1, 1$. Each plot shows three curves at different level of $S = 10$ (red, squares), $S = 100$ (green, diamonds), $S = 1000$ (blue, triangles). The black line (circles) correspond the the gross case. In all cases $\tau_M = 51.2$, $\mu = 0.1$, $N_a = 100$.

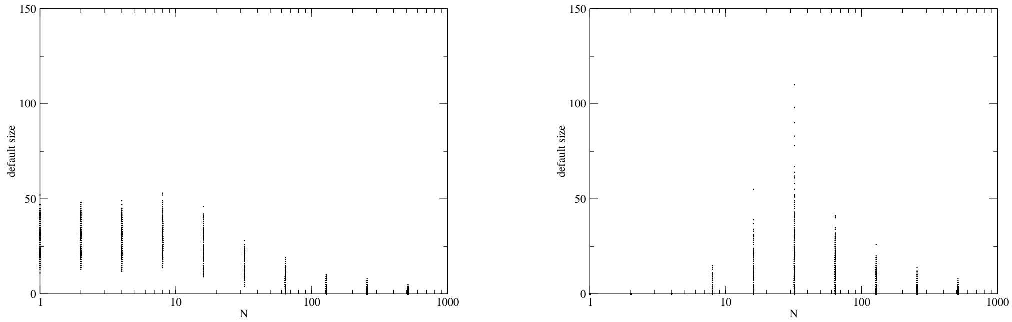

FIG. 5. Default size in gross (left) and net system (right) as a function of N with $\sigma = 0.01$ $\tau_M = 51.2$, $\mu = 0.1$, $\lambda = 0.01$, $N_a = 100$, $S = 1000$

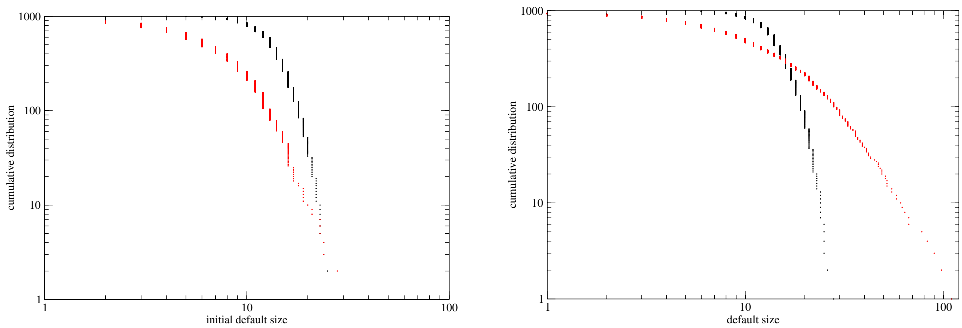

FIG. 6. Cumulative distribution of initial default size (left) and total default size (right) in gross (black) and net systems (red) with τ_M 51.2, $\lambda = 0.01$, $\mu = 0.1$, $\sigma = 0.01$, $N_a = 100$, $S = 1000$ and $N = 32$. For the gross system (black) the average size of default is 14.145 and for the net system (red) the average size of default is 13.30. The average number of transaction before settlement is 160.

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