An analysis of systemic risk in alternative securities settlement architectures

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Conference on Clearing and Settlement of Financial Markets
CASS Business School, June 16-18, 2005.

Clearing and settlement architectures

Securities settlement systems (SSSs) are institutional arrangements for confirmation, clearance and settlement of securities trades and safekeeping of securities.

- **Confirmation:** 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.
- **Clearance:** the computation of the obligations of the counterparties to make deliveries or to make payments on the settlement date.
- **Settlement:** final transfer of securities from seller to buyer and payments from buyer to seller.

Risks

- participants will not settle credit risk
- delay in settlement liquidity risk
- securities are delivered but payment not received and vice-versa principal risk
- mistakes and deficiencies in information and controls operational risk
- deficiencies in the safekeeping of securities by third parties custody risk
- failures of the legal system that supports the rules and procedures of the settlement system legal risk
- failure of one participant renders other participants unable to meet their obligations systemic risk .

Settlement arrangements

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, in intraday batches, or at the end of the day.

Real time gross settlements systems (RTGS):

- settlement is done continuosly by transfers of central bank funds from the account of the buyer to the account of the seller and securities from the security account of the seller to the one of the buyer.
- reduce systemic risk
- increase liquidity risk (on payment side).

  Participants need to hold for a given volume of transactions, on average more reserves and gridlocks may also occur: participants may have incentives to waiting to receive payments before sending them (behavioural modelling).
- increase operational risk.

Netting arrangements

- each party only delivers its net sale, or receives its net purchase, resulting in very significant reductions in gross exposure.
- a failure to settle results in an unwind, i.e., the deletion of provisional transfers involving the defaulting participant and the recalculation of the settlement obligations of the non-defaulting participants.
- unwinding imposes liquidity pressures and replacement costs on the non-defaulting participants that had delivered securities to, or received securities from, the defaulting participant.
- One or more of the initially non-defaulting participants may be unable to cover the shortfalls and default in turn: systemic failure.

Operational Risk

In some markets the rate of settlement falls significantly short of 100%, because of human errors or operational problems.

Errors or delays in transactions processing (particularly during confirmation) may result from

- incomplete or inaccurate transmission of information or documentation
- system deficiencies or interruptions.

Aim of the paper

Study the effects of increasing the number of intraday settlement batches, when exogenous random delays affect the confirmation of trade.

For a given distribution of lengths of delays, when decreasing length of settlement cycles

- likelihood that delays will lead to settlement failure increases : destabilising effect
- number of parties affected by the default is reduced: stabilising effect

An interesting dynamics is generated by the interplay between these two effects.

The model

- The system consist of N_a participant.
- S shares of the same securities are traded. Trades are for one unit of the security.
- No securities lending markets is in place.
- Securities are exchanged with a probability λ per time unit over a trading day T.
- 1 minute is the unit of time, (shortest time necessary for executing a transaction). $T = 512$ minutes (about 8.5 hours).
- Transaction experience, with a probability μ, a random delay τ to settle. $\tau \sim U(0, \tau_M)$.
- Settlement is done in N intraday batches.

The length of each settlement interval is $T_i = T/N$. Real time settlement is recovered in the limit of N large.

Gross algorithm

A default occurs if a delay τ occurs at time t s.t. $t + \tau > T_i$. The first time this happen for each share γ is denoted t^*_γ.

All subsequent trades of that share will fail to settle under gross arrangements.

The number of trades in an interval (t_1, t_2) is given by m_{t_1,t_2}.

The size of the settlement failure over a settlement cycle is given by $d = \sum_{\gamma=1}^{S} m_{t^*_\gamma, T_i}$. The default ratio r_d is calculated dividing d by the total number of transactions over the same cycle. We then average this quantity over 1000 simulations.

Netting algorithm

1. Trades of participants stored 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 each participant 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 $t + \tau > T_i$ as in the gross system. Number of trades that each participant i fails to settle with participant j stored in a matrix $F_{i,j}$. Total number of failure of participant i is given by $F_i = \sum_{i=1}^{N} F_{i,j}$.

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.

4. If a participant net position is positive at the settlement time 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.

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.

6. We average results over 1000 simulations.

Simulation and results: Gross Settlement

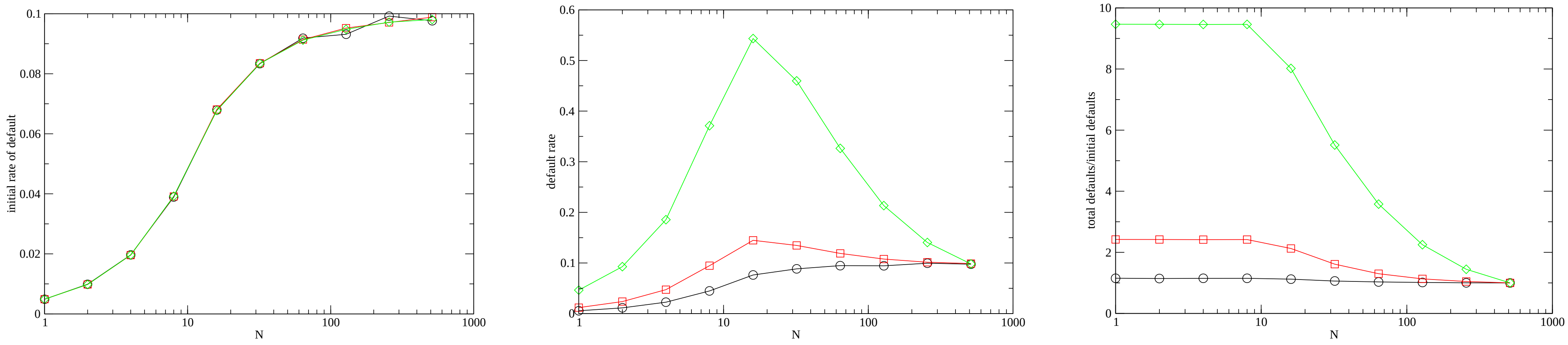

Figure 1: Initial default rate (left) total default rate (center) and ratio of total defaults over initial defaults in gross systems as a function of N at various levels of λ: 0.01 (black, circles), 0.1 (red, squares), 1 (green, diamonds). In each case $\tau_M = 51.2$, $\mu = 0.1$, $N_a = 100$ and $S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

When increasing N, T_i 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. 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).

Simulation and results: Net Settlement

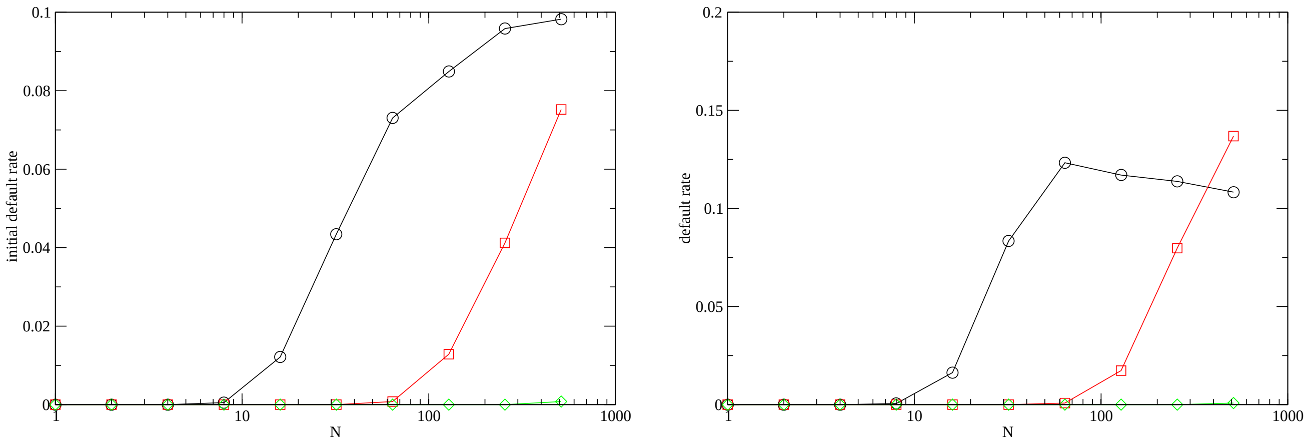

Figure 2: Initial default rate (left) and total default rate (right) as a function of N at various levels of λ: 0.01 (black, circles), 0.1 (red, squares), 1 (green, diamonds). In each case $\tau_M = 51.2$, $\mu = 0.1$, $N_a = 100$ and $S = 1000$.

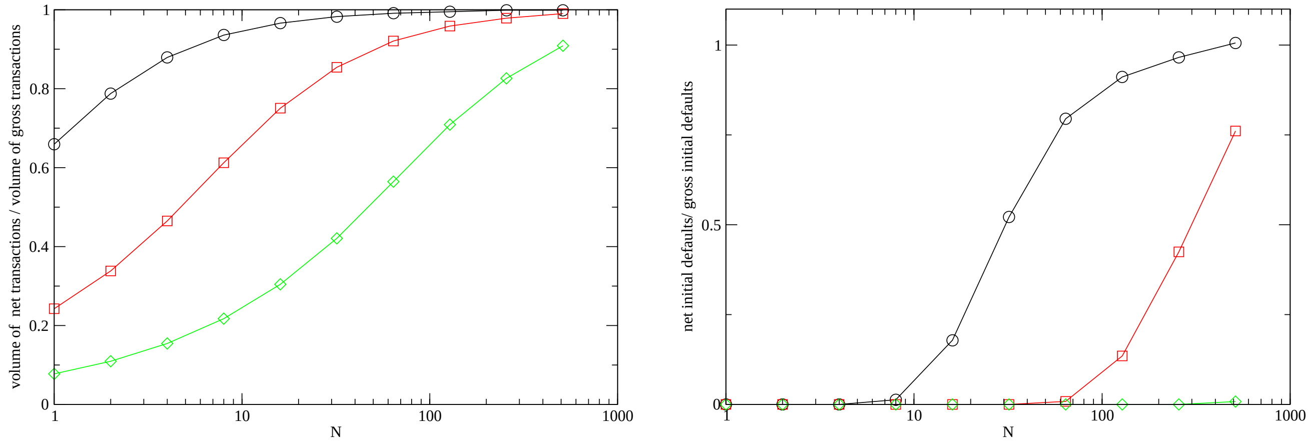

Figure 3: Ratio between total volume of net transaction to be settled and total volume of gross transactions to be settled (left) and ratio between initial number of defaults in net and initial number of defaults in gross systems (right) as a function of N at various levels of λ: 0.01 (black, circles), 0.1 (red, squares), 1 (green, diamonds). In each case $\tau_M = 51.2$, $\mu = 0.1$, $N_a = 100$ and $S = 1000$

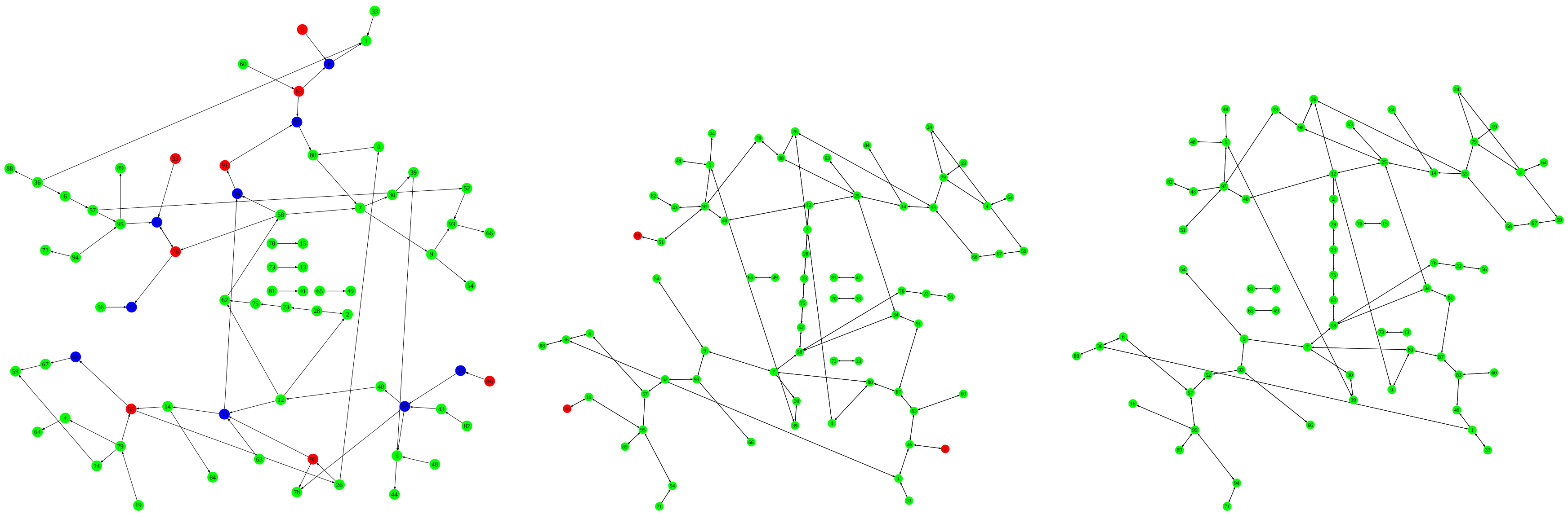

Figure 4: Gross (left) and Net system (center and right). In each case $N = 64$, $\tau_M = 51.2$, $\mu = 0.1$, $S = 100$.

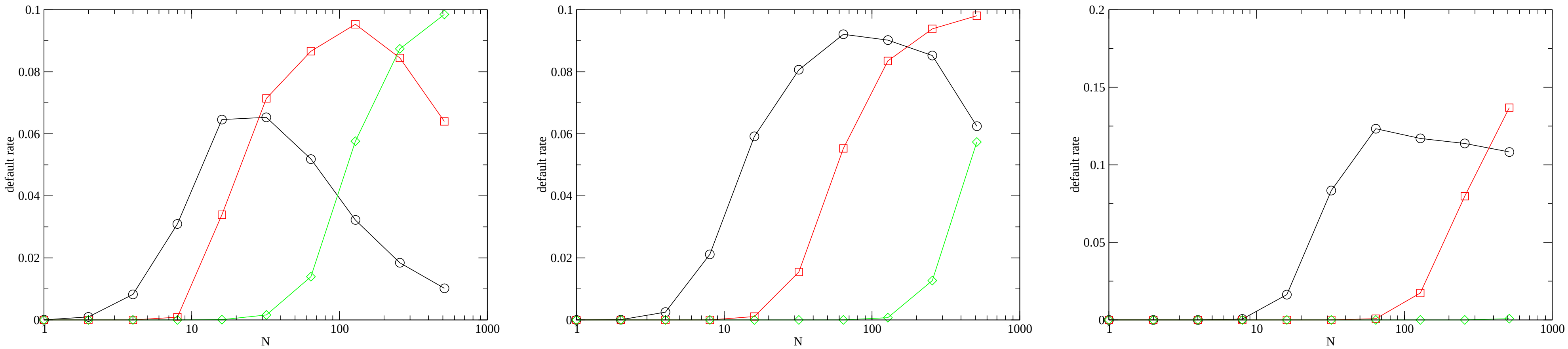

Figure 5: Default rate in net systems as a function of N at various levels of λ: 0.01 (black, circles), 0.1 (red, squares), 1 (green, diamonds) at different level of S: $S = 10$ (left), $S = 100$ (center), $S = 1000$ (right). In each case $\tau_M = 51.2$, $\mu = 0.1$, $N_a = 100$.

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 untill 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.

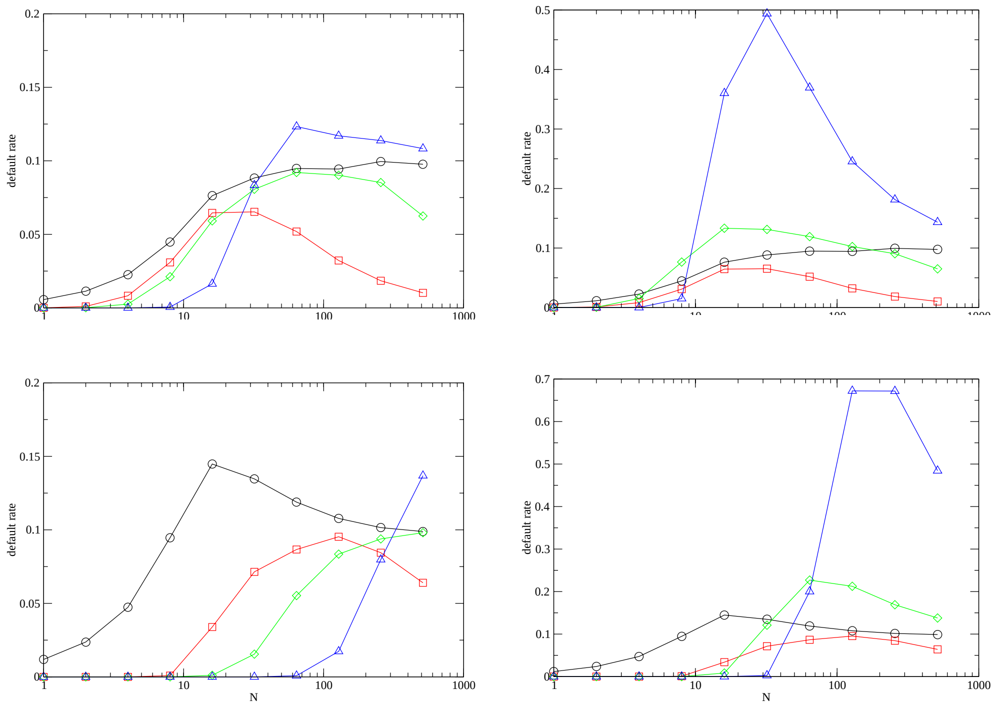

Figure 6: Default rate in netting systems at different level of λ, S and σ. λ increases from top to bottom: $\lambda = 0.01, 0.1$ and σ increases from left to right $\sigma = 0.01, 0.1$. Each plot shows three curves at different level of $S = 10$ (red, square), $S = 100$ (green, triangle), $S = 1000$ (blue, diamond). The black line correspond the the gross case. In all cases $\tau_M = 51.2$, $\mu = 0.1$, $N_a = 100$.

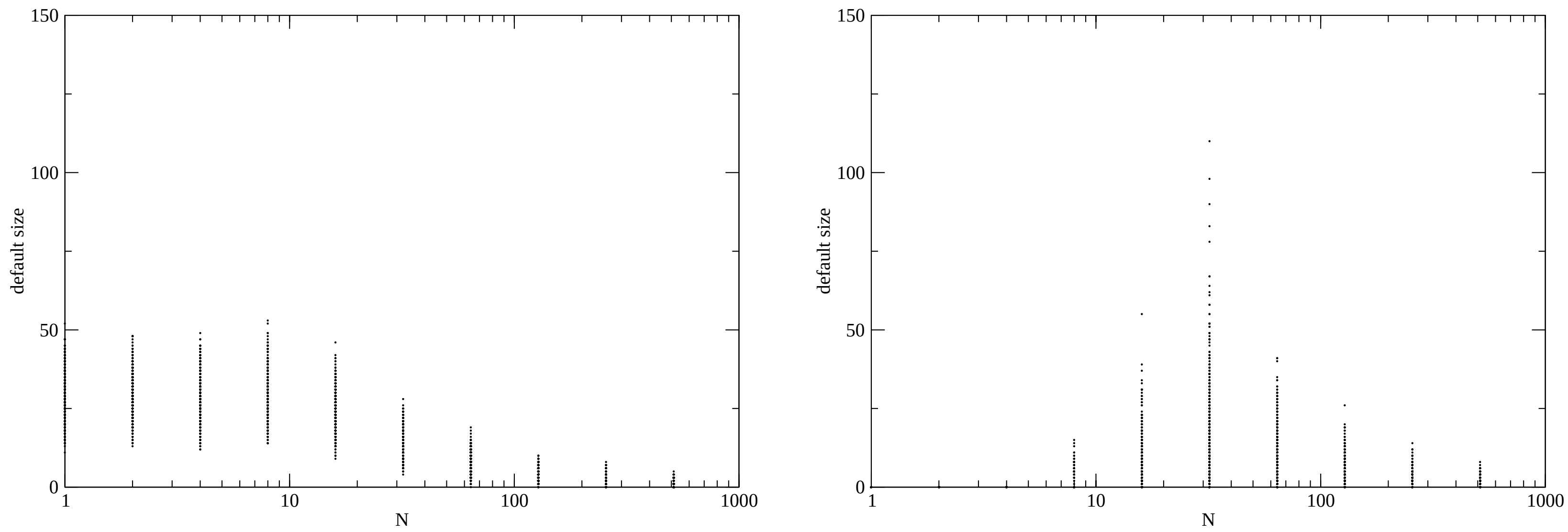

Figure 7: Default size for all 1000 simulations in gross (left) and net system (right) as a function of N with $\sigma = 0.01$ $\tau_M = 51.2$, $\mu = 0.1$, $\lambda = 0.01$, $N_a = 100$, $S = 1000$. When defaults event start to appear in net system they can generate much larger disruption even if the average rate is comparable.

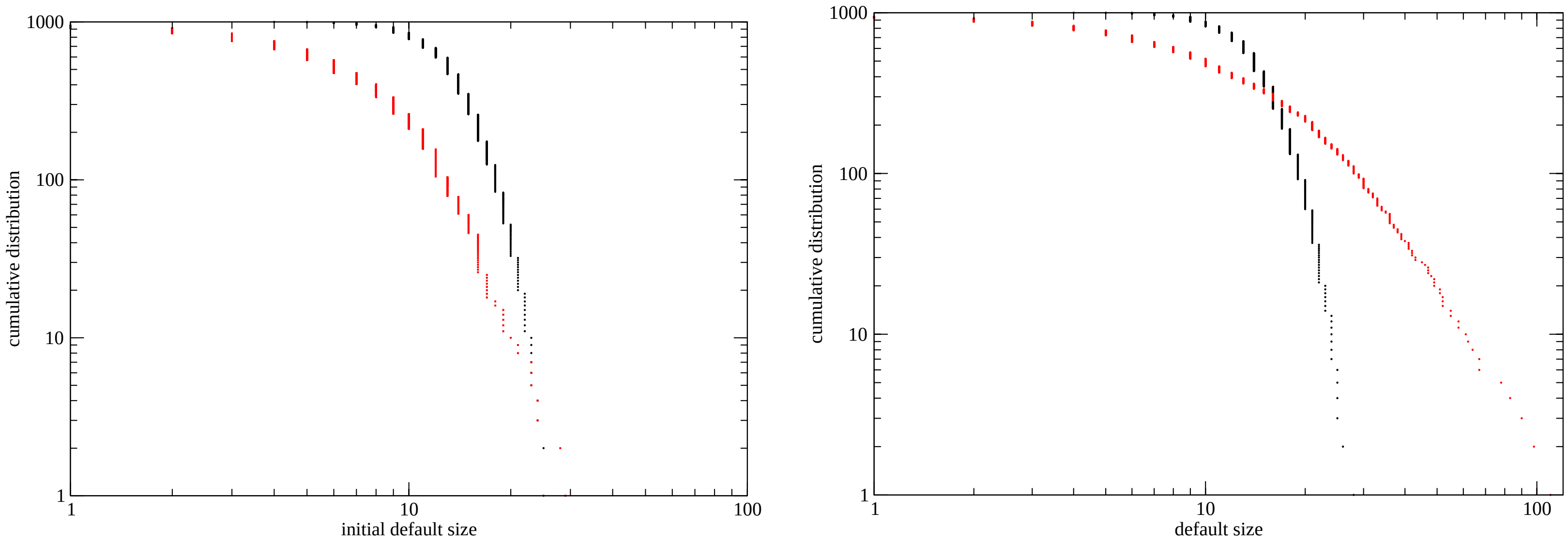

Figure 8: Cumulative distribution of initial default size (left) and total default size (right) in gross (black) and net systems (red) with τ_M 51.2, $\lambda = 0.01$, $\mu = 0.1$, $\sigma = 0.01$, $N_a = 100$, $S = 1000$ and $N = 32$. For the gross system (black) the average size of default is 14.145 and for the net system (red) the average size of default is 13.30. The average number of transaction before settlement is 160.

Conclusions

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.

Main results

- 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.
- On average netting systems seem to be more stable (at least in homogeneus consitions) but rare events may lead to defaults that spread over the all system.
- Netting system are very sensitive to the number and the distribution of traded shares.