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Анализа Платног система Народне банке Србије – симулациони приступ

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Анализа платног система Народне банке Србије – симулациони приступ

Александар Димитријевић, Милан Николић, Миро Вукоје

Апстракт: Примењујући симулациони приступ, овај рад испитује утицај оперативних проблема два најзначајнија учесника на систем у целини као и на остале учеснике Платног система Народне банке Србије. Ово је први рад који испитује последице испољавања оперативних проблема учесника платног система Народне банке Србије. Посматрана су два сценарија. У првом сценарију се најзначајнији учесник сусреће са оперативним проблемима, док се у другом симулациони приступ базира на оперативним проблемима два најзначајнија учесника. Рестриктивно дизајнирани сценарији показују да оперативни проблеми назначајнијих учесника умногоме утичу на способност других учесника да изврше своја плаћања. Као једна од могућих реакција учесника на ситуацију у којој се појављују горе наведени проблеми, примењено је стоп-сендинг правило и испитано је како оно може ублажити неповољне утицаје тих проблема. Примена стоп-сендинг правила може значајно утицати на смањење неповољних ефеката оперативних проблема. Ипак, треба имати на уму да примена овог правила смањује број трансакција у систему, као и промет. На крају, анализом је утврђена вероватноћа појављивања бар једне непоравнате трансакције за сваки од рачуна.

Кључне речи: симулације, платни систем, оперативни ризик, стоп-сендинг правило
[JEL Code]: C15, G28

Analysis of National Bank of Serbia’s Payment System – simulation-based approach

Aleksandar Dimitrijevic, Milan Nikolic, Miro Vukoje

Abstract: Using the simulation-based approach, this paper aims to investigate the influence of operational problems which occur at two most important prticipants on the system as a whole as well as on the other participants of the payment system of the National Bank of Serbia. To the best of our knowledge, this is the first paper which examines, by use of simulations, the consequences of operational problems ocurring at the participants of the payment system of the National Bank of Serbia. Two scenarios were examined. In the first scenario, the most important participant is facing operational problems, while in the second scenario operational problems at two most important participants were supposed. Restrictively designed scenarios show that operational problems at the most important participants can seriously affect other participants' ability to settle their payments. In addition, in order to capture possible behavioral reactions by other participants, we investigate whether the application of the stop-sending rule can reduce the magnitude of contagion. We find that the application of this rule can substantially reduce the effects of the operational problems. However, the rule also reduces the number of transactions in the system as well as the total turnover. At the end, we determined the probabilty of defaults for each account used in our analysis.

Key words: simulations, payment system, operational risk, stop-sending rule
[JEL Code]: C15, G28

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Contents

1. Introduction

This paper presents the simulation-based analysis of the Payment System of the National Bank of Serbia. The paper contributes to the analysis from different perspectives. We investigated how operational problems which occur at some participants can affect others to settle their payments. As a reaction of other participants to this problem, we examined the application of the stop-sending rule on the system as a whole. Lastly, we determined the probability of defaults for each account.

Our analysis is based on operational problems that occur at some participants of the Payment System of the National Bank of Serbia. We used historical transaction data which are held by the Operater of the Payment Systems Department.[1] The data cover the period from 01.12.2009 to 31.10.2011, which is sufficient for analysis of this type. We examined two scenarios:

- In the first scenario, the most important partcipant is unable to settle its payments at the very beginning of a working day
- The second scenario examines the consequences of operational problems at the two most important participants

These scenarios are simulated rather than actual, since they appeared very rarely in the past period. The significance of participants was determined according to data for individual node risk for the examined period. For the purpose of payments' simulations, we used BoF-PSS2 - specialized software implemented by Bank of Finland. We executed 1948 simulations covering two scenarios for the period used in our analysis. Basic functionalities of the Payment System were implemented as closely as possible.

The paper is structured in the following manner: in section 2 we outline earlier findings on this topic, while section 3 gives technical description of the payment system of the National Bank of Serbia. Section 4 explains the methodology of simulation execution and the way important participants were determined. Basic indicators resulting from our analysis are presented in section 5. Section 6 presents results of simulated events for the one and two most important participants, i.e. the main results of our analysis. Section 7 provides further guidelines for research on this topic.

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[1] Unlike other papers which deal with financial stability issues, in this paper we did not use any individual participants' data, e.g. balance sheets, income statements, etc.

2. Earlier findings

There are several papers which provide quantitative assessment of how operational incidents affect settlement in RTGS payment systems. A lot of studies concerning payment systems and financial stability issues were obtained using BoF-PSS2. Some of these used actual historical data (which is the case with this paper), while the others employed simulated (fictive) data.

Bedford, Milliard and Young (2004) were among the first who applied simulation techniques for examining systemic risk as a consequence of operational risk of one of the participants. They concluded that for CHAPS Sterling (UK Payment System) there is very low chance of an appearance of systemic problems given the high liquidity of banks in that payment system. Significant systemic effects were noticed in case of operational problems of three most important participants while the liquidity in the system was below its theoretical value. Many other papers confirmed relatively small impact of operational problems of some participants on systemic risk (Bech, Soramaki (2005) for US Fedwire, McVanel (2005) and Ball, Engert (2007) for Canada's large-value payment system - LVTS). However, some papers do indicate possibility of essential systemic effects. Such conclusions were obtained by Ledrut (2007) for Dutch payment system, Mazars and Woefl (2005) for French payment system and Hellquist and Snellman (2007) for Finish equities settlement sytem.

Authors who investigated the effects of using the stop-sending rule and at the same time inspired this analysis were Schmitz et al (2006) for ARTIS (Austrian Large Value Payment System) and Lubloy and Tanai (2008) for VIBER (Hungarian Real Time Gross Settlement System).

Schmitz et al (2006) were examining the application of the rule in case when the national TARGET operator in charge of the most active transfer account was affected by an operational incident. Analysis showed that the application of the stop-sending rule can substantially decrease unfavorable effects of operational problems of one of the participants. Results show that value of unsettled transactions with the stop-sending rule applied, compared to the case when it was not implemented, increased from 780 millions to 1,3 billion euros. However, the total turnover was also higher in the situation when the stop-sending rule was not implemented. This paper also examines the influence of this rule on the liquidity in the system and authors concluded that liquidity sink effect increased from 1,2% (when the rule was implemented) to 26,9% (when it was not). On the other side, Lubloy and Tanai (2008) observed the usefulness of this rule but only in case when particular participant could not settle its payments for a limited period during the working hours of the operater. This analysis showed that the resilience of the VIBER depends heavily on liquidity on participants' accounts as well as on the total turnover in the system.

3. Payment System of the National Bank of Serbia

National Bank of Serbia is authorized to manage undisturbed and safe functioning of the payment system, as well as to control the system and to improve its performance[2]. Payment Systems Department is organizational unit in charge of the above-mentioned functions. This department is the operator of three payment systems:

- Real time gross settlement system – RTGS
- Interbank clearing in dinars
- Interbank and international clearing in foreign currency

RTGS payment system is used for the settlement on a gross basis and is mostly used by participants in processing their payments. Interbank clearing in dinars allows for processing payments on a net basis. Net positions are settled in three settlement cycles. This system carries higher settlement risk than RTGS since the operational problems of one participant can affect the others to settle their own payments. All payments in dinars are processed using these two systems. Interbank and international clearing in foreign currency is used for the settlement of payments denominated in euros on a net basis and was not the subject of our analysis.

Payment system in dinars, RTGS and interbank clearing form a unique hybrid system. These systems are logically independent, but operate on the same systemic platform. Simulations were executed using the transaction data from the RTGS and we used only net positions from the clearing which are settled within RTGS. Therefore, we shall concentrate on these systems in the sequel.

3.1 RTGS

This mechanism allows for the settlement of transactions in real time and gross amount in dinars i.e. automatic settlement of transactions provided there is enough liquidity amount on the participant's account. The mechanism is primarily designed for the payments of higher value (above 250.000 RSD). However, it is also used for time-critical payments of any amount. Working hours of the system are from 09:00 to 18:00.

3.2 Interbank clearing in dinars

This system allows for net calculation of higher number of transactions carrying smaller amount. Net positions are settled within RTGS system. Before every settlement occasion, participants reserve funds for that settlement and the settlement

[2] See Law on the National Bank of Serbia

takes place up to the reserved amount, which prevents from recalculation of the net positions. There are three settlement cycles within this system.

3.3 Queue

In case there are not sufficient funds on participant's account, its payment is being placed into the queue. The queue is organized according to FIFO (first-in-first-out) method where priority of the payments first takes into account and submission time after that. In case some participant does not have enough funds for the settlement of the payments not even at the end of the day, these payments are going to be cancelled.

In practice, use of the queue is very rare.

3.4 Priorities

Every payment in RTGS system gets a priority in the form of a number in range from 11 to 99. Given that, the smaller the number the higher the priority. If the priority in range from 50 to 99 is assigned to some payment and it is not settled whatever the reason, this payment is not going to be placed into the queue, but will be cancelled. On the other side, the simulator supports only ten priorities (from 0 to 9) and does not support above-mentioned facility for the priorities between 50 and 99. Also, it puts priorities in ascending order which means that the higher number defines the higher priority which is the opposite from the order of priorities in our system. Therefore, in order to use priorities' facility in the simulator we modified them in the following manner:

$$PRSIM = 5 - div(PRRTGS, 10) \quad if \quad 11 \leq PRRTGS < 50$$
$$PRSIM = 0 \quad otherwise$$

where *PRSIM* is the priority we used in the simulator, *PRRTGS* is the priority from our RTGS system and *div* is the function which gives the quotient when *PRRTGS* is divided by 10.

Analysis showed that none of the participants uses every priority in the system. In fact, they use very few which are characteristic for every participant. However, we did not find any rule participants obey while using these priorities. Also, we confirmed that there are many priorities with the same function which is not necessary. It is sufficient to keep lower number of priorities.

3.5 Transactions and participants

In this paper we observe all participants of the hybrid system which contains RTGS system and interbank clearing in dinars. These participants are: commercial banks (33), Ministry of Finance, organizational departments of the National Bank of

Serbia (Sector for Monetary Operations, Accounting and Finance department, Cash Operations department) and clearing houses – National Center for Payment Cards (in charge of payment cards' clearing), Association of Serbian Banks (in charge of clearing of checks) and Central Securities Depository. The total number of accounts observed in our analysis is 65 (one participant can have multiple accounts). It should be noted that the value and the number of unsettled transactions were regarded with respect to accounts rather than participants. Because of the technical features of the payment system of the National Bank of Serbia, some participants were allowed for infinite overdraft, which in turn implies that these participants could not have unsettled transactions.

Transaction data which were used in our analysis cover the period from 01.12.2009. to 31.10.2011. The total number of simulated transactions is 69.623.506. Although software allows for possibility to differentiate between intraday loans which National Bank of Serbia provides commercial banks with based on collateral, they were regarded as common transactions. Also, we took into account transactions from external clearing houses like National Center for Payment Cards (in charge of clearing of payment cards), Association of Serbian Banks (in charge of clearing of checks) and Central Securities Depository. Given that, while implementing the simulations of incidents, we could not exclude transaction data in situations where these clearing houses appear as senders nor receivers. These transaction data were not modified. If this was not the case, accounts which belong to this clearing houses would have had unsettled transactions as a consequence of modification of the transaction data through the input data (i.e. deletion of the transaction data) and this would affect the results of our analysis. The same approach was used while implementing the stop-sending rule.

4. Methodology of simulations' execution and determination of participants' significance

We examined two scenarios. The first scenario relates to operational problem which occurs at the most important participant (we explain further how we determined the importance). In the second scenario, operational problems of the two most important participants were supposed at the same time. Inability of participant to process its payments was hypothesized such that operational problem occurs at the very beginning of a working day and that participant is unable to process its payments during the whole day. However, this incident is simulated problem actually, since such operational problems occurred very rarely in the payment system of the National Bank of Serbia.

In both scenarios we examined the next two cases: case when the stop-sending rule was not applied and case when it was. In each case we were looking at five indicators. These indicators are: number of unsettled transactions, value of unsettled transactions, number of accounts with unsettled transactions, lower bound of liquidity and liquidity usage indicator. In this way we can fortify whether there exist and what are the benefits of the application of the stop-sending rule i.e. compare how these indicators were changing from case to case.

Stop-sending rule implies that, after an appearance of an operational problem, other participants are notified so as not to process payments to participant who is facing operational problems. We shall suppose that one hour is sufficient to carry out that procedure[3], so as from 10:00 until the end of an operator's working day, other participants will not send payments to the affected participant.

The exclusion of participants was implemented through deletion of their transaction data from the input data. Payments of that participant were not executed for the whole working day. When applying the stop-sending rule, we deleted transaction data in cases where affected participant appears as a sender or a receiver. In this way, the number of settled transactions and total turnover decreased even more in comparison with real situation in the system. To clarify the methodology, we shall repeat that transaction data which were excluded from the input data were not processed in any instance after the exclusion i.e. they were not transferred for the settlement at the end of the day neither in the future period.

Simulations actually show what would happen in the system in case of the first or the second scenario. Every simulation represents one working day, one scenario and one case (whether the stop-sending rule was applied or not). Nevertheless, in this paper we did not implement any other model of participants' behavioral reaction to operational problems of the most important ones other than the stop-sending rule. This means that we supposed two possible reactions from participants not affected by the operational problems of the important ones:

- they will continue to process payments in the same manner as in the case when none of the participants is facing operational problems through already predetermined schedule (there is no change in the submission time of the transactions)
- they will stop sending their payments to the affected participants

It should be mentioned that possibility of the appearance of this restrictively-based scenarios is low, but results of this paper should not be viewed only from this perspective. By applying the simulation techniques, we cannot only realize what would happen in case simulated events actually occur, but also contribute to better understanding of relationships which exist between participants, which participants would be the first to be affected, what is the level of contagion etc. We should also bear in mind that, although these situations are rare, if they occur, that can be

[3] See Schmitz et al (2008)

detrimental for the whole country's financial system. One of such situations is the terrorist attack on the World Trade Center in New York in 2001. The number of transactions after this incident had a sharp decrease and there were also delays in payments' settlement. Participants were facing the liquidity shortage as well. After that day, there were significant participants' behavioral deviations in contrast to days before the attack[4] as well as other anomalies which ocurred in the system.

In order to determine two most important participants which we simulated the incidents for, it is necessary to quantitatively specify this importance. The importance of the participant is defined taking into account both the value and volume of transactions. In the first instance, we calculated the individual node risk for each participant based on both the value and the volume of transactions. Individual node risk represents ratio between volume/value of transactions of the particular participant and the total volume/value of transactions in the system. It is calculated according to the following expression:

$$INR_i = \frac{P_{i,Submitted} + P_{i,Received}}{\sum_{j=1}^{n} P_{j,Submitted} + P_{j,Received}}$$

$P_{i.Submitted}$ – value (volume) of debit transactions for i-th account

$P_{i.Received}$ – value (volume) of credit transactions for i-th account

n - the total number of accounts

After that, we standardized this indicator for each account. The reason for this is equivalent contribution of both value and volume to significance indicator which we used to measure the importance of the participants. The standardization was implemented in the following manner:

$$INRst_i = \frac{INR_i - \frac{1}{n}\sum_{j=1}^{n} INR_j}{\sqrt{\frac{1}{n}\sum_{j=1}^{n}(INR_j - \frac{1}{n}\sum_{s=1}^{n} INR_s)}^2}$$

$INRst_i$ – standardized value for individual node risk

n – total number of accounts

Finally, the significance indicator was determined as:

$$PS_i = \frac{(INRst_i^{va} + INRst_i^{vo})}{2}$$

where index *va* indicates individual node risk based on value of transactions and index *vo* individual node risk based on volume of transactions. We determined the two most important participants (those for which we simulated the incidents) by taking two highest values of this indicator.

[4] For detailed data see McAndrews, Potter (2002)

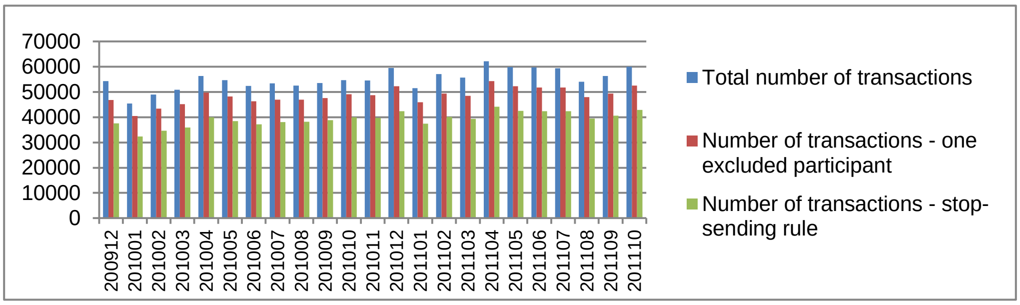
5. Basic indicators

We shall denote following indicators as basic indicators:

- the number of transactions during the specified period,
- the total turnover
- the number of simulations (days) when there was one unsettled transaction at least.

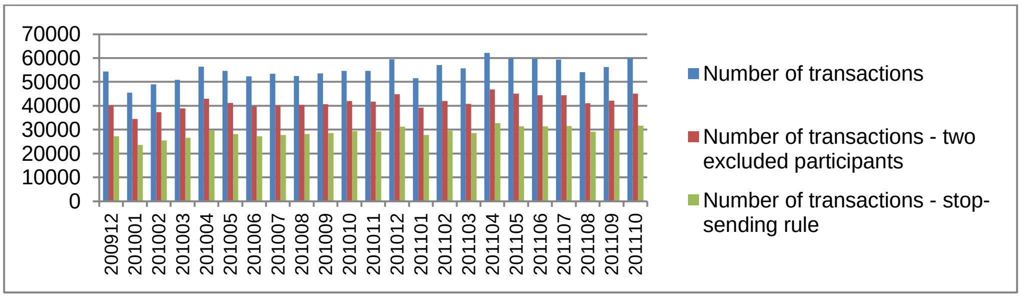
We define unsettled transactions as those which were not processed for the whole operator's working day as a consequence of the lack of liquidity on the sender's account. In that way, we can observe how the application of the stop-sending rule affects the total number of settled transactions, the total turnover and to what extent the number of simulations with at least one unsettled transaction will be reduced.

Chart 1- The number of transactions in period 01.12.2009.-31.10.2011 – first scenario.



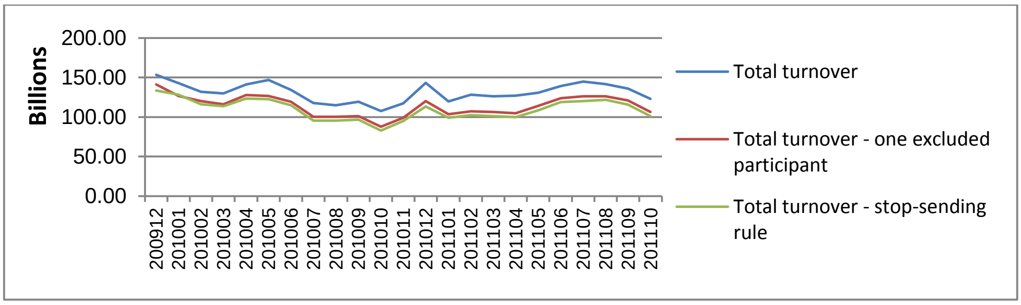
Charts 1 and 2 show the average daily number of transactions per each month during the analyzed period for the first and the second scenario respectively. The number of transactions in the first scenario and with one excluded participant fell down by 11,9%, while in the same scenario and with stop-sending rule it was reduced by 28,5% with respect to the unstressed scenario. The average daily number of transactions during the analysed period was 55.104. With one excluded participant this number fell down to 48.514 transactions, while with stop-sending rule the average number of transactions went down to 39.344 transactions.

Chart 2 – The number of transactions in period 01.12.2009.-31.10.2011 – second scenario



The number of transactions in the second scenario decreased by 24,6% as a consequence of exclusion of the two most important participants. When the stop-sending rule was applied, this number fell down by 47,4%, which is very significant. When we excluded the two most important participants, there was 41.546 transactions on average per day. Stop-sending rule causes this number to drop significantly to 28.952 transactions on average per day. Now we can see what could be potential problem when applying the stop-sending rule. The more participants we exclude, the less the number of settled transactions.

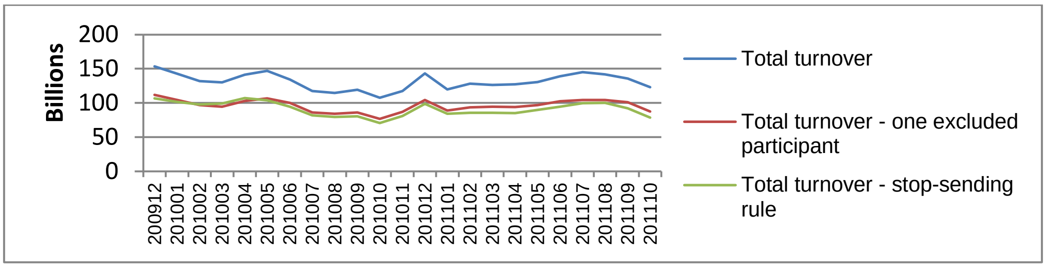
Chart 3 – The average daily turnover in period 01.12.2009-31.10.2011. – first scenario



Charts 3 and 4 show the average daily turnover per month in the specified period for the first and the second scenario. The average daily turnover in the analyzed period accounted for 131.256.226.407 RSD in the unstressed case. With one participant excluded, the value of this indicator dropped by 12,9% to 114.323.767.404 RSD. In case where the stop-sending rule was applied, the value of this indicator fell down to 109.639.146.103 RSD i.e. there was a decrease by 16,4% compared with situation when there was not any operational problems. Although the number of transactions was lowered by 18,9% in case when the stop-sending rule was applied compared to the case when there was one excluded participant, the total turnover did not fall down dramatically and in January 2010 it was even higher than in the case when the rule was not applied. Albeit it was reasonable to expect that the turnover was going to fall down in parallel with the number of transactions, it decreased at a lower rate, which is a good feature of the application of this rule. In the worst case there would be difference of 53.099.164.180 RSD in the total turnover between cases we observed in this scenario.[5]

[5] The worst case in this situation is defined as the case when the difference between value of the paremeter when the rule was not applied and the value of the same paremeter but when the rule was applied is the highest.

Chart 4 - The average daily turnover per month in period 01.12.2009-31.10.2011. – second scenario

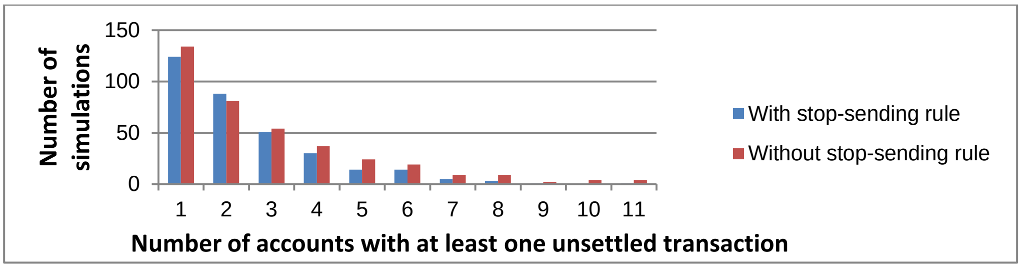


When we excluded two most important participants the total turnover dropped by 26.7%, while in the case we applied the rule this indicator dropped by 30.44% compared with the case of no operational problems. This decrease appears because of the three factors:

- Exclusion of the participant results in lower turnover because of the exemption of its debit transactions
- Application of the stop-sending rule leads to the exclusion of the payments where the most important participants appear as payment receivers
- Unsettled transactions contribute to additional decrease in turnover. These transactions appear as a result of insufficient liquidity on participants' accounts

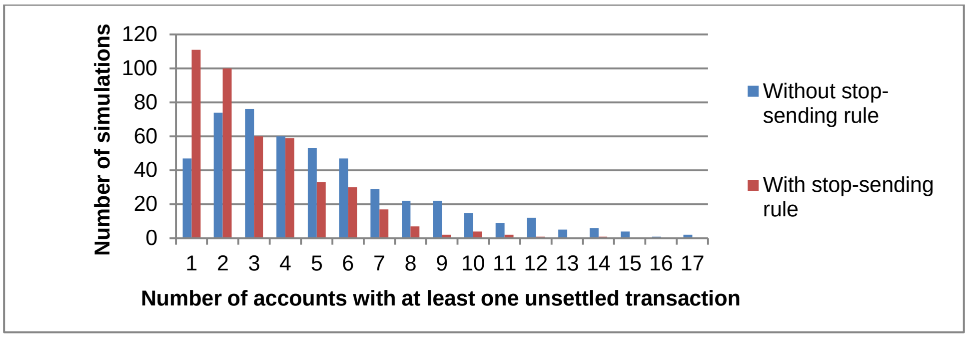
The first factor contributes to lower turnover in both cases: when the stop-sending rule is applied and when it is not. Second factor has a big influence on decreasing the turnover only when the stop-sending rule is applied. We saw that the difference in turnover when the stop-sending rule is applied and when it is not is relatively small. Consequently, we can expect that the value of unsettled transactions is going to be far less in case of the application of the stop-sending rule. We shall confirm this in the next section.

Chart 5 – The number of simulations vs number of accounts with one unsettled transaction at least – first scenario



Charts 5 and 6 show how many simulations contained a particular number of accounts with at least one unsettled transation for the first and the second scenario. The number of simulations with unsettled transactions is decreasing in case when the stop-sending rule is applied. In 377 out of 487 simulations there was at least one account with at least one unsettled transaction. On the other hand, when we apply the rule this number comes to 331. Moreover, when the rule was not applied, there were 1077 situations when some account had unsettled transactions against 806 when it was applied. As we can see on the chart 5, the maximal number of accounts with at least one unsettled transaction was 11.

Chart 6 – The number of simulations vs number of accounts with at least one transaction unsettled – second scenario



We can detect, in case the stop-sending rule was applied, an increase in number of simulations with smaller number of accounts with at least one unsettled transaction, which is a good feature of the stop-sending rule. This characteristic is a consequence of the fact that stop-sending rule is lowering the number of accounts with at least one transaction unsettled, which in turn increases the number of simulations with smaller number of accounts with at least one unsettled transaction. As we can see on the chart 6, the maximal number of accounts with at least one unsettled transaction was 17, while this number comes to 14 accounts in case we applied the rule. In 484 out of 487 days there was a situation when one account had at least one unsettled transaction while the application of the stop-sending rule decreases this number to 427. We had 2439 cases when participants expierenced problems to settle their transactions. However, when the rule was applied this number fell down to 1353.

6. The results of the analysis

We shall now present the explanation of five indicators which were calculated in case when the stop-sending rule was applied and when it was not.

- *Value of unsettled transactions* is the total value of transactions which could not be settled due to lack of funds on the participant's account. This indicator was calculated as the sum of individual values of unsettled transactions.

- *The number of unsettled transactions* shows the total number of transactions which could not be settled in the system.
- *The number of accounts with at least one unsettled transaction* is the total number of accounts in the system which had one transaction or more left unsettled
- *Liquidity usage indicator* for the particular account represents the ratio between the difference of the beginning of the day's balance and the minimal balance and the total value of outgoing payments. It is calculated in the following manner:

$$LUI_i = \frac{BOD_i - MB_i}{\sum_j OP_{i,j}} \quad (1)$$

LUI_i – liquidity usage indicator for i-th account

BOD_i – beginning of the day balance for i-th account

MB_i – minimal balance for the i-th account

$OP_{i,j}$ – the value of the j-th outgoing payment for the i-th account

This parameter shows which portion of the funds from the participant's account was used for the purpose of executing outgoing payments. On the system's level, this parameter is calculated as an arithmetic mean of the individual values. The value of this indicator in our analysis is calculated on the system's level. When no participant is facing operational problems, the value of this indicator is 0.27. This means that a typical participant executes 27% of outgoing payments using the funds from its own account.

- *Lower bound of liquidity* is calculated in the following manner:

$$LB_i = \max\left(0, \sum_{\substack{j=1 \\ j\neq i}}^{n} \sum_{k=1}^{d_j} a_k\,(\mathrm{i},\mathrm{j}) - \sum_{\substack{j=1 \\ j\neq i}}^{n} \sum_{s=1}^{s_j} a_s\,(\mathrm{j},\mathrm{i})\right) \quad (2)$$

The first sum is the sum of outgoing payments for the i-th account, while the second sum denotes the sum of incoming payments. Why this parameter is called the lower bound of liquidity? Suppose that every participant has enough funds to execute its transactions at the end of a working day. Given that, all of the transactions could be settled using the multilateral netting of transactions. Thus the only value needed for the settlement of all transactions for the i-th account will be LB_i . If the sum of incoming payments is greater than the sum of outgoing payments, than it is not necessary that there exist any funds on that account for the settlement of all transactions. However, if the situation is reversed, than the lower bound of liquidity will be greater than zero and one should have at least that amount on its account in order to settle all of the payments. On the system's level, this indicator was calculated as the sum of individual values for this indicator. In our analysis, this parameter was calculated on the system's level. The lower bound of liquidity on the system's level when there are no operational problems accounts for 12.096.060.871 RSD.

Each of the five indicators was calculated for the period 01.12.2009.-31.10.2011. Liquidity usage indicator and the lower bound of liquidity were calculated on the system's level. Values for these indicators are shown on charts as average daily values per month for the total of 23 months covered in our analysis.

6.1 I scenario

Now we shall present the values for indicators in case when the most important participant experienced operational problems.

Chart 7 – The value of unsettled transactions – first scenario

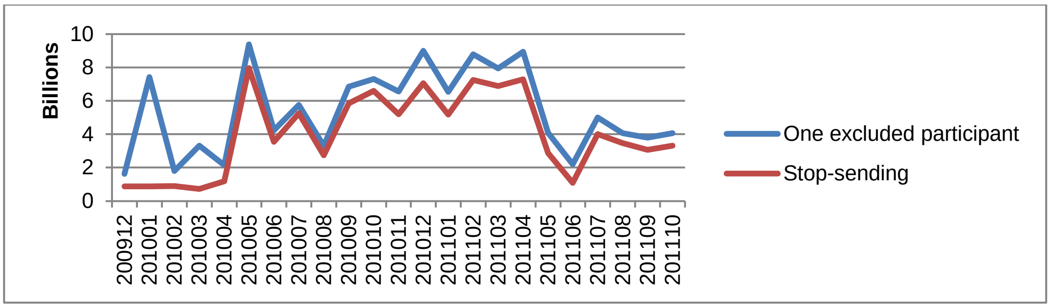
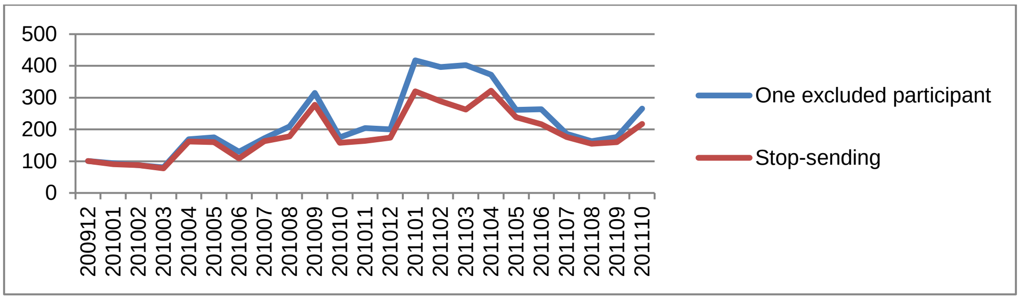


Chart 7 shows the average daily value of unsettled transactions per month for the first scenario. The average daily value of unsettled transactions for the whole period was 5.355.687.949 RSD. The highest daily value of unsettled transactions was 9.372.631.066 RSD. We can notice that the application of the rule can substantially decrease the value of unsettled transactions. In case this rule was applied, the average daily value of unsettled transactions was 4.037.490.634, or 24.6% less than in the case when the rule was not applied. The highest difference was recorded in January 2010, with the decrease of 88,13%[6]. The average daily turnover was reduced by 16,4% when the rule was applied while the value of unsettled transactions was decreased by 24,6%, which tells us that good sides superseded bad sides of the stop-sending rule. As an example, in case of the operational problems of the most important participant in ARTIS (Austrian Large Value Payment System), the daily

[6] For the month with the greatest efficiency of the application of the stop-sending rule. We used daily average data for each month to calculate this efficiency

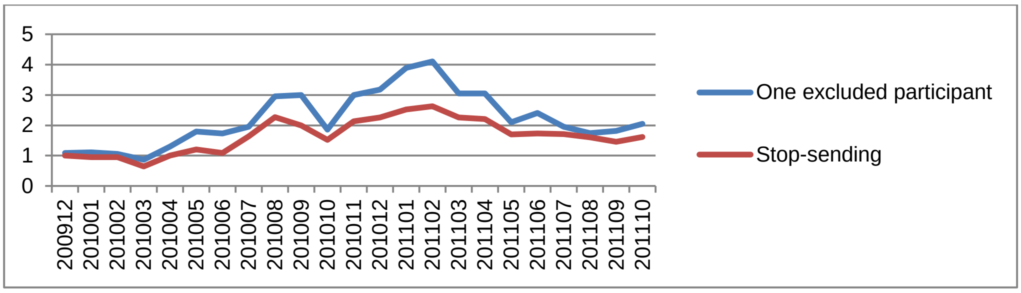
average value of unsettled transactions was 800 million EUR for the period of one month, which is almost 15 times higher than in our case (if we regard the average daily value for the whole period taken into consideration). On the other hand, the total turnover in ARTIS for that month amounted 717 billion EUR, which is 25 times larger than average monthly turnover for our case. The standard deviation is smaller when we applied the stop-sending rule compared to the stressed case of the first scenario. Since standard deviation shows what is the extent of aberration from the mean, we conclude that the rule can lower the oscilations in this parameter.

Chart 8 – The number of unsettled transactions – firstscenario



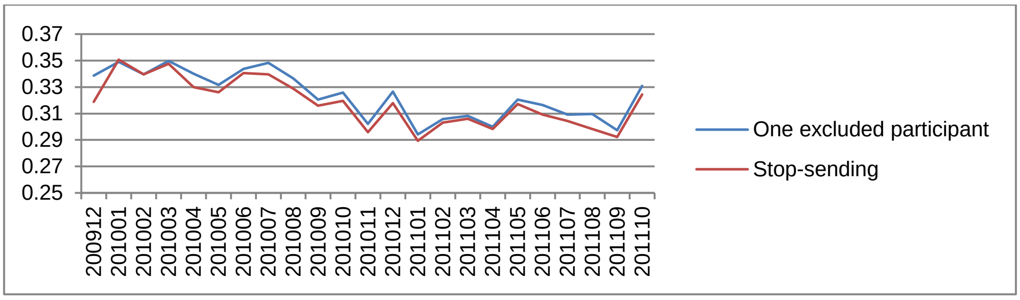
On average, there were 216 unsettled transactions daily, while this number dropped down to 183 in case the rule was applied, which represents the decrease of 15%. The maximal decrease accounted for 139 transactions on March 2011. We can notice that there has been slow decrease in the number and the value of unsettled transactions since May 2011, which can be due to an increase in funds on participants' accounts.

Chart 9 – The number of accounts with at least one unsettled transaction – first scenario



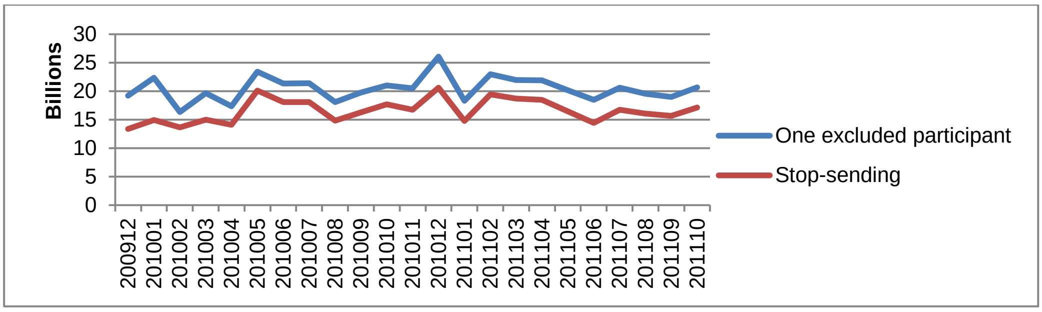
The average number of accounts with at least one unsettled transaction during the specified period for the first scenario is shown on chart 9. The average number of accounts (daily) with at least one unsettled transaction during the observed period was 2,2. As a result of that, we can expect that approximately two accounts will face the problems to settle their transactions. In case the rule was applied, this number fell down to 1,65.

Chart 10 – Liquidity usage indicator – first scenario



In case we do not apply the stop-sending rule, average daily value of this indicator is 32,3% for the total period. In other words, 32,3% of the outgoing payments the average participant settled using funds from the account, while the 67,7% it executed by using the funds it got from the received payments. In case we apply the rule, this indicator fell down to 31,7%. Obviously, the stop-sending rule does not affect much the way the average participant will execute its outgoing payments. With the stop-sending rule applied, both the nominator and the denominator in formula (1) should decrease. Although little, decrease of this indicator only points out that above-mentioned values do not have proportional decrease. In conclusion, when applying the stop-sending rule, the average participant will tend to use less funds from its own account - although this decrease is not substantial. Generally speaking, this indicator was higher in 2010. than in 2011.

Chart 11 – Lower bound of liquidity – first scenario



The average daily lower bound of liquidity is 20.434.815.217 RSD in the stressed scenario without the stop-sending rule. The application of the rule contributes to the decrease by 18,9% and this indicator fell down to 16.571.940.452 RSD. In other words, this is the decrease in funds which will be necessary on participants' accounts in order to settle their payments with the condition that all of them settle their payments with multilateral netting at the end of a working day.

6.2 II scenario

Chart 12 –The value of unsettled transactions – second scenario

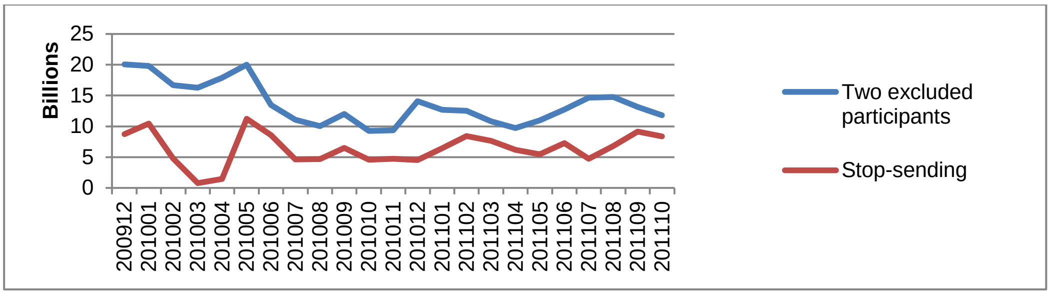
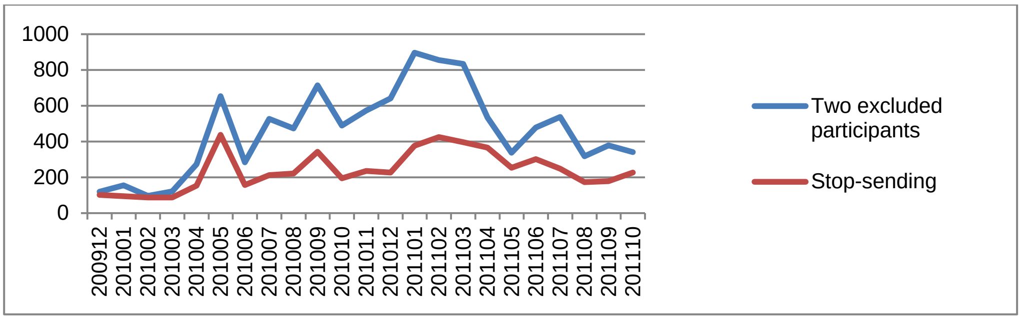


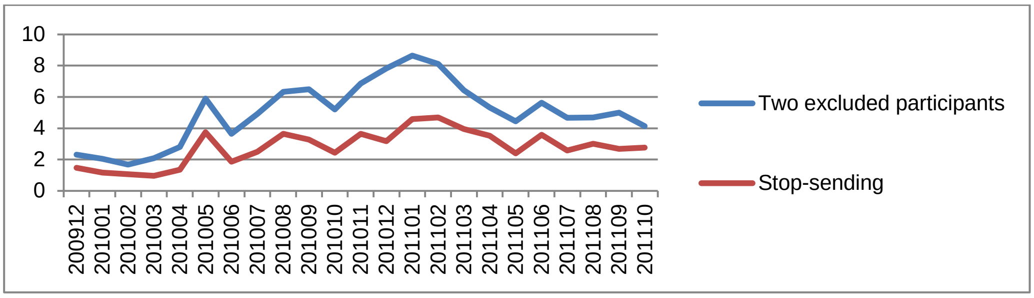
Chart 12 shows the average value of unsettled transactions per month for the second scenario for 23 months taken into consideration. Daily average value of unsettled transactions for the whole period was 13.706.756.659, which is 2,5 times higher than for the same case in the first scenario. In case the rule was applied, this sum will decrease for impressive 53,5% and accounted for 6.325.173.940. Obviously, as more participants experience the operational problems, the more effective the stop-sending rule is. In the best case, this rule will decrease the daily average value of unsettled transactions for 95,2%.

Chart 13 – The number of unsettled transactions – second scenario



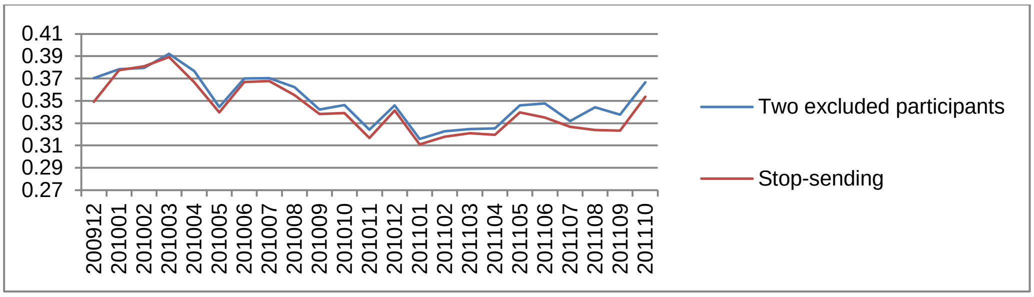
The average daily number of unsettled transactions for the whole period in this scenario was 460. This number came down to 237 in case the stop-sending rule was applied, which is the decrease by 48%. In comparison with the first scenario, the average number of unsettled transactions increased by 53%. We notice again that as we are increasing the number of excluded participants, the rule gets more effective. In favour of this fact we can see that we have bigger decrease in the number of unsettled transactions than in the first scenario. In the best case, the rule caused the decrease of 64,4%.

Chart 14 – The number of accounts with at least one transaction unsettled - second scenario



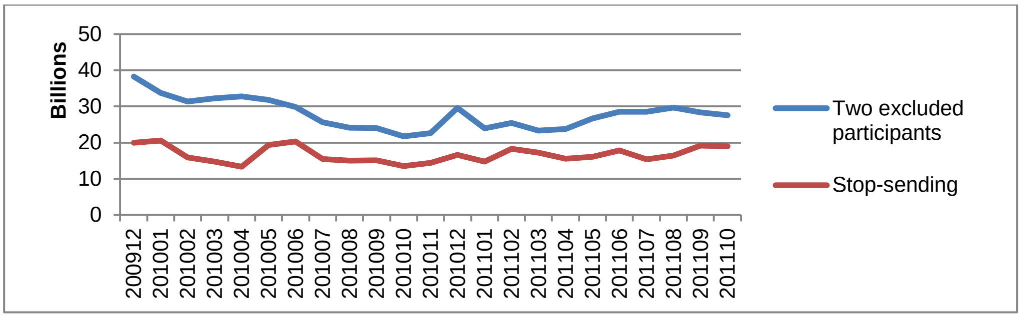
On average, five accounts daily had at least one unsettled transaction in the stressed case. With the stop-sending rule, this number fell down to 2,77. It is interesting that the application of this rule lowers the oscilations in indicators. This is shown by looking at the standard deviations of these indicators. The standard deviation (for this indicator) in the stressed case was 3,31 and with the rule applied it was 2,29. In other words, apart from lowering the number of accounts with at least one unsetled transaction, there is also the decrease in risk that large deviations will occur.

Chart 15 – Liquidity usage indicator – second scenario



The average daily value of this indicator for the whole period was 35,08% for the stressed case, while the application of the stop-sending rule lowers it to 34,34%. We can notice the difference of 3% with respect to the first scenario. So, in case we exclude more participants, we can expect that other participants will tend to use funds from their own accounts more than it was the case in the first scenario. The standard deviation of 0,4 when this rule was not applied against 0,36 when it was applied again confirms above hypothesis of lower oscilations in parameters. In case of the biggest effectiveness, the value of this indicator was lowered by 5,75%.

Chart 16 –Lower bound of liquidity - second scenario



Daily average value for the lower bound of liquidity in case of exclusion of two most important participants was 27.983.807.082 RSD. If we apply the rule we would reduce this value by 40,3%. In other words, theoretical liquidity that participants need to settle all transactions in the system would decrease (bearing in mind how the lower bound of liquidity was determined). The value of the accounts' outflow is higher in the stressed case than in the case when the rule was applied in the expression (2) (because those participants which are not excluded will keep sending payments to the most important ones). Thus, the decrease is largely due to the exclusion of the payments sent from participants who do not face operational problems to the most important ones.

6.3 Subsample analysis

It is interesting to see what could be potential drivers of unsettled transactions across the observed period. Therefore, we estimated our results on smaller subsamples to capture the possible causes of these. We found that:

1. Total unsettled transactions are largely due to the unsettled transactions which involve securities' trading. We illustrate this on the next two graphs.

Chart 17 – Value of unsettled transactions caused by unsettled transactions which involve securities trading – first scenario

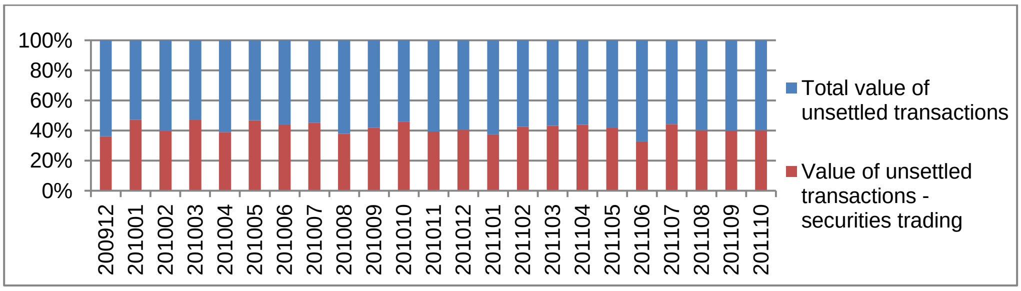
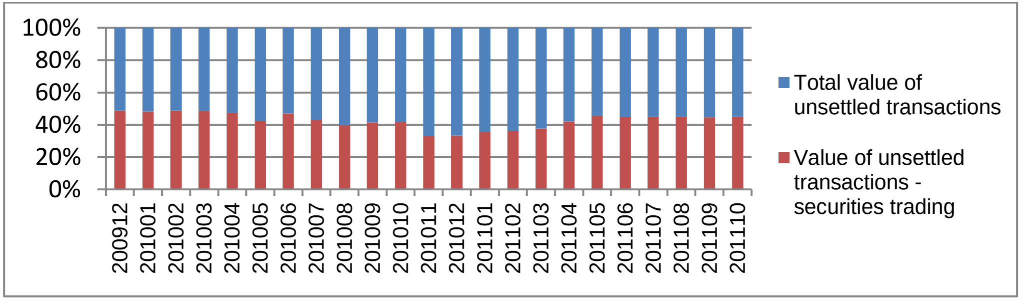


Chart 18 - Value of unsettled transactions caused by unsettled transactions which involve securities trading – second scenario



2. Higher daily average turnover for particular month does not necessarily imply higher daily average value of unsettled transactions for the same month. This is particularly true for the period from September 2010 to April 2011 when there was lower average daily turnover for these months but higher daily average value of unsettled transactions. In fact, the ratio between these variables (average daily turnover and average daily value of unsettled transactions) was the highest for the months in this period.
3. Higher volume of overnight loans in the Serbian money market does not necessarily imply higher value of unsettled transactions.

Our results are shown as average daily values for each month in the observed period. However, we confirmed that the existence of the outliers does not affect the results of our analysis.

6.4 The most affected participants

We shall now present the level of contagion for participants in our analysis caused by simulated incidents. The measure of the influence of these incidents on participants' ability to settle their payments was the total value of their unsettled transactions and the probability of defaults in the observed period. The notion *default* means that some participant is not able to settle its payments because of the lack of the funds on the account for a particular day. The probability of a default was calculated as the ratio between the total number of days when there was at least one unsettled transaction and the total number of simulated days for that scenario. We left accounts' name unrevealed for security reasons.

Chart 19 – The most affected participants – first scenario

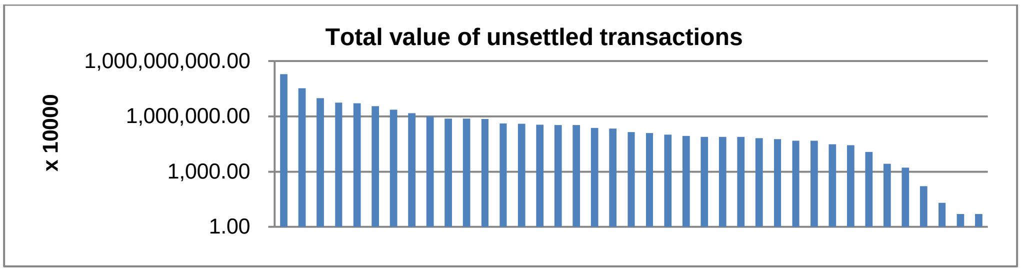
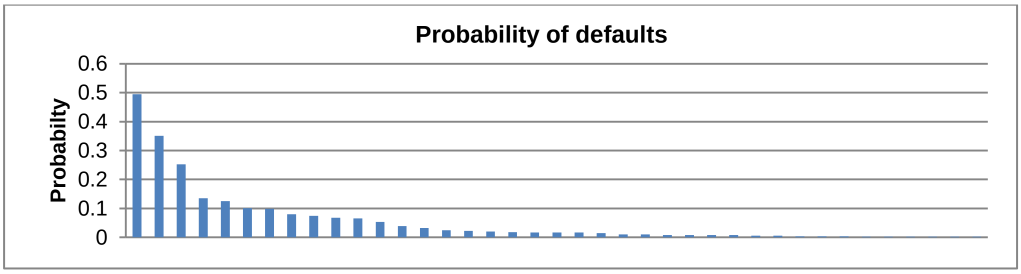


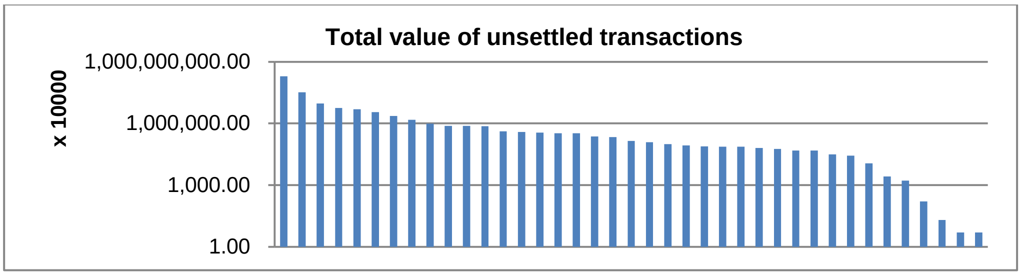
Chart 19 shows the total value of unsettled transactions for the accounts in our analysis during the observed period. Every blue rectangle shows the value of unsettled transactions for one particular account. The total number of accounts with unsettled transactions during the period 01.12.2009-31.10.2011 was 39. Other accounts did not have any unsettled transactions and thus are not shown on the chart 19. The highest value of unsettled transactions reached by particular account was 1.940.000.000.000 RSD. Seven more accounts had the value of unsettled transactions above 10.000.000.000 RSD. The majority had the value of unsettled transactions between 10.000.000 and 10.000.000.000 RSD.

Chart 20-Probability of defaults – first scenario



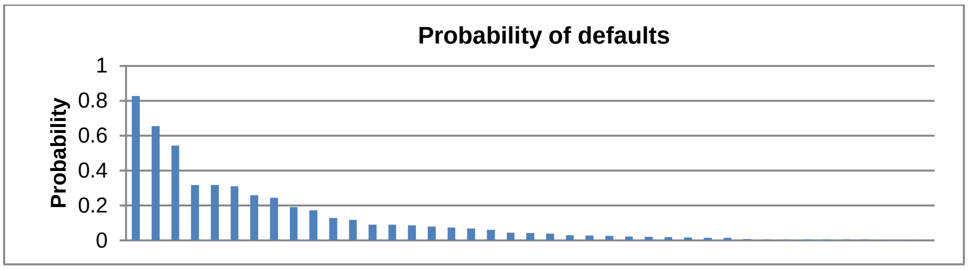
Probability of at least one unsettled transaction on any account is 0,7741. Given that, three accounts on which we can expect the unsettled transactions will occur firstly have the probabilities of defaults of 0.49, 0.35, 0.25 respectively. In approximately 50% of cases of operational problems we remarked that defaults occurred at one of these accounts. As we can see, only three more accounts have the probability of a default higher than 0,1. Thus we get the guidelines which participants will be the most affected in case that operational problems of the two most important ones occur.

Chart 21-The most affected participants - second scenario



In the second scenario, the order of the participants with the highest values of unsettled transactions did not change significantly with respect to the first scenario. There was an increase in the number of accounts with at least one unsettled transaction. Thus we now have 41 accounts with at least one unsettled transaction for the whole period. The highest value of unsettled transactions for one account was 5.182.100.000.000 RSD which is 2,7 times more than in the first scenario. Interestingly, this was for the same account as in the first scenario. The situation when this account had unsettled transactions occurred in 403 out of 487 days (that is the total number of working days during the observed period). There were four accounts whose value of unsettled transactions was between 100.000.000.000 RSD and 500.000.000.000 RSD, which is very significant. This means that, on average, these acounts had daily value of unsettled transactions roughly between 200.000.000 RSD and 1.000.000.000 RSD. In this scenario, there are 15 accounts more whose total value of unsettled transactions is above 10.000.000.000 RSD.

Chart 22 – Probability of defaults – second scenario



The probability of a default on any account is 0,9938. This means that we are almost sure that the operational problem of the two most important participants will result in the unsettled transactions for the other participants. Given that, three accounts which we can expect that would be affected in the first place have the probabilities of defaults of 0.827, 0.655, 0.544. In case that unsettled transactions appear, the probability they will be on these three accounts is 0,4. The order of the participants with the highest probabilities of defaults changed with respect to the first scenario. This tells us that some of the participants are more dependent on the funds they receive from the second excluded participant. Some of the accounts with greater probability of a default were the external clearing houses accounts. This is why the operator of the payment system should devote its attention on these accounts more in case of the operational problems since the net positions in these are not secured by guarantee fund or by some kind of mutual bearing of losses.

7. Conclusion and guidelines for further research

The main objective of this paper is to quantify the contagion effects of operational incidents at the most important participants of the payment system of the National Bank of Serbia as well as to infer how and to what extent the application of the stop-sending rule can contribute to the decrease in these effects. Given that, we simulated the scenarios which reflect the operational problems through the use of a specialized software of the Central Bank of Finland. We examined two scenarios. The first scenario investigates how the operational problem at the most important participant affects the others to settle their payments while the second examines the influence of operational problems at two most important participants.

The total value of unsettled transactions in the first scenario accounted for 4,88% of the total turnover for that scenario. The average daily number of unsettled transactions was 216, with 2,2 accounts with at least one unsettled transaction on average daily. This shows that the contagion effects were very signicant. A good example of this is also the fact that the probability of a default was 77,4%. Results also show that typical participant will execute on average 32,3% of the total value of its outgoing payments using the funds from its own account, while the rest he will execute using the inflow from other participants.

In the second scenario, the value of unsettled transactions increased 2,5 times compared to the first scenario. We can expect that operational problems of the two most important participants will almost sure affect the others i.e. one of them almost sure will have at least one unsettled transaction. The expected number of unsettled transactions is 460. This number of payments along with the payments which were not executed by two most participants have to be settled using some other procedures (manual-based or the web application) or by providing additional liquidity to participants. The lower bound of liquidity for this scenario was 27.983.807.082 RSD against 12.082.443.750 RSD in the unstressed scenario. So we have huge increase in liquidity in order to settle those payments. Also, there was an increase in use of funds from the participants' accounts for executing outgoing payments (the liquidity usage indicator increased to 35,08%).

How the application of the stop-sending rule can help to mitigate these effects? The total value of unsettled transactions decreased by 24,6% for the first and 53,5% for the second scenario. The number of unsettled transactions also decreased significantly (15% for the first and 48% for the second scenario) as well as the number of accounts with one unsettled transaction at least (from 2,2 to 1,65 and from 5 to 2,77). If we apply this rule, we can expect less deviations from the mean in indicators compared with stressed case. The higher the number of participants facing the operational problems the greater the efficiency of the rule's application. It is interesting to notice that participants will use inflow for executing outgoing payments more than in the case when the rule was not applied (smaller value of the liquidity usage indicator). However, the application of this rule reduces the total turnover in the system as well as the total number of settled transactions. Since the goal of every operator of the payment system is to have settled transactions as more as possible, this is not a good feature of the application of this rule. The total turnover will decrease for 16,4% in the first and for 30,44% in the second scenario compared to the unstressed case (4% and 5% compared with the stressed case for the first and the second scenario respectively). The number of the total transactions settled decreased dramatically – 28,5% for the first and 47,4% for the second scenario.

Results indicate which accounts would be the most affected in case of operational problems at the two most important participants. We left them unrevealed in the work for security reasons. Among accounts which would be the most affected are also the accounts of clearing houses, which indicates that these accounts should be treated with increased attention. Moreover, we confirmed that unsettled transactions which involved securities' trading formed a large portion of the total unsettled transactions.

It should be noted that these scenarios are highly restrictive because of the assumptions. However, we think they can prove very useful to indicate the relations between participants as well as the consequences for the financial system in case similar scenarios appear. Also, we can determine participants which deserve more attention from the operater of the payment system if similar situations occur.

Further research in this field would suppose shorter period during which participants face the operational problems. In that way, we would obtain the situation which is more practical. In this paper, the stop-sending rule was implemented as one of the possible behavioral reactions of the other participants. However, it could happen that some participants would send their payments for some period of time to participants which face the operational problems and only after that period they would stop sending their payments. In other words, we could model the behavioral reactions of the other participants and see what would happen in that case (would we have unsettled transactions). Also, the effects of this incidents on participants' liquidity could be examined. The analysis also can include testing whether the unsettled transactions could be executed by some backup procedures which the operator allows for.

It is necessary to note that there is no law regulation for implementing this rule as a possibility for the participants of the payment system of the National Bank of Serbia. Therefore, this paper can serve as a signal for authorities to discuss this issue and propose the implementation of the stop-sending rule. We concluded that the rule proved very effective in mitigating undesirable consequences but it also decreased the total turnover. Since the aim of every payment system is to have the highest possible efficiency in terms of number and value of settled transactions, sometimes it is not always useful to implement this rule. However, if operational problems of some participants can cause others to run out of liquidity because of the liquidity sink effect, this rule can prove very helpful. It also remains questionable what is the most optimal period after which this rule should be introduced in order to mitigate undesirable effects of the operational problems, but at the same time not to decrease the total turnover significantly.

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