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Instant payments as a new normal: Case study of liquidity impacts for the Finnish market

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Abstract

The amount of central bank money, or liquidity, needed to settle payments, depends on the way the settlement is organized. It is largest when payments are settled individually on gross basis and smallest with settlement in one big netting cycle. Retail payments are increasingly processed in instant payment schemes and systems. We evaluate how the result of this transition affects the liquidity needs of the Finnish banks. For the analysis we generate artificial transaction level data, which mimics the Finnish retail payment flows processed in the STEP2 system. This allows us to estimate the difference between the liquidity needs for the settlement in a cycle based model and in a full instant payment mode. We also present a regression model for the bank level additional liquidity needs. A full migration to instant payments is expected to cause only a small aggregate increase in the liquidity needs. However, the variations between banks or between days can be significant and emphasize the need of liquidity buffers.

Keywords: instant payments, liquidity needs, payment systems, netting

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1. Introduction

In this paper we analyze how a full transition to instant payments (IP) in the processing of retail payments would affect liquidity needs of banks. The study is focused on Finnish market and retail payments settled in the STEP2 system of EBA Clearing[2]. This system covers large share of all those Finnish retail payments, which are not settled instantly. It includes the euro denominated traditional credit transfers, which are the largest retail payment method in Finland based on total transaction values.

Because we do not have transaction level data, we need to generate artificial transaction level data samples, based on STEP2 participant level monthly statistics. The artificial data matches the value and volume of submitted transactions and the value of received transactions for each participant. Additionally, the value distribution of transactions is matched to known value band frequency data from the statistics. The structure of the flows between the banks, the payment topology, is not known to us, but we generate data with two different possible topologies. Transactions are generated with a Poisson-Lognormal model (Baksys - Sakalauskas 2006).

The generated artificial data is used to calculate the minimum amount of central bank liquidity needed by individual banks in two different situations. This is the smallest amout of funds that each bank needs to have available to ensure transactions are not rejected because of lack of funds. First case is the cycle based settlement model, which is currently used in STEP2, and the second case is settlement in instant payment mode. Artificial data is generated for 1000 independent days, which allows us to estimate the distribution of the increase in liquidity need and to analyze what variables explain the increase in liquidity needs on participant level.

Currently the Finnish market uses 6 settlement cycles in STEP2. With a smaller 30-day sample, we also compute liquidity needs for setups with different number of settlement cycles. The liquidity needs for the alternative settlement cycle setups are computed with the Bank of Finland payments and securities settlement system simulator (BOF-PSS3[3]).

Our analysis indicates that the migration to full instant payment processing from settlement in cycles could increase the daily liquidity need of banks on the system level with less than 8.6% on 95% of the cases. The average increase is 2.7%. In absolute terms the total system level daily liquidity need would similarly increase at most 28 million euros up to 324 million euros. The average increase is 8.6 million euros. This can be considered a rather small increase, when it is compared to the total daily value of processed payments, which was 1376 million euros in system level. We show with regression analysis that most of the additional liquidity need in participant and cycle level can be explained with ex ante known characteristics

[2] EBA CLEARING is a company, which provides pan-European payment infrastructure solutions. See www.ebaclearing.eu It should not be confused with the European Banking Authority (EBA).
[3] https://www.suomenpankki.fi/en/financial-stability/bof-pss2-simulator/

of the liquidity flows of the banks. We find that the topology of bilateral flows does not affect the bank level increase of liquidity needs – at least in the setup used in our study. It is likely that the topology would be significant in many other situations.

The paper is related to analyses of payment systems, where the liquidity needs of Real time gross settlement systems have been quantified.[4] These may include comparison of gross and net liquidity need as well as quantification of impacts of different liquidity saving mechanisms. There are also studies of intraday liquidity needs from systems, where retail and large value payments are settled within the same infrastructure, which are closely linked to the current paper.[5] The current analysis differs from the former with its focus on retail payments, which causes massively larger transaction volumes. Compared to the latter papers, we do not have actual transaction level data and we need to generate the transactions used in the analysis. Naturally there are also differences in national institutional features between financial market infrastructures used in different countries.

The rest of the paper is organized as follows. Section 2 introduces the systems and situation we analyze and defines the liquidity concepts. Section 3 presents the statistics of STEP2, which are used as the basis for the data generation. Section 4 introduces the data generation model and provides validation of the generated sample against the statistics. Section 5 present the results on liquidity need changes and the regression. Finally, the section 6 concludes and discusses the results.

2. Liquidity measures and the Finnish retail payment systems

A large share of Finnish retail payments is cleared in STEP2 system operated by EBA Clearing. This includes all credit transfers, which follow the single euro payment area scheme for credit transfers (SEPA Credit Transfer, or SCT) and SEPA Direct debit transactions (SDD) between banks. STEP2 functions as an ancillary system of TARGET2, the large value payment system operated by the Eurosystem.

STEP2 currently contains two settlement mechanisms, namely cycle based settlement and the continuous gross settlement. In the cycle based mechanism, the settlement process has five mandatory daytime cycles and two optional night-time settlement cycles every day. At the time of our data sample the finnish community used only the cycle based settlement and one of the optional night time cycles in addition to the five daytime cycles. Thus our analysis refers to six settlement cycles as the current STEP2 settlement mechanism.

Banks can submit individual payments or payment files to STEP2 throughout the day. Each cycle has a defined cut-off time and the settlement process will include all the payments

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[4] See e.g. Koponen – Soramäki 1998, or Leinonen – Soramäki 1999.

[5] The Mexican SPEI system is the prominet example of a system whch includes both large value and retail payments. The settlement dynamics and liquidity needs in SPEI have been extensively analysed e.g in Alexandrova-Kabadjova 2016 and Gavilan-Rubio & Alexandrova-Kabadjova 2018.

submitted to the cycle before this. The multilateral net liquidity need from a cycle is calculated separately for each participant.[6] The related transfers of funds are settled on TARGET2. Payment orders are only accepted for settlement provided there are sufficient funds. In case a participant does not provide sufficient funds for settlement, the calculation of the positions and settlement will occur without the respective participant and its payment transactions, which are carried forward to the next cycle, except for the messages in the last cycle of the business day which are cancelled in case of insufficient funds.

Possibility to process instant payments has been increasingly used for Euro retail payments after the SCT Inst scheme was launched in November 2017. The Finnish banks currently primarily use RT1 system of EBA Clearing for this purpose, which is also an ancillary system of TARGET2.[7] The real time settlement of instant payments requires that central bank liquidity can be accessed any time, unlike with the cycle-based settlement where liquidity needs to be provided only at the end of each cycle. Liquidity for instant payments is typically made available or prefunded into dedicated accounts. In TARGET2 these dedicated accounts are called technical accounts.

In this study, we aim to quantify the amount of additional liquidity, which would be needed if similar transaction volume, which is currently cleared in STEP2, would be fully migrated into instant payment settlement. We are agnostic on which system is used but do assume that the full volume of instant payments is processed in one system.The increase in the liquidity need is calculated for individual banks both on the level of cycles and full calendar days.

For the cycle level measures we calculate the multilateral net liquidity need for the generated retail transactions for each bank on each of the analyzed settlement cycles. This is the liquidity needed in cycle processing mode for a given cycle. Or in other terms, the liquidity need in a given cycle corresponds to the multilateral net positions calculated from the transactions involved in the cycle.This definition aligns with lower bound of liquidity, as it has been used in RTGS analyses and defined in Koponen- Soramäki (1998).

The liquidity need of a cycle in instant payment mode is the minimum position which would be reached during the cycle if the full transaction set was all processed successfully one-by-one in instant payment mode. This definition equals the upper bound of liquidity -indicator used in the RTGS studies. The additional liquidity need caused by the instant payment processing is the difference between the net liquidity need and IP liquidity need of the cycle. Position of each bank is set to zero in the beginning of each cycle in this calculation and thus the liquidity need values calculated in cycle level are independent from each other.

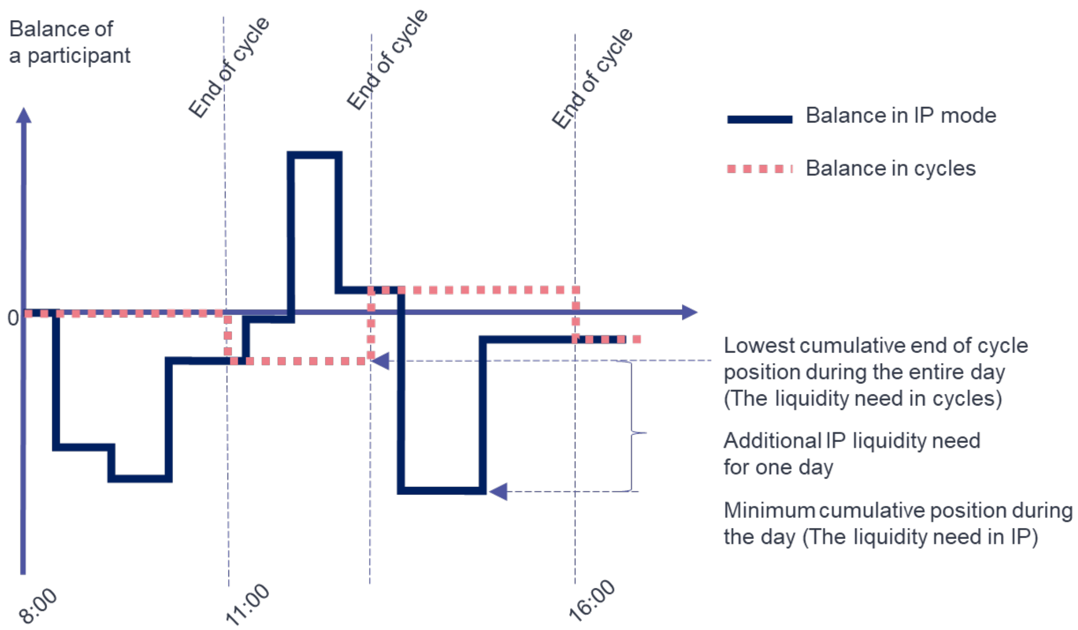
[6] Our focus is on the liquidity need, which is defined as multilateral net position in a cycle. It is noted, however, that the legal design for settlement of STEP2 is based on simultaneous settlement on a gross basis of all payments included in a cycle.

[7] At Q4/2020 the share of Finnish SCT traffic by payment service providers, which were also addressable in RT1 was 87%, which was second highest number in Europe. In addition the TIPS system operated by the Eurosystem allows interbank processing of euro instant payments. Domestically also Siirto system can process payments instantly between some payment service providers.

The liquidity needs over the course of an entire business day are calculated similarly. When payments are settled in the instant payment mode, the liquidity need is simply the minimum liquidity position throughout the entire business day.

The daily liquidity need associated with batch processing with settlement cycles is defined by the minimum balance among the end of cycle positions. The Figure 1 illustrates the indicators for the whole day with the example of three cycles.

Figure 1. Example of liquidity position of one participant over three cycles. New incoming (outgoing) payments indrease (decrease) the position of the bank immediately in the IP mode but only at the end of the cycle in the deferred settlement.



It is noted that in reality, Banks' prefunding of sub accounts for instant payment settlement is likely significantly larger because the exact minimum balance is not known ex ante and some buffers need to be provided. In this sense, the liquidity needs calculated represent strict minimum values.

3. Available data

The statistics related to the Finnish banks participating in STEP2 are reported monthly by EBA Clearing S.A.S. to the Bank of Finland. In this study, statistics reported for April 2020 are used. This data includes the total monthly value and number of incoming and outgoing transactions for each participant in each STEP2 settlement cycle. The counterparty for each sender is reported in the statistics at country level. In this study we focus on the domestic subset where both the sender and recipient are from Finland. This covers 96% of the number of sent payments and 74% of value of sent payments of Finnish banks in the data.

The statistics also includes information on the distribution of the value of transactions on system level. The breakdown is provided as number of payments sent within 12 different value bands starting from “payments below 1250 Eur” and ending in “payments above 1 billion”.

As all the data is provided on an aggregated level, we do not have information about the structure of the bilateral relationships between participants. The analysis of liquidity needs requires granular transactional data and we generate it based on the available information.

Finnish banks use all daytime settlement cycles and one of the optional nighttime cycles of STEP2. Every bank does not have equal activity in each cycle, but the whole market is present in six settlement cycles and our analysis is focused on these.

Table 1. Average daily number of payments and share of sent payment value in the different STEP2 cycles used by the Finnish banks in April 2020. Cycle 1 is the night cycle, the other five are the different daytime cycles.

Cycle nr	Number of sent payments	Share of sent value
1	477 577	31.5 %
2	206 871	5.1 %
3	297 248	14.3 %
4	265 100	19.8 %
5	183 274	18.5 %
6	85 683	10.8 %

Source: Step2 statistics from EBA Clearing.

4. Generation of artificial transaction data

The required transaction level data is generated stochastically in two stages. In the first stage, all the parameters for the used distributions and data genetarion methods are estimated based on the reported statistics of the actual system. The parameter values are calibrated and fixed so that the expected values of the statistics which describe the generated payments data will be correct. In the second stage the actual transaction data is generated with the model and the given parameters. Thus, the second stage does not include any feedback or ex post correction for the aggregate indicators of the generated data. These are controlled only in the first stage. The second stage can be repeated multiple times, and in this way generate big number of independent data samples with Monte Carlo type sampling.

For each participant and each settlement cycle separately, the data generation process aims to produce the correct number and value of sent payments and correct value of received payments. In addition, the distribution for the value of sent payments for each participant in each cycle is matched to the statistics of the entire system. The current method allows the received payments to be calibrated either based on value or volume.[8] We choose to replicate exactly the expected value for received payments instead of received number of payments. The former is clearly more important for the liquidity needs and consequently the number of received payments is not directly controlled. The calibration of received values will somewhat align the received volumes as the value distributions of sent payments are similar between individual banks.

The transaction data is generated with a Poisson-Lognormal process as suggested in Baksys – Sakalauskas (2006). The timing for individual payments is derived from a process, where the time difference between each two subsequent payments sent by a given bank i during a cycle j follows a Poisson distribution with parameter λ_{ij} . The parameter lambda is estimated so that expected total number of sent payments will align with the statistics for that bank and cycle. This is done simply by dividing the length of the cycle by the expected number of payments. The time intervals between any consequent payments of the same sender in the same cycle are independent and identically distributed. Thus, they are also independent of the arrival of payments to the given bank.

The value for generated transactions is similarly derived from a log-normal distribution. The parameter values μ_{ij} and σ_{ij} of the log-nomral distribution are calculated for each participant and cycle separately. The parameter values μ_{ij} and σ_{ij} are estimated in the first stage with an optimization, where the minimized variable is the square sum of differences between a set of expected values given by the estimated distribution and respective values in the known statistics. The differences are calculated first for the number of payments in each value band. This part is equal for each case as the value bands data is only available in the system level. We then also include the relative difference in the total value of sent payments to the square sum. As this is reported individually for each participant and cycle in the statistics, the resulting size distribution becomes also specific for participant and cycle.

The final part of the first stage of the data generation process is to define the recipient distributions for each participant. These are used later, in the second stage to define the receiver for each generated payment. The topology is defined in adjacency matrix V, where the individual entries v_{ij} correspond to the share of payments sent from bank i to bank j out of all the payments sent by bank i. No payment from a bank to itself is allowed and thus $v_{jj} = 0 \; \forall j$.

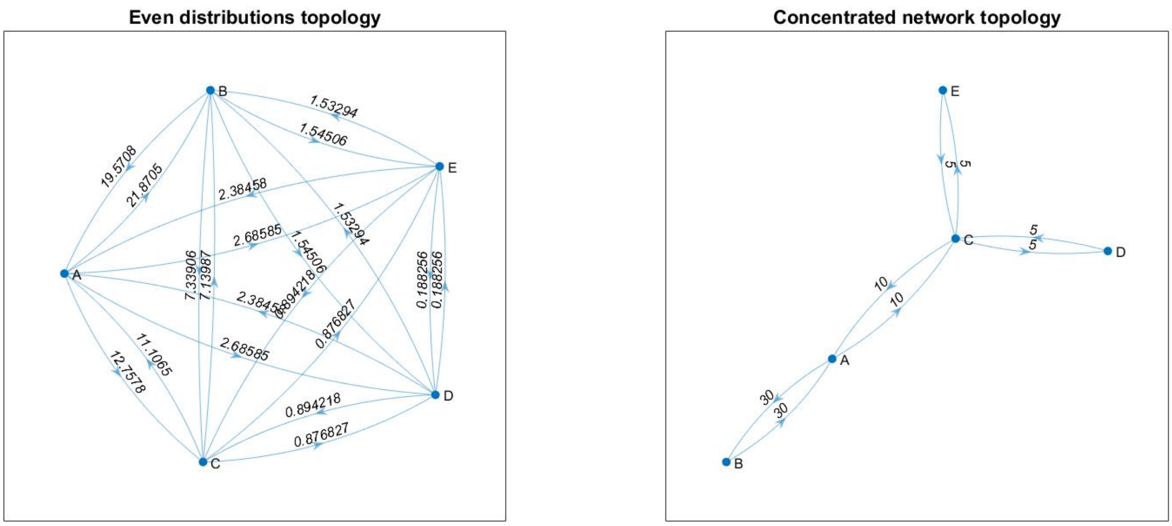
[8] While it could be possible to try to calibrate both volume and values explicitly, this was not included in the current approach as it would complicate the process and potentially decrase the accuracy of calibration of the received values.

The available statistics does not provide any information about the structure of the flows between individual banks. The impact of topology is tested by generating two very different network structures. We call the first topology “even distributions”. Here the goal is to construct a fully connected network, where every bank sends payments to every possible recipient. Additionally, we try to allocate a constant share for each individual receiver of the payments sent by other participants. If a bank i receives the share s_i of all payments within a given cycle, a value $x_i \geq s_i$ is found where x_i is the share of the outgoing payments all the other banks send to this one counterparty. x_i is larger or equal than s_i because it is not allowed for banks to send payments to themselves. As an extreme example, if one bank would receive and send 50% of all the payments sent in any given cycle, all the other counterparties would send 100% of their payments to this one recipient. In the calculation, the row sum of the distribution matrix is calibrated to 1.

Even distributions topology V_{even} is then found numerically by minimizing the square sum of difference between the expected value of received payments by each participant and the respective statistics.

The first panel in the Figure 2 illustrates the even distribution for a five-bank case, where the participants A, B, C, D and E send and receive 40, 30, 20, 5 and 5 units of payments respectively. It can be noted that even topology creates a fully connected network where large number of flows will take place between different participants.

Figure 2. Illustration of the two different tested topologies. In both cases the banks send the same amount of payments: A sends 40 units, B sends 30, C sends 20 and both D and F send 5 units respectively. The numbers at the edges show the value which is expected to be sent in that link based on the created distribution.



Source: Bank of Finland calculations.

The second topology is called “concentrated network”. Here the expected payment volumes are assigned sequentially in the generation of the receiver dirtibutions by first choosing the sender randomly and by assigning the receiver as the one with the largest open incoming position. Reciprocal bilateral flows are then assigned as much as possible. Finally, if needed, a circle of participants is created for the potential remaining payment volume of the last participant.[9] This sequence creates a very sparsely connected topology with few links and high concentration of payment flows to some of the largest participants. It assigns the expected value of incoming funds exactly according to the statistics for all the participants. A concentrated topology created for the same five bank example case is shown in the second panel of the Figure 2.

The data generation process is implemented as a Matlab code, which can generate an arbitrary amount of days. The second stage of the code, which generates the transactions based on the fixed parameters also calculates simultaneously the liquidity need which would result from the generated transaction flow when settled in instant settlement mode or with settlement in batches. The generated transactions can also be saved into a file if needed. The quality of the generated data is checked against the underlying statistics and was found to be accurte. The validation of the generated data is presented in more detail in the appendix 1.

5. Results

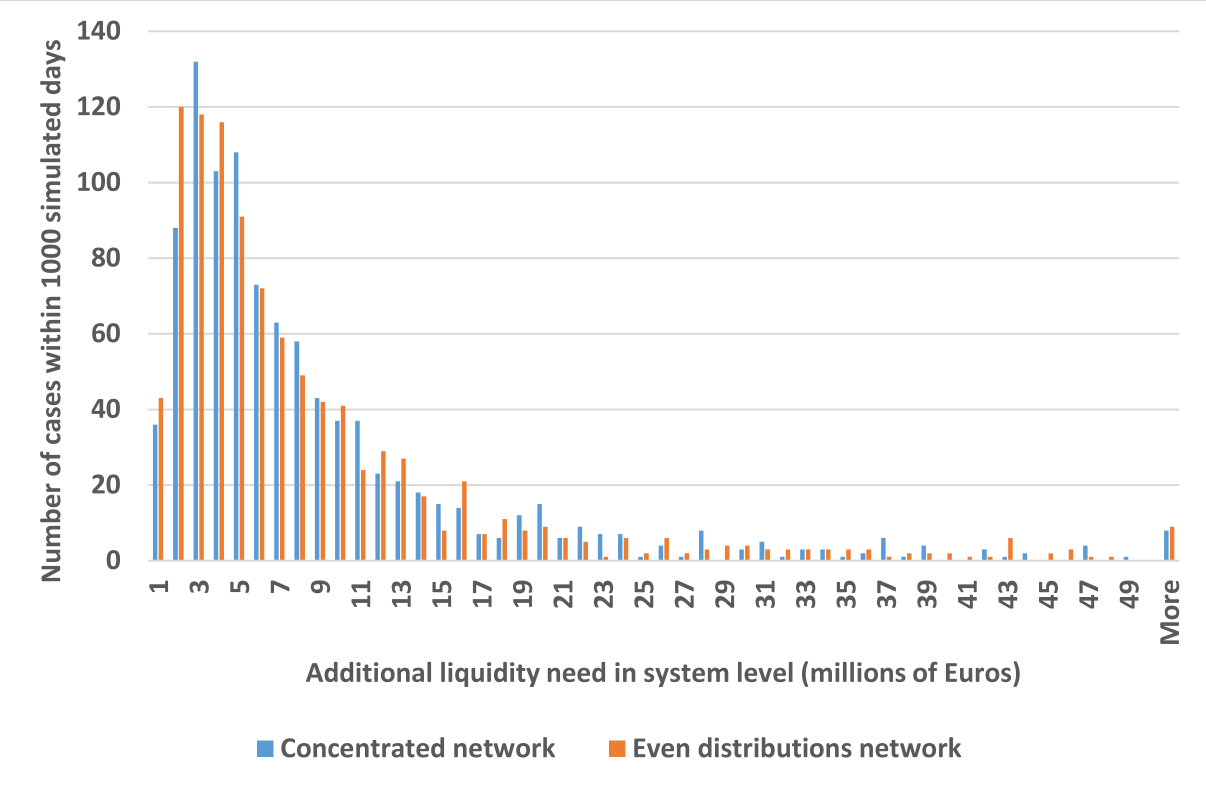
The migration from clearing in cycles to instant payments requires somewhat more liquidity at system level. The distribution of the daily increase in the intraday liquidity need is displayed below in Figure 3 separately for the two topologies. The result is derived from 1000 generated days and aggregated to the system level from the increases in the liquidity need of individual participants. The aggregation does not consider momentary liquidity need across the system, but instead aggregates the participant level peak values. Thus, it includes individual peak liquidity needs which necessarily take place on different moments during the day.

The result shows that on average the migration to full IP mode would increase the intraday liquidity needs of Finnish banks in system level with less than 28 million euros in 95% of cases. On average the increase would be 8.6 million euros. The former number is more useful because some precautionary buffers are likely to be used.

[9] If at the end of the procedure, only a solitary bank A is remaining with an unallocated expected sending and receiving balance x, this can not be assigned directly as it is not allowed for the bank A to send payments to itself. The algorithm tries to form a loop of three participants as follows. Two other banks B and C are searched, which have bilateral payment flows larger than the remaining orphan balance x. Primarily B and C are selected so that either of them has already some expected payment flows assigned towards bank A. If such banks are not found, then any banks B and C with suffifiently large bilateral flow are selected. The circle is formed by diverting share of the expected bilateral flow between B and C via the bank A in the receiver distributions. This procedure is not generally guaranteed to always find a solution, as it could be possible to end up with larger x than the flow in any other bilateral pair of banks. However, given that the procedure maximizes the bilateral flows and first clears the largest open positions on receiver side, it is very unlikely that one circle would not be sufficient and the procedure would not converge.

The increase in the liquidity need can be compared to the total liquidity need in system level, which is on average 324 million euros with the current settlement cycles. The full transition of all retail payments to instant payments would be expected to cause liquidity increase of less than 8.7% in 95% of cases or 2.7 % on average.

Figure 3. Histogram of daily increases in liquidity needs in system level from 1000 generated days. The increase in liquidity need on participant level are summed up on each day.



Source: Bank of Finland calculations.

The histogram of liquidity increases at system level resembles a log-normal distribution, which was used for the generated transaction values. It is known that he sum of individual log-normal distributions can be approximated with a log-normal distribution.[10] Combination of participant level distributions with different parameters and the random structure of inflows and outflows would make it complex to derive the exact distribution for the system level. For individual participants, however, it could be a useful possibility to model the liquidity need directly based on the value distribution of outgoing and incoming payments.

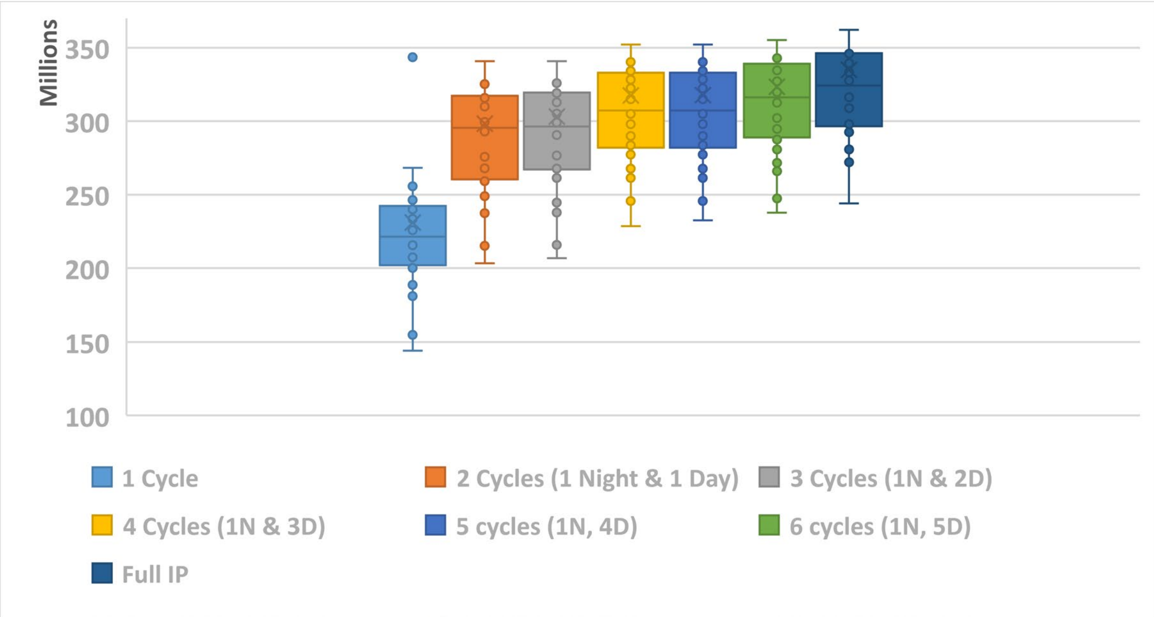
The modest increase in liquidity need was validated by calculating the amount of liquidity, which would be needed with smaller numbers of settlement cycles. We performed simulations with the BoF-PSS3 simulator with a smaller generated data set of 30 days. The hypothetical situation with only one cycle for the whole day would require on average 231 Million euros in

[10] Discussion of log-normal distribution can be found e.g. from Dufresne, D. (2008).

system level. This corresponds to the daily net liquidity needs. From Figure 4 we see how liquidity needs grow gradually as the number of settlement cycles is increased. The highest liquidity consumption values are associated to the IP settlement mode with an average of 335 million euros with this separate smaller data set. The IP mode is equivalent with running a cycle after each individual transaction.

These simulations confirm that the marginal effect of additional cycles on the additional liquidity need decreases quickly. For instance, the step from three cycles up to current 6 cycles create a larger increase than the transition from six cycles to full instant payment settlement. The biggest increase in liquidity need occurs already when moving from a daily net to 1-night cycle and one day cycle. This first step accounts for 65% of the total liquidity need increases on the way to full IP settlement. From the results we also observe that the variance of liquidity needs seems to stay unchanged with different frequency of cycles. These results are in line with other studies which show that netting or gridlock resolution algorithms decrease liquidity needs[11]. More on the dynamics between liquidity needs and settlement processes can also be found in Laine, Korpinen and Hellqvist (2012).

Figure 4. System level average liquidity needs from simulations of 30 days with different number of cycles and ultimately full instant payment processing.



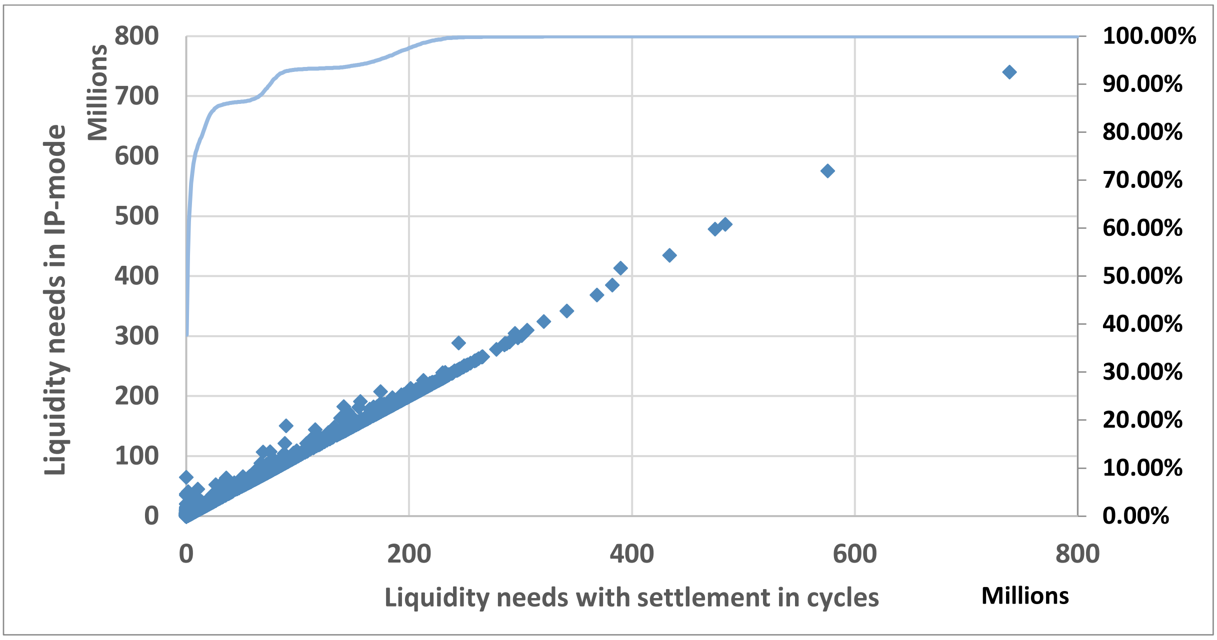
Source: Bank of Finland calculations.

The liquidity needs can be analyzed also at the level of individual participants. Figure 5 shows the daily liquidity needs for all individual participants in both settlement regimes as a scatter plot. Y axis shows liquidity needs with IP settlement and x- axis liquidity needs with multilateral

[11] See e.g: BIS (1989), Koponen-Soramaki. (1998), Leinonen-Soramäki (1999),Tsuchiya (2013).

netting with 6 daily cycles. The cumulative share of observations over the x-axis is displays as the solid line on the secondary y-axis.

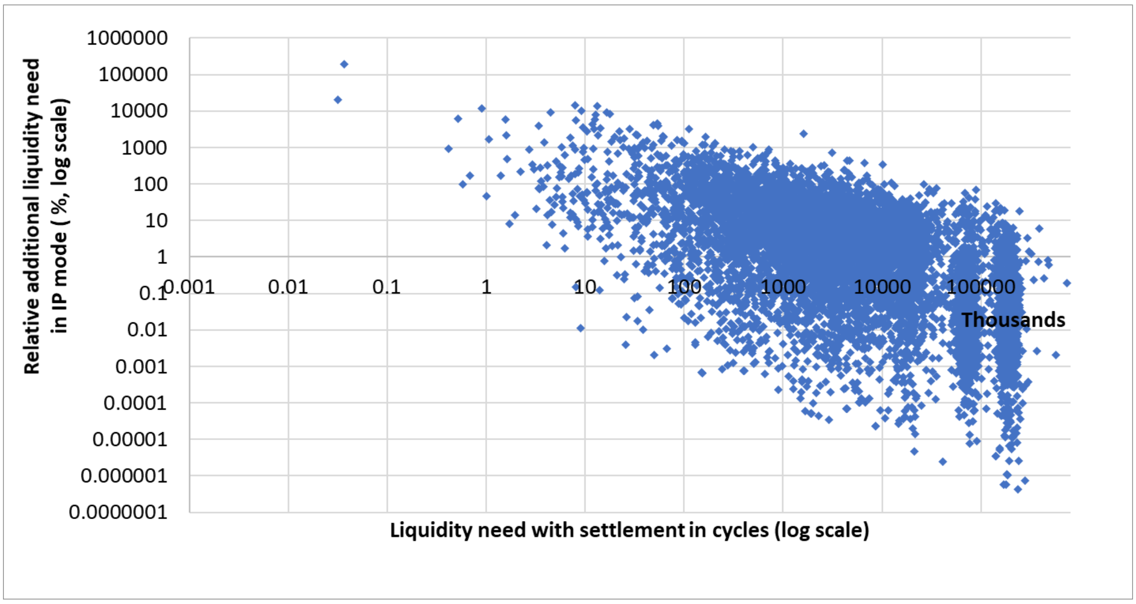
Figure 5. Participant level observations for the daily liquidity need in the current setup of six cycles (on x-axis) and in the instant payment mode(on y-axis). Each dot represents one participant on individual day on the data sample. Cumulative share of observations over x-axis is displayed with a line on the right Y-axis.



Source: Bank of Finland calculations.

A large majority of participant level daily observations have very small liquidity needs in cycles. In 38% of the cases the liquidity need in cycles was zero and in 90% of the cases it is less than 75 million euros. It is also noted that the occurrences of clearly increased liquidity needs due to IP settlement concentrate on the lower end of liquidity need in cycles. Even if the absolute numbers are small, the relative increases can be very substantial in such situations. This is more clearly illustrated in Figure 6 below, which displays these variables on logarithmic scale. This shows an clear inverse relationship between the liquidity need in cycles mode and the additional liquidity need in IP mode (relative to the need in cycles). Cases with significantly more liquidty need in IP mode, with increase of 100% or more, are only present when the participant level liquidity need in cycles is less than 10 million euros and they form majority of the observations when the liquidity need in cycles in in the scale of tens of thousands.

Figure 6. Participant level relative increase of liquidity need in IP mode (Y-axis) compared to the liquidity need in cycles mode. Both variables are displayed on logarithmic scale.



Source: Bank of Finland calculations.

Two very different network topologies were tested in this study. Their results in terms of liquidity needs of the participants are very closely identical, as it was shown in Figure 5. We use a F-test to check if the liquidity needs from the two different topologies have equal variances. Based on the observed log-normal shape of the result distribution, the values were first normalized with natural logarithm. The test confirmed that there was no statistically significant diference between the results. T-test for the sample means confirms similarly that the two samples have the same mean. Thus, we conclude that from a liquidity usage perspective the topology of the network does not matter. For each participant only the timing and order of incoming and outgoing payments is relevant payment for the liquidity needs. It does not make a difference where each payment came from or to whom it was sent.

The situation is likely different in stressed situation, e.g. in an operational failure of individual participant. Then the network topology affects the form and intensity of contagion channels and may become important for the overall results. It may also be important for the liquidity needs in a situation where only part of the banks has shifted to use of instant payments. However, as we do not have information on the actual bilateral flows, the current analysis focuses on the assumed final state where the full migration has taken place.

Regression analysis of additional liquidity needs

We construct a simple regression model to test if the expected additional liquidity need of an individual participant in one clearing cycle can be predicted. All the independent variables are derived only from the participant level statistics which are available ex ante. The dependent variable is calculated from the generated artificial data. It is the average additional liquidity need of instant payments in one cycle, i.e. the difference between liquidity required for settlement in one cycle and settlement in instant payment mode.

The regression was calculated with a stepwise regression method using OLS.[12] We allowed linear and quadratic terms in the model including the possibility of cross terms between any of the variables. Our data has 15 banks and 6 cycles and thus it contains 90 observations for the variables. The regression results were calculated from data for individual participants on the level of one separate cycle. Thus, the regression setup differs from the liquidity needs presented above in system or participant level, which were calculated always for a full day.

We included the following variables in the stepwise regression method as possible explanatory variables:

- Value of payments sent by the bank in the given cycle in thousands of Euros
- Absolute value of net position of the bank in the given cycle in thousands of Euros. Net position is the value of received payments minus the value of payments sent.
- Number of payments sent by the bank in the given cycle
- Average value of payments sent by the bank in the given cycle
- Net payer-dummy variable (1 for banks with negative net position, 0 otherwise)
- Net receiver dummy variable (1 for banks with positive net position, 0 otherwise)
- Liquidity recycling measure: the value of sent payments divided by the absolute value of net position.

The progression of the stepwise regression is presented in the annex 2 for normalized variable values. The final outcome of the regression is also summarized in the table below for the non-normalized “real world” variable values. We display this version of the model and also choose not to use e.g. logarithmic transformations on the variables to keep the results directly applicable in practice as such. For instance the coefficient for the variable of value of sent payments below tells directly the additional expected liquidity need for each thousand of euros of sent value.

[12] Addition or removal of a variable was decided based on p-value for an F-test of the change in the sum of squared error that results from adding or removing the term. Threshold was 0.05 for an addition and 0.10 for removal.

Table 2. Regression model fitted with stepwise OLS for the non-normalized variables. For normalized variables, where the magnitudes between the coefficient can better be compared, see annex 2.

Variable	Coefficient estimate	SE	t-stat	P-value
Intercept	76874	62312	1.2337	0.22089
Value sent (thousands)	1.8779	0.13024	14.419	4.4525e-24
Abs NetPosition (thousand euros)	-0.69922	0.17823	-3.9232	0.0001822
Liq Recycling	34364	8578.1	4.006	0.00013632
Sent volume	-6.083	3.3913	-1.7937	0.076592
Sent volume * Value sent (thousands)	-6.5884e-06	1.1065e-06	-4.6578	1.2188e-05
R-squared:	0.833			
Adjusted R-Squared:		0.822		
F-statistic vs. constant model:		80.6	p-value	5.51e-30

Source: Bank of Finland calculations.

A relatively simple set of explanatory variables yields the model with highest R-squared value. All the included coefficients get statistically significant estimates. Strongest independent variable is naturally the value of sent payments which increases the expected additional liquidity need. Negative coefficient for the absolute net position means that when a bank is large net payer or net receiver in a cycle, the increase caused by instant payments is likely to be smaller. The liquidity need in such a case is dominated by the trend of liquidity inflow or outflow.

Number of sent payments explains also some part of the expected liquidity increase. When the number of payments is large, the individual payment which represents the amplitude of variations in the bank's position, is smaller. This can decrease the magnitude of deviations of the liquidity position, which results into smaller difference between IP and cycle modes and is displayed by the negative coefficient of this variable. The number of payments is included in the model also as a cross term with payment value. This follows the same logic, the total value of payments just provides an additional weight or scaling factor to the impact.

The liquidity recycling variable was the last one to be included. It is large when the net position is small compared to the total turnover. In such a situation, the payments must move in and out frequently from the account of the particular bank, which means that there would be a lot of offsetting. This increases the likelihood of observing minimum positions further away from the final net position, which equals larger liquidity need in IP mode. This is displayed by positive coefficient of the liquidity recycling variable in the regression. Finally, the model also includes a small constant term signaling that in the IP mode somewhat more liquidity is expected to be needed in any case.

The results of the regression can be used to anticipate the magnitude of average liquidity increase for a bank in a cycle. Below two generated example cases are given as illustration for two different bank profiles with same total value of sent payments. The first case is a bank with rather equal liquidity inflows and outflows and large average payments in the artificial example cycle. This leads to relatively large expected need for additional liquidity for instant payment processing in the given cycle. The other example has the opposite case; unbalanced liquidity flow and large number of payments result in small additional liquidity need. While the regression model can also give negative values in reality the liquidity need in IP mode is always at least the same as with settlement in cycles.

Table 3. Example of additional liquidity need for one bank in one cycle predicted by the regression model.

	Bank 1, cycle 1	**Bank 2, cycle 2**
Description	Balanced liquidity flow (low net position) and small number of payments	Unbalanced liquidity flow (high net position) and large number of payments
Value of sent payments in thousand euros [a]	100 000	100 000
Net position (abs. value) in thousand euros [b]	1 00	10 000
Liquidity recycling [a / b]	1000	10
Number of sent payments [n]	1 000	10 000
Expected average additional liquidity need [x]	34.6 million euros	534 thousand euros

Source: Bank of Finland calculations.

6. Conclusion and discussion

The analysis based on large generated artificial data indicates that in 95% of the cases, the total liquidity need increases with less than 28 million euros if a set of payments resembling the share of the Finnish market in STEP2 -system would be fully processed in instant payment mode instead of settlement in cycles. The average increase in liquidity need for the whole Finnish market is 8.6 million, which is 2.7% of the liquidity need in the current setup. These figures cannot be taken as an absolute as there are daily variations, also on participant level, and buffers will have to be kept to fund these fluctuations. The results also show that the increase of liquidity need in IP mode is inversely related to the need in cycles mode. Relative liquidity need increases can be substantial for participants who needed very little funds when settling in cycles.

Simulations, where the number of settlement cycles is varied, confirm that marginal increase of liquidity need with additional settlement cycles is already very limited with the current number of six daily cycles in STEP2. The biggest increase in liquidity need occurs when the settlement is divided from one cycle for the whole day to 1-night cycle and 1-day cycle. This step alone delivers 67.2% of the total difference in liquidity need between full IP and settlement in one cycle. In comparison, the liquidity need increase from 6 cycles to IP settlement accounts only for 7.7%. The results confirm former observations that a cycle based settlement model reduces liquidity needs.

Regression analysis of additional liquidity need on participant or cycle level shows that large share of expected increase in liquidity need can be explained with statistics which describe the payment flows of the given participant. If these are known ex ante, the magnitude of expected liquidity needs can be calculated in advance. When the outgoing and incoming payment values of a bank in one cycle are large and balanced, and when the payment sizes are additionally large, this situation is likely to create largest expected additional liquidity needs in instant payment processing. This seems intuitively logical as the more there are liquidity savings present because of settlement in cycles, the more there is potential for liquidity need increases in transaction-by-transaction processing.

This paper was based on analysis of artificial generated data. The methodology for generating the data samples was able to accurately match the statistics of the actual system and thus simulate possibly realistic transaction flows. We also tested the generation of data with two different artificial topologies. This allowed us to conclude that topology of the payment flows does not matter for the liquidity needs – at least with the current assumption of full transition into instant payments. To conclude, we know that moving towards instan payments inevitably increases liquidity needs. Transition from one settlement mode into another will split the payment flows and at least temporarily diminish the offsetting possibilities and increase liquidity needs above what was reported in this study for the situation of full migration.

Because the current liquidity levels held by banks are generally very high, the timing in the eurozone for a transition to instant payments might be favourable as the high liquidity leves can accomodate the temporary increases in liquidity needs possibly associated with an assymetric transition.

Scenarios like progressive or partial transitions and stress situations do require information on the network topology and bilateral relationships. Extending the analysis for such situations is left for future studies.

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Appendix 1. Validation of the generated data

The results of this analysis are based on generated artificial data and their reliability depends on the quality of the data generation process. It is thus important to separately assess the accuracy of the data generation and the features of the generated data. Each of the statistics which were calibrated in the data generation process are assessed here separately. We also compare the accuracy of the data produced by the two different network topologies for the value of received payments.

The differences in the aggregate values on system level are negligible. This comparison is summarized in the table below.[13] Variation in values is larger, as the standard deviation is 4.1% of the average total value. Still this could be too small as in real life, the differences between days are likely to be larger.

Table 4: Aggregate level statistics on the accuracy of generated data for the sent values and volumes.

	Total daily number of payments, system level (count)	Total daily value of payments, system level (Euros)
Step2 statistics	1 515 751	1 884 595 451
Average in generated data	1 515 722	1 884 362 603
Relative difference of averages	-0.002%	-0.012%
Standard deviation in generated values	1235	76 940 000

Source: STEP2 statistics from EBA Clearing and Bank of Finland calculations.

The accuracy of data generation can also be reviewed on the level of participants and individual cycle. We calculate the difference between statistics for the given bank and cycle and respective generated data and call this the “error term” for the respective variable. For the sent values, the comparison is additionally calculated as the difference between the statistics and the expected value of the sent payments based on the estimated distributions. This is because in some cases the banks have only few payments in a given cycle. In small sample sizes the skewed log-normal distribution of payment values causes the frequently observed smaller payment values to dominate the samples. This leaves out the impact of rare and larger payments

[13] The values are from one data generation with 1000 generated days.

in the average payment size and causes a downward bias in the sent payment values for banks with less payments.

We use a Student t-test whether the mean of the error term equals to zero. The two tailed test value which is significantly larger than threshold of 0.05 confirms the null hypothesis of the test and thus the generated data is nonbiased. For the payment values this holds for the expected values, which are accurate similarly as the aggregate sent values in the system level. However, in the generated data the values tend to be too small for banks with small sending volumes, which causes the test to fail. These comparisons are collected in the Table 3 below.

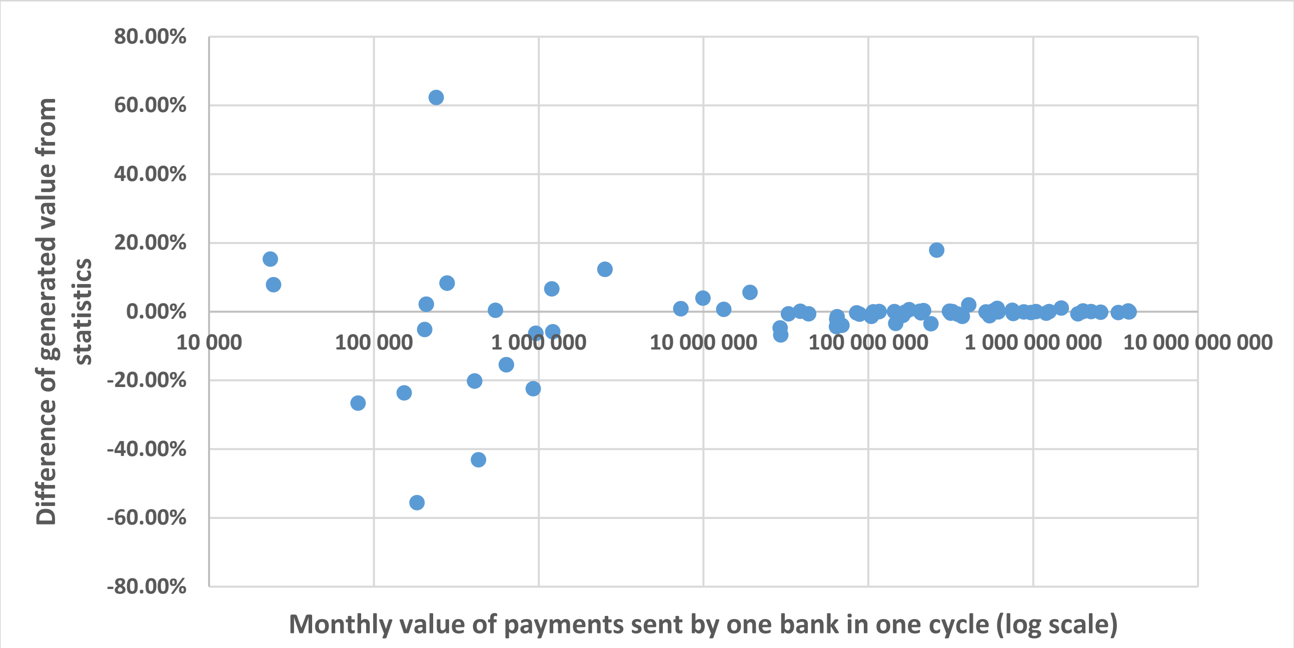
Table 5. Comparison of generated data and statistics on the level of individual participant and cycle on the sender side.

	Sent volumes, generated data vs statistics on participant and cycle level	Expected sent value vs statistics on participant and cycle level	Generated sent values vs statistics
Average of error term divided by replicated value in statistics	-0.024%	0.0000041%	-4.56%
Standard deviation of the relative error term	0.66%	0.000074%	13.7%
t-test value for null hypothesis of zero mean in error term, P(T<=t) two-tail	0.734	0.596	0.002

Source: Bank of Finland calculations.

The accuracy of the generated data in the participant and cycle level observations depends on the absolute value of the data point which is tried to be replicated. There is significantly more noise in the generated data when the replicated number or value of sent payments is small. The error converges to zero when the replicated data point is larger. As an illustration, the difference in the generated value of submitted payments as a percentage of the respective value in statistics is presented below in Figure 7as a function of the value of payments sent by one participant in one cycle.

Figure 7. Y-axis shows the difference in the average value of generated outgoing payments for individual banks on individual cycle as a percentage of the respective value in statistics. X-axis shows the absolute value of the same data point i.e. how large was the replicated value of sent payments Indicators from generated data are compared to the monthly statistics of the STEP2 system. Cases with zero payments (expected and generated) are omitted.



Source: Bank of Finland calculations.

The accuracy of the value of received payments in the generated data depends on the used network topology. Similar comparison as before is made between the two different payment topologies. In table 4, the error term in the value of received payments of participant by cycle are compared. As an additional measure, the share of payments delivered to unexpected recipients, which had zero received funds in the data is included. It is noted again that the number of incoming payments is not tried to be matched as the accuracy of the value of received payments is clearly more relevant to the liquidity needs.

Table 6. The difference in the value of received payments in generated data and statistics on the level of individual participant and cycle. Comparison of the two different topologies.

	Concentrated network, received values on participant and cycle level	Even distributions network, received values on participant and cycle level
Average of error term divided by replicated value in statistics	-2.38%	1.29%
Standard deviation of relative error terms	15.1%	8.92%
t-test value for null hypothesis of zero mean in error term, P(T<=t) two-tail	0.138	0.840
Sum of absolute value of deviations relative to total value of payments	0.71%	0.85%
Share of total value sent to receivers with zero in statistics	0%	0.01%

Source: Bank of Finland calculations.

Both the equal distribution and concentrated network produce very accurately the expected liquidity flows, as the share of deviations compared to total values sent in participant and cycle level is 0.85% or 0.56% respectively. The accuracy increases for larger transaction values and relative differences converge to zero in both cases.

The value distributions for individual participants on each cycle were matched with the value bands data of the statistics. As a result, the value distribution in the aggregated system level also follows this distribution and is presented in the table below. The last column shows the difference of liquidity flow in a given value band as a percentage of the total generated liquidity flows.

Table 7. Number of payments in different value band categories in the statistics and in the generated data. Average over 1000 generated days is presented. Overrepresented value bands have positive values in the last column.

Valueband upper limit (Euros)	Number of payments in statistics, April 2020	Number of payments in generated data	Difference of generated liquidity flows as a share of total
1250	30764838	30003766	-0.56 %
12500	3523563	2899549	-4.55 %
50000	277611	344241	1.94 %
250000	67774	84927	2.50 %
1000000	10985	11336	0.20 %
10000000	3405	1860	-9.02 %
25000000	252	41	-3.08 %
50000000	29	8	-0.61 %
100000000	32	3	-1.69 %
inf	4	3	-0.29 %

Source: EBA Clearing and Bank of Finland calculations.

The value distribution is generally well replicated. Larger transaction values are systematically somewhat underrepresented, which might mean that log-normal distribution is not optimal to describe the value distribution and some other distribution with fatter tails would be even better. Given that the liquidity outflows and inflows on participant level were observed to be accurate at least for larger flows, the accuracy of the replication of the value distribution is sufficiently good.

In the current instant payment schemes, there can be an upper limit for the value of payments. For instance, in SCT-inst scheme the current limit is 100 000 Euros. Still, banks can form closed user groups where this limit is not applied. According to our knowledge, all Finnish banks belong to such a closed user group. Thus, in the current analysis all the generated payments were included. This can cause some noise or individual outliers to the results if very large individual payments get generated and cause some payment flows to become unbalanced.

The used data generation process has some simplifications. The time pattern of payments, which follows from the Poisson process means that there is a rather monotonous stream of payments sent out from each participant. If in reality there were different submission behaviors between the customers of individual banks, e.g. increasing activity of instant payments to be processed at the end of a cycle by some banks, this would not be reflected in the generated data. However, we do not have data to describe the real timing of payments inside the cycles. The current setup will assign randomly the value and the recipient of payments and this will drive the sequence of outflows and inflows for each bank and define the simulated liquidity needs.

The data generation does not try to match the number of received payments for participants. To avoid complicating the generation algorithm, we decided to focus on correct replication for the value of received transactions as it is considered more important for the liquidity needs. This may cause that the frequency of outflows or inflows differs for some participant in the generated data compared to realistic situation, but the total value of flows is correct. In addition, it is noted that the value band statistics is available only for the whole system and it is a rather strict assumption to require that the value distribution in every subset (each sender in each cycle separately) follows this overall distribution. If other data sources or more granular data was available, the data generation process could be adjusted to be more realistic.

Appendix 2. Stepwise progression of the OLS regression for the additional liquidity need in IP mode

The stepwise progression of the regression analysis for the additional liquidity need in IP mode is presented below for normalized variable values. Here in each round, either a new variable is included or an old one is discarded. Addition or removal of a variable was decided based on p-value for an F-test of the change in the sum of squared error that results from adding or removing the term. Threshold was 0.05 for an addition and 0.10 for removal. The dependent variable is the increase in the liquidity need for an individual participant during one individual settlement cycle when the payments would be fully settled in IP mode instead of cycle based settelement.

The regression was started with a model containing only a constant term. Exactly the same outcome is reached with much larger number of steps, if the initial model includes all linear, quadratic and cross terms of the explanatory variables. These are omitted from the table below for presentation reasons.

Variables with p-value below 0.001 are marked with (***), the ones with p-value below 0.01 with (**) and below 0.05 with (*).

Stepwise round	1	2	3	4	5
R-squared	0.434	0.61	0.671	0.801	0.833
	Variable coefficients				
Constant	-6.4692e-17	-7.3341e-17	-9.2705e-17	0.046958 (**)	0.042706 (**)
Value sent	0.62078 (***)	1.0306 (***)	1.4415 (***)	1.6062 (***)	1.4308 (***)
Abs net position	-	-0.98237 (***)	-0.76757 (***)	-0.66731 (***)	-0.47732 (***)
Liq. recycling	-	-	-	-	0.4105 (***)
Sent volume	-	-	-0.69769 (***)	-0.31243 (*)	-0.34443 (**)
Sent volume * value sent	-	-	-	-0.95128 (***)	-0.83488 (***)
P-value of of the test to include / exclude a variable	1.68205e-12	1.44141e-08	1.45389e-06	5.47608e-09	0.0044938
F-stat	67.4908	39.1269	26.8146	42.1133	4.0962