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A Calibrated Model of Intraday Settlement

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by

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Abstract

This paper estimates potential exposures, netting benefits and settlement gains by merging retail and wholesale payments into batches and conducting multiple intraday settlements in this hypothetical model of a single "calibrated payments system." The results demonstrate that credit risk exposures faced by participants in the system are largely dependent on their relative activity in the retail and wholesale payments systems. Participants experience lower exposures in the calibrated system owing to increased netting and significant gains through higher payment values and volumes. This result is reinforced when analyzing participant exposures in periods of stress, particularly during the Great Recession. Relative activity is also indicative of the variations in exposures across participants when implementing multiple batch sizes, especially because increasing batch sizes enhances the value and volume of payments accumulated, thus leading to higher netting and lower exposures. These results and further work may contribute to a better understanding of participant exposures and trade-offs arising from this potential system design.

Bank topics: Econometric and statistical methods; financial stability; payment clearing and settlement systems
JEL codes: G21, G23, C58

Résumé

Cette étude vise à estimer les expositions potentielles, les avantages sur le plan de la compensation et les gains en matière de règlements d'un modèle hypothétique de « système calibré de paiements » unique permettant de regrouper par lots des paiements de détail et de gros et de procéder à de multiples règlements intrajournaliers. Nos résultats démontrent que l'ampleur du risque de crédit auquel sont exposés les participants au système dépend largement de leur activité relative dans les systèmes de paiements de détail et de gros. Le système calibré réduit les expositions des participants grâce à une amélioration de la compensation et aux gains importants que permet la hausse de la valeur et du volume des paiements. L'analyse des expositions des participants en période de tensions, surtout pendant la Grande Récession, corrobore ce constat. L'activité relative révèle aussi la variation des expositions qui se produit parmi les participants lorsque les paiements sont regroupés en lots de multiples tailles, ce qui est particulièrement le cas parce que l'élargissement de la taille des lots accroît la valeur et le volume des paiements accumulés et, par conséquent, fait augmenter la compensation et diminuer les expositions. Ces résultats, ainsi que d'autres travaux, pourraient aider à mieux comprendre les expositions et les arbitrages des participants qui découlent de ce système.

Sujets : Méthodes économétriques et statistiques; Stabilité financière; Systèmes de compensation et de règlement des paiements
Codes JEL : G21, G23, C58

1 Introduction

Advances in technology and shifts in the payment method preferences of consumers have engendered a change in the payments ecosystem. To maintain pace with these developments, a modernization of the country's legacy systems is required. The primary motivation for this paper is driven by Payments Canada's objectives of revamping the wholesale and retail systems through the "Payments Modernization" project. The large-scale and complex nature of the project provides opportunities to study the effects of potential system designs and evaluate a broad array of policy questions, specifically as interbank settlement is conducted on the settlement accounts of direct participants on the central bank's books in the high-value payments system. This paper combines retail and wholesale payments and proposes a "calibrated" model of a single system that conducts the clearing, netting and settlement of these aggregated intraday payments. The aggregated payments are further grouped into payment batches - a function of time - to study their effects on participant exposure. To further test the risk trade-offs arising from batches of combined payments, multiple intraday settlement stops are implemented and netting efficiencies are analysed.

2 Current Payment System Landscape

2.1 Canadian Legacy Systems

Introduced in 1999, the high-value payments system currently in operation in Canada is known as the Large Value Transfer System (LVTS). Along with the settlement of payments, the LVTS also serves as the primary environment for daily implementation of Canadian monetary policy. It is a deferred net settlement (DNS) design, where payments are processed with finality in real time, and settlement occurs on a multilateral net basis at the end of the day. LVTS settlement is guaranteed under all circumstances, facilitated by the use of pledged collateral - to secure the intraday debit positions of participants - and the provision of a residual guarantee by the Bank of Canada. A participant default leads to the pledged collateral being used to cover the defaulter's settlement obligations. If participants default on their end-of-day LVTS settlement obligations, and collateral apportioned to the system is insufficient to cover the total value of the defaulting participants' settlement obligations, the Bank of Canada will dtaw on available collateral and become an unsecured creditor of the defaulting institutions for the residual amount. (Arjani and McVanel, 2006)

The Automated Clearing and Settlement System (ACSS) is a DNS system for retail payments in Canada and was designated by the Bank of Canada in May 2016 to be overseen as a prominent payment system. Each time payment items are exchanged between direct clearers in the ACSS, data are entered into the ACSS to track the total volume and value of items cleared through each payment stream. At the end of the daily clearing process, these entries are used to determine the net position of the direct clearers. The ACSS processes a high volume of lower-value, less time-sensitive payments that do not require intraday finality provided by the LVTS. Settlement for the ACSS takes place on the settlement accounts of direct participants on the books of the Bank of Canada via LVTS payments, on a multilateral DNS basis after final positions are determined.

2.2 Cross-Jurisdictional Comparison

Payment system designs that meet Committee on Payments and Market Infrastructures (CPMI) risk standards provide an avenue for risk trade-offs and are implemented based on the risk preferences of the appropriate authorities. The choice between payment systems designs are confined to two opposing styles: real-time gross settlement (RTGS) and deferred net settlement (DNS). The key trade-off defining the difference in fundamental characteristics of the settlement model of payment systems is between credit and liquidity risks. RTGS demonstrate higher liquidity needs but no credit risk, whereas DNS are emblematic of lower liquidity while generating credit risk. However, according to Wilson (2004), there exists a set of alternatives to RTGS and DNS, known as hybrid payment systems. Wilson suggests that a hybrid envelops one of RTGS and DNS but augments this design with rules and procedures one would normally associate with the other. Based on these definitions, payments systems in different jurisdictions can be categorized as follows:

2.2.1 Real-Time Gross Settlement (RTGS)

In gross settlement systems, payments are settled individually across the books of the central bank in real time and final settlement occurs continuously throughout the day, provided that a sending participant has sufficient credit balance in its accounts at the central bank. The irrevocable nature of transfers of central bank funds indicates an absence of counter-party credit risk, but this is in lieu of increased liquidity costs. Low credit risk can also be attributed to the minimal time period between sending, processing and settlement of payment messages.

Due to the nature of a gross settlement system, liquidity costs include direct funding costs and opportunity costs of maintaining funds in the central bank or tying up collateral to obtain central bank credit. Examples of basic RTGS systems are the U.S. Federal Reserve's Fedwire and South Africa's SAMOS.

2.2.2 Hybrid Real-Time Gross Settlement (Hybrid RTGS)

The key difference between RTGS and hybrid RTGS systems is that the latter incorporates sophisticated liquidity saving mechanisms (LSM), allowing participants to reduce liquidity costs while avoiding a significant increase in participant credit risk. LSMs can take the form of payment splitting, liquidity reservations, offsetting algorithms, and central queueing. LSMs allow for efficient use of liquidity, as settlement requires the net difference between the values of the offset payments.

Liquidity risk is considerably less with a hybrid RTGS system than with a full RTGS, as this type of system inherits a degree of liquidity need from settling payments on a gross basis, with the potential for transaction delays. Reduction in liquidity gridlock by a central queue and payment prioritization creates disincentives for liquidity-hoarding behaviour. Examples of hybrid RTGS systems include the U.K.'s CHAPS and the E.U.'s Target2.

2.2.3 Hybrid Deferred Net Settlement (Hybrid DNS)

In contrast to RTGS models, hybrid DNS systems use net settlement schemes. A hybrid DNS provides participants with real-time access to funds and the use of appropriate credit risk mechanisms, thus guaranteeing settlement certainty of all approved payments and real-time participant access to funds. Comparatively, the system's liquidity risk is low as participants obtain more benefit from settlement netting, along with increased flexibility in settlement and liquidity arrangements.

As a net settlement system, the hybrid DNS design may have a lower final settlement speed than RTGS systems, and participants can be exposed to credit risk via survivor-pay liquidity pools. However, there is a significant reduction in liquidity gridlock due to netting. Hybrid-DNS systems differ greatly in terms of the credit risk management tools they employ.

Canada's LVTS is a hybrid DNS system that facilitates the transfer of irrevocable payments between financial institutions. These transactions settle on the books of the Bank of Canada at the end of each day; however, intraday payment finality is ensured by the Bank of Canada's residual guarantee of settlement in the LVTS. Funds are credited to the recipient's account in near real-time once the risk controls are passed.

According to Tompkins and Olivares (2016), few countries have adapted their large-value payments system (LVPS) to process both high-value and low-value retail payment transactions. From their study of 27 countries, only 3 have structured their LVPS to serve single direct credit payments of all values, including retail transactions.

3 Data

3.1 Data Sources and Patterns

This section details the characteristics of the retail and wholesale payments datasets used in the analysis; namely, daily received and sent payment flows between participants in the ACSS and the intraday payment flows received and sent between participants in the LVTS.

3.2 Retail Payments Data

Current retail data consists of netted ACSS payments, and observations are limited to end-of-day net settlement obligations (NSO) for each participant. NSOs signify the amount that participants owe to the system (or that they are owed by the system) at the end of each cycle, and can be assumed to be an exposure for the ACSS in case of participant default.

Participant-specific patterns: Figure 1 shows the distribution of the final net obligation of a few participants for the sample period 2002-14. This distribution is approximately bell-shaped for every participant and has a relatively small mean and median. However, participants also have relatively large values, with the largest observed debit and credit positions larger than one billion dollars. The shape of the distribution also depends on whether the participant is a net receiver or a net sender. The distribution for a net sender will be skewed to the right (meaning that more often there is a net debit settlement obligation), and the distribution for a net sender will be skewed to the left (meaning that more often there is a net credit settlement obligation).

Additionally, as demonstrated in Figure 2, the daily net flows of participants are random and can be approximated as independent and identically distributed (i.i.d.) draws from a bell-shaped distribution centred approximately at zero. The randomness of payments is an expected observation, as retail payments are typically not predictable in any given day. This hypothesis is tested by conducting a regression of the daily net flows of every participant on the lagged daily net flows and controlling for fixed participant and weekly effects. Table 1 shows the empirical results. The coefficient for the lagged variable is different from zero at the 1 per cent significance level but it is statistically very small. The R2 coefficient is also very small. This suggests that the daily net flows of every participant are independent and participants cannot predict net flows for the next day based on the flows from the present day.

System-wide patterns: The evolution of the distribution of NSO over 2004-14 is analysed and all net obligations in a given month for every participant are considered. Two key statistics are examined: The mean of net flows - which does not change across years and is centred around zero (see Figure 3a) and the standard deviation of net flows - which increases from 2006 to 2012 before levelling off (see Figure 3b). According to Payments Canada's latest (2016) Canadian Payment Methods and Trends report, between 2009 and 2015, the volume and values of cash, cheques and paper declined by approximately 11% and 6% respectively, whereas payment values and volumes for electronic forms of payments such as debit, credit cards, prepaid cards and EFT increased by approximately 27% and 28%, respectively. This trend of substitutions towards more electronic forms will lead to an increase in the usage and widening of the distribution in the ACSS. (Arango et al., 2012)

3.3 Wholesale Payments Data

Available wholesale data consist of intraday sent and received payments in the LVTS between each direct participant. During a normal business day, the payments are netted out to produce an end-of-day obligation for each participant. This is the amount that each participant owes to the system (or is owed by the system) at the end of each cycle, and it can be described as the net exposure for participants during the day.

Participant-specific patterns: Figure 4 provides an example of the evolution of a participant's net position on a typical day. Key patterns exhibited by the participant in the figure indicate an accumulation of liquidity to produce a positive net position at around 12 pm before a drop in the net position at around 2 pm – usually indicating a Continuous Linked Settlement (CLS) system payment – and an attempt to flatten their position towards the end of the day.

System-wide patterns: Most participants tend to flatten their positions at the end of the day due to the minimum zero requirement for settlement balances in the LVTS accounts. Table 2 represents a few characteristics of payments in the LVTS. The total value and volumes of payments sent during an average day in 2015 are approximately 154 billion dollars and 33,200 payments, respectively. The LVTS has two tranches for high-value payments, with Tranche 1 representing approximately 1% of daily volume and 24% value, whereas Tranche 2 represents approximately 99% of the daily volume and 76% of value.

4 Methodology

For an appropriate study of participants and systems, intraday retail payments data are generated to match the available intraday wholesale payments data. The design of the calibrated model for intraday settlement merges intraday LVTS payments with simulated intraday ACSS payments to generate combined intraday net positions for each participant between 2004 and 2014. The next sections expand on the techniques used in the manipulation of this dataset in order to generate intraday retail payments and batches of total payments and implement a rolling window mechanism to analyse intraday credit exposures.

4.1 Generating Simulated Retail Payments

Due to the limited nature of currently available ACSS data, retail payment observations are restricted to end-of-day net settlement obligations (NSO) for each participant. Conducting the appropriate analysis on intraday payments required simulating intraday retail payments by treating each participant's end-of-day NSO with a known intraday retail payments distribution.

The known intraday payments profile used in this paper derives volume of gross payments per minute from the U.K. Faster Payments system. The payments profile represented by the system exhibits the usual charactersitics of retail payment activity on an average day. The morning hours show a rapid increase towards a peak in volume at around 11:00 am, after which activity slows down to a moderate level of payments, and is assumed to be representative of Canadian retail payments behaviour on an average day.

This distribution was applied to the ACSS E.o.D observations to estimate intraday retail payment activity.

The following assumptions were made for the generation of intraday retail payments:

(a) Every individual retail payment P_i follows an unknown distribution with mean μ and σ.

(b) The sign conventions for payments sent to and from the system were matched to the LVTS:

(i) If $P_i>0$ then the payment is sent by the financial institution

(ii) If $P_i<0$ then the payment is received by the financial institution

(iii) The total number of daily payments sent to and from each participant is n_d

In a given day, a participant sends or recieves 'n' payments, where 'n' is very large. Currently, payments are netted out in the ACSS and the end-of-day NSO for each participant is observed:

$$\sum_{j=Participant,i=1}^{n_d} p_{j,i} = NSO \tag{1}$$

Where NSO>0 implies an obligation of the participants with ACSS, whereas NSO<0 implies an obligation of ACSS with the participant.

From the Central Limit Theorem, the sum of all payments received is equal to:

$$\begin{aligned} \lim_{n_d \to +\infty} \sqrt{n_d} \left[\frac{1}{n_d} \sum_{i=1}^{n_d} p_i - \mu \right] &\to N(0, \sigma_d^2) \Leftrightarrow \\ n_d \left[\frac{1}{n_d} \sum_{i=1}^{n_d} p_i - \mu \right] &\approx \sqrt{n_d} N(0, \sigma_d^2) \Leftrightarrow \\ \sum_{i=1}^{n_d} p_i &\approx N(n_d \mu, n_d \sigma^2) \end{aligned} \tag{2}$$

When n_d is very high, the formula becomes

$$\sum_{i=1}^{n_d} p_i \approx N(n_d \mu, n_d \sigma^2) \tag{3}$$

Using the observed distribution of payments in the ACSS, and the observed number of payments per participant, values of the underlying distribution can be obtained (μ_d and σ_d^2) and therefore generate the underlying sent and received payments. For daily observed means and variances μ_d

and σ_d the following can obtain:

$$\mu = \frac{\mu_d}{n_d}$$
$$\sigma = \frac{\sigma_d}{\sqrt{n_d}}$$

Given the daily observed mean and variance the following expression signifies the end-of-day NSO for each participant, where n_d is the total number of payments during a day:

$$\sum_{i=1}^{n_d} p_i \tag{4}$$

Similarly, if payments are accumulated by minutes with n_m signifying the total number of payments in a given period of minutes, the following distribution can be generated:

$$\sum_{i=1}^{n_m} p_i \approx N(n_m\mu, n_m\sigma^2) = N\left(n_m\frac{\mu_d}{n_d}, \left(n_m\frac{\sigma_d}{n_d}\right)^2\right)$$

After the characteristics of the distribution are obtained, simulated retail payments are then generated through random draws with moments μ and σ. Figure 5 graphically compares the distribution of generated payments with the observed NSO for a single participant over the time period of 2004-14. Similar results have been produced for each participant during the same time period, and Table 3 compares the skewness, the 90th and 1st percentiles of the simulated and observed NSOs for each participant. As mentioned earlier, the direction of the skewness determines whether the participant is a net sender or reciever. The simulated and observed datasets exhibit similar participant behaviours in most cases, and the magnitudes of the three variables, indicate an acceptable level of discrepancy. It is obvious that the availability of actual intraday retail payments data would augment this analysis.

4.2 Generating Batches

Once intraday retail payments n_m for each participant between 2004 and 2014 are simulated, payment batches - aggregations of payments - over time periods ranging from one minute to eight hours are calculated. A batch of payments is a function of the period within which the payments are aggregated. As the time period increases from one minute to eight hours, the batch size or the aggregated payment value and volume increases from individual payments to a single payment containing eight hours worth of transactions, respectively. Payment batches are created on an individual participant basis and are an aggregation of all payments sent and received within that time period:

$$Batch = \sum_{j=part, i \epsilon [Minute]}^{n_d} p_{j,i} \tag{5}$$

Each participant's intraday retail payment and high-value payment activities are aggregated to create augmented batches containing combined payments. These augemented batches are then examined and compared to study the intraday net positions and participant exposures across the current and combined configurations of the systems. Table 4 compares the daily average value and volume of total LVTS and batched ACSS payments for each participant. For some participants as the ACSS batch size increases, the value and volume of payments relative to their LVTS activity is enhanced.

These combined and batched payments are representative of potential activity in a "calibrated" payment system where, unlike the ACSS and LVTS, all payments are cleared and settled in an HVPS. The analysis conducted in this paper compares participant exposures, the effects of multiple settlement stops and the netting benefits across the three systems.

4.3 Rolling Window

Exposures of participants in the ACSS, LVTS and a "calibrated system" are:

(1) Analysed on an intraday basis for each business day of 2014.

(2) Compared across the system setups, specifically studying the impacts of various payment batch sizes.

A "rolling window" tool is applied across a dataset that consists of LVTS payments, simulated ACSS payment batches and combined payments for 12 participants over 2014. Figure 5 demonstrates the function of a rolling window by capturing the highest exposures that fall within a predefined time window and is adjusted at predefined time intervals. Window sizes range from 90 minutes to 24 hours to capture the evolution of exposures during a day for each participant. As shown in Figure 5 the average of the daily exposures for a participant across the various window sizes is calculated and a risk profile is developed.

5 Results

In this section, results from applying the aformentioned methodologies are discussed. More specifically, this includes (i) the relationship between participant size and their exposures in the combined system, (ii) the effects of batched payments on exposures, (iii) implementation of potential settlement stops and (iv) the trade-off between liquidity and credit risk given multiple intraday settlement windows is analysed.

5.1 Effects of Combining Retail and Wholesale Payments

The first stage of the analysis provides insights into the implications for exposures and risks of combining, clearing and settling both payment types in a single system.

Figure 7 shows how the effects of combining retail and wholesale payments are dependent on the size of a participant. The sizes of a participant's combined LVTS exposures are observed and compared. Evident are differences in participant exposures that might be reflective of their LVTS and ACSS payment activities. On average, higher levels of LVTS exposures are representative of larger participants and they display minimal changes in total exposure when combining payments. Smaller participants exhibit lower levels of LVTS exposures and display significant changes in total exposure after combining their payments. This might be due to larger participants having more ACSS payments than smaller participants and thus finding the increases in exposures to be insignificant. The increased value and volume of payments for smaller participants allows for the realization of netting efficiencies and is a contributing factor to their total exposures. Figure 7 shows significant variation in total exposures between small participants, which may be attributed to the behaviour of these participants in the ACSS. In the combined system, the group facing a decrease in total exposures are net receivers in the ACSS and contribute to a reduction in their LVTS exposures, whereas the group facing increasing exposures are net senders and contribute increasingly to LVTS exposures.

Similar analysis is conducted on combined payments during November and December 2006 to examine the impact that hightened retail activity during the holiday period would have on total participant exposures. Similar to the results in Figure 7, seasonal retail payments have minimal effect on larger participants. However, as a consequence of enhanced retail activity, net senders in the ACSS contribute significantly to their LVTS activity and deal with appreciably higher combined exposures when compared with net receivers who experience a reduction in exposures. Regardless of participant characteristic, combined exposures are consistently larger during the "holiday season" than in any other period during the year.

For completeness, exposures during periods of increased stress were analysed. Specfcially between August 2007 and December 2007 when there was a significant contraction in the asset-backed commercial paper (ABCP) market in Canada. According to Covitz et al. (2009) the ABCP market suffered a $350 billion contraction in the last five months of 2007 due to runs on ABCP programs. Collateral pledged at the Bank of Canada for LVTS activities, as well as for other purposes, is composed of many asset classes, including ABCP, and the contraction would have impacted the liquidity available to members. However, the results from this analysis do not demonstrate any significant impact on participant exposures in the calibrated system.

Also analysed were the levels of exposures generated by batching aggregated payments. Payment batches ranging from one minute to six hours were developed to determine their netting effects on participant exposures and sensitivity to a set of window sizes. Batch exposures are compared across system participants, and their potential effects on exposures studied.

Figure 8 shows the maximum exposures that participants generate during an average day in 2014 where their payments are batched. As mentioned in the methodology section, a single batch contains aggregated payments over a specified time period, whereas a rolling time window accumulates consecutive units of time (hours). It can be observed from the figure that, on average, the maximum exposure of a participant decreases as the batch size increases, regardless of the window size. For a four-hour window size, the exposures for Participant A increase from approximately $950 million - when four hours worth of payments are accumulated and netted and exposures are calculated - to almost one billion when individual payments contribute on a gross basis to the intraday position and increase exposures. Increasing the batch encapsulates a larger volume of payments, which allows for further netting and a reduction in exposures. Also evident are increases in exposures (for all batch sizes) as window sizes increase, since this allows for more frequent instances of encapsulating higher pariticpant debit positions. Eventually, a window the size of a full operational day will capture the largest debit position and have the highest exposure compared with smaller window sizes.

Participant characteristics are a factor in the severity of batch exposures. A comparison of Figure 8a with Figure 8b demonstrates a minimal difference in exposures for participant B, regardless of the batch or window size. This variation between participant A and B is representative of others in the system. Most participants exhibit a considerable reduction in exposures when their payment batch sizes increase, but the rate of reduction decreases as batch sizes grow larger than two hours. Most participants exhibit significant reductions in exposures due to payment batching.

5.2 Further Extensions

As an addition to examining differences in exposures, effects of multiple intraday settlement stops and potential netting efficiencies were also studied.

Intraday settlement stops were implemented in the calibrated system at four intervals: 12pm, 2pm, 4pm and EoD. At each time stamp, the net positions for each participant are settled and a new intraday session begins immediately after, at which point the net positions are calibrated back to zero.

Figures 9a and 9b show the intraday maximum debit positions, on average, in 2014 for two participants. The charts compare maximum positions for these participants under an EoD settlement and multiple intraday settlement regimes. The 45-degree line represents the highest exposure incurred by the participants in 2014 and highlights differences in maximum exposures under the various intraday settlement stops.

As can be observed, the participants exhibit similar results when implementing multiple intraday settlement stops. On average, the maximum intraday exposure is higher for participants and occurs more often under a multiple-settlement scheme. Under this scheme, the risk faced by participants is reduced, mainly due to the duration of the exposure. However, shorter periods lead to lower netting efficiency, thus producing, on average, higher maximum exposures. The trade-off between higher exposures and shorter periods of exposure is an important policy decision faced by numerous operators.

Table 5 shows the percentage of days where each intraday settlement regime produces the highest exposure, on average, for each participant. From a sample dataset of 252 business days in 2014, most participants are better off with a higher number of settlement stops, with the exception of participants four, five and six, who show an increase in the number of days with worse exposures as multiple intraday settlement is implemented. Some participants exhibit significant "gains" from the addition of more settlement windows, whereas some are no better off. This result mirrors the relationships between participant size and the effects of batching ACSS entries from participants when combining retail and wholesale payments.

This analysis does not take into account the anticipatory changes in participant behaviour in light of adding multiple settlement stops to a combined system. Participants may optimize the timing of payment messages sent as multiple settlement stops are incorporated. Behavioural changes are beyond the scope of this paper but should be considered for future work.

Figure 11 represents the evolution of the intraday net positions of a participant on February 3, 2014. As the legend in the chart suggests an end-of-day settlement scheme has a lower net position at every time stamp when there is a proposed settlement stop. The intraday net position follows a similar path before the first window, at which point all positions level off and the participant begins sending payments in the new session. This figure reinforces the result of the earlier analysis that the increase in settlement windows reduces the duration of exposure but also the netting efficiency of a participant and primarily represents a trade-off between credit risk and liquidity risk.

The plot of the netting ratio shown in Figure 10, is calculated as:

$$Netting\ Ratio = \frac{Net\ Position}{\sum |Gross\ Payments|} \tag{6}$$

This ratio provides insights on how exposures and settlement frequency are related to any trade-offs that exist between the two factors. The figure illustrates an inverse relationship between the netting ratio and the settlement window size. As the settlement window size increases from one to eight hours, the netting ratio decreases exponentially. The size of a time window is proportional to the amount of gross payments and therefore – consistent with the mechanisms of netting – a decrease in the netting ratio and increase in netting efficiency. More time between settlements ultimately leads to reduced exposures in the system. However, it is important to note that the netting efficiencies occur at a decreasing marginal rate. When settlement reaches approximately two hours, the gains of netting efficiency from additional time between settlements is reduced significantly. This ultimately points to the existence of an optimal timing for settlement.

A natural extension to calculating exposures faced by the participants in a combined system is to consider the cost of collateral to potentially cover the exposures. Considerations should be made regarding the collateral participants would pledge to cover the largest intraday positions and the existence of risk controls to cover all risk. Collateral costs are a function of participant preferences; namely, the ability of participants to vary pledged collateral intraday. In an RTGS case, each payment has to be collateralized, and the representative cost would approximately be the total area under the intraday position line in Figure 4.

6 Conclusion

This paper has attempted to study the risks that participants face in a system where their intraday retail and wholesale payments are combined. The focus is on four key points: (i) the relationship between the size of the participants and the effects of combining, (ii) the effects of batching combined payments on risk exposure, (iii) the effects of multiple intraday settlement stops on exposure, and (iv) the netting efficiencies and trade-offs between credit and liquidity risks.

Results from the analysis suggest that participant size and activity are key in understanding the effects of combining intraday retail and high-value payments. Implementing potential settlement stops to control the duration of credit risk exposures has an adverse effect on the overall positions. These results may also help inform policy decisions, especially when considering potential system designs.

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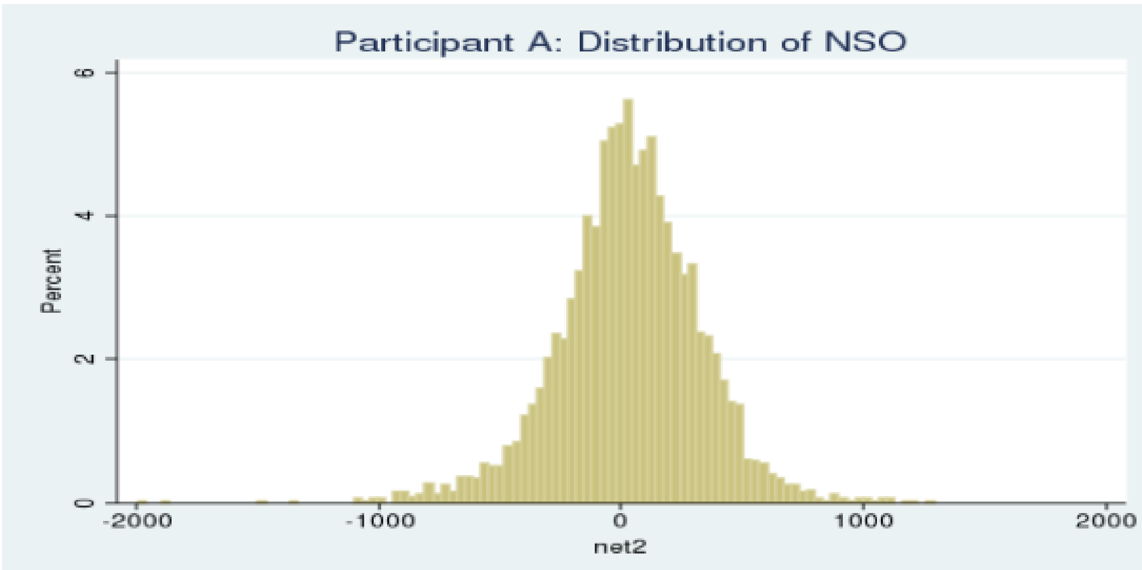
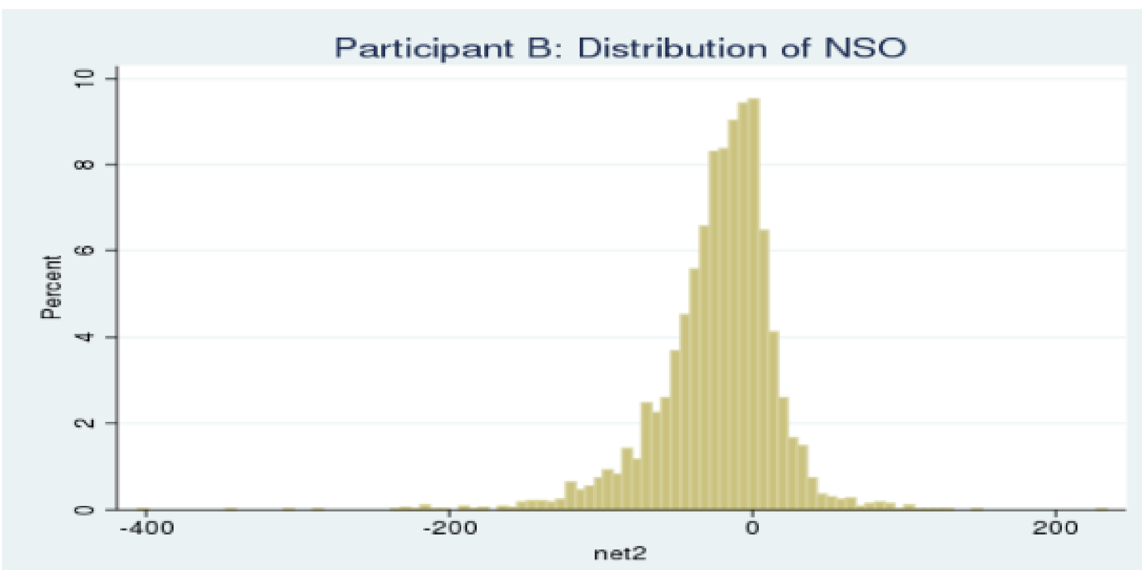
A Figures and tables

Figure 1: Evolution of net settlement obligations in the ACSS

This figure shows the distribution of net settlement obligations for two participants in the ACSS for the period 2004–14. A few extreme values are eliminated for confidentiality reasons. A positive value signifies a debit position of the bank. A negative sign signifies a credit position of the bank. Source: Bank of Canada calculations using Payments Canada data.



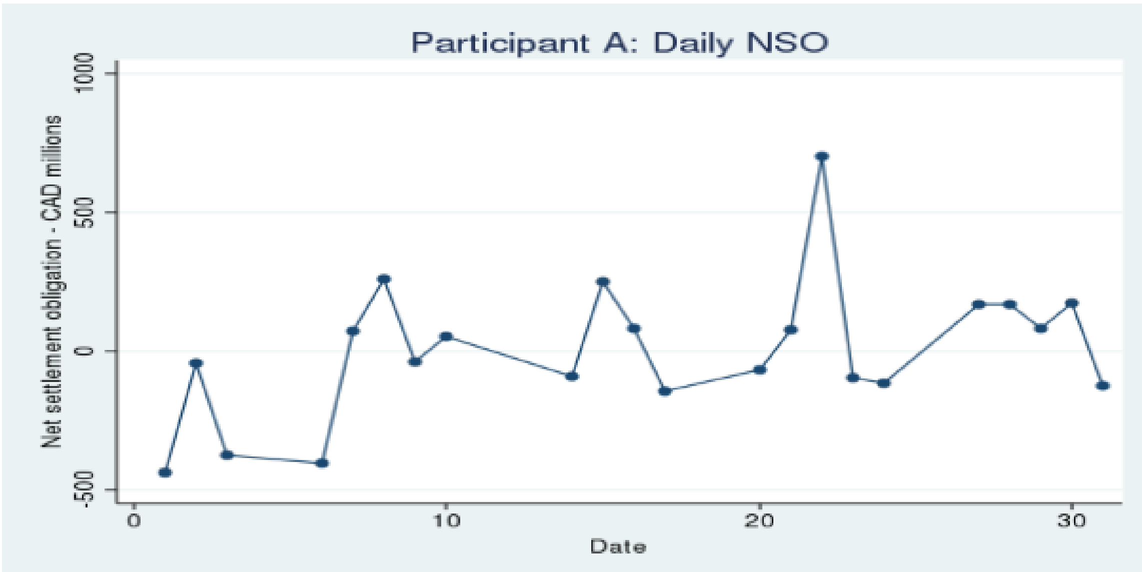
(a) Distribution of net settlement obligations for Participant A



(b) Distribution of net settlement obligations for Participant B

Figure 2: Net settlement obligations of two participants

This figure shows the daily net settlement obligations with the ACSS of two participants during October. A positive value signifies a debit position of the bank. A negative sign signifies a credit position of the bank. Source: Bank of Canada calculations using Payments Canada data.



(a) Net settlement obligations for Participant A

(b) Net settlement obligations for Participant B

Table 1: Regressions for net settlement obligations on lagged values.

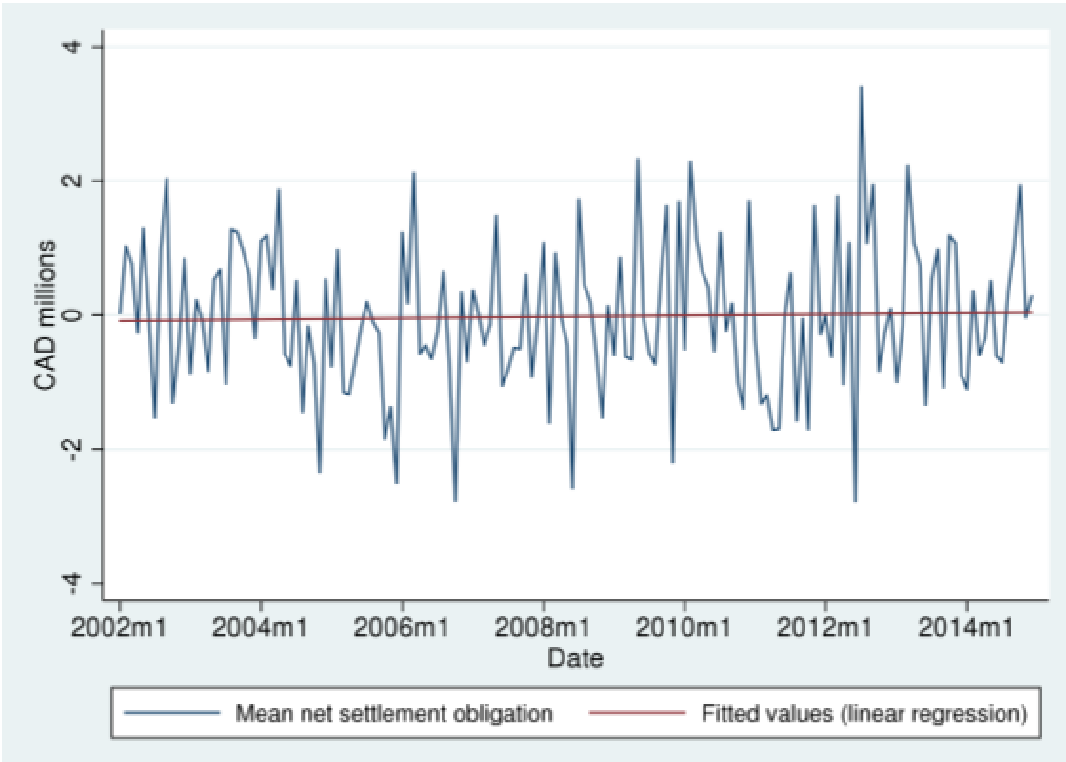
This table shows results of OLS regressions of net settlement obligations on lagged values for every participant in ACSS for period 2002-2014. We use banks level and weekly fixed effects. Source: Bank of Canada calculations using Payments Canada data.

Regressors	(1)	(2)	(3)
Lag net obligation	0.0435***	0.0277***	0.0277***
	(0.00944)	(0.00949)	(0.00960)
Participant fixed effects	NO	YES	YES
Weekly fixed effects	NO	NO	YES
Constant	-0.0448	5.928e+07***	5.928e+07
	(1.037e+06)	(5.584e+06)	(6.227e+07)
Observations	30,888	30,888	30,888
R-squared	0.002	0.019	0.019

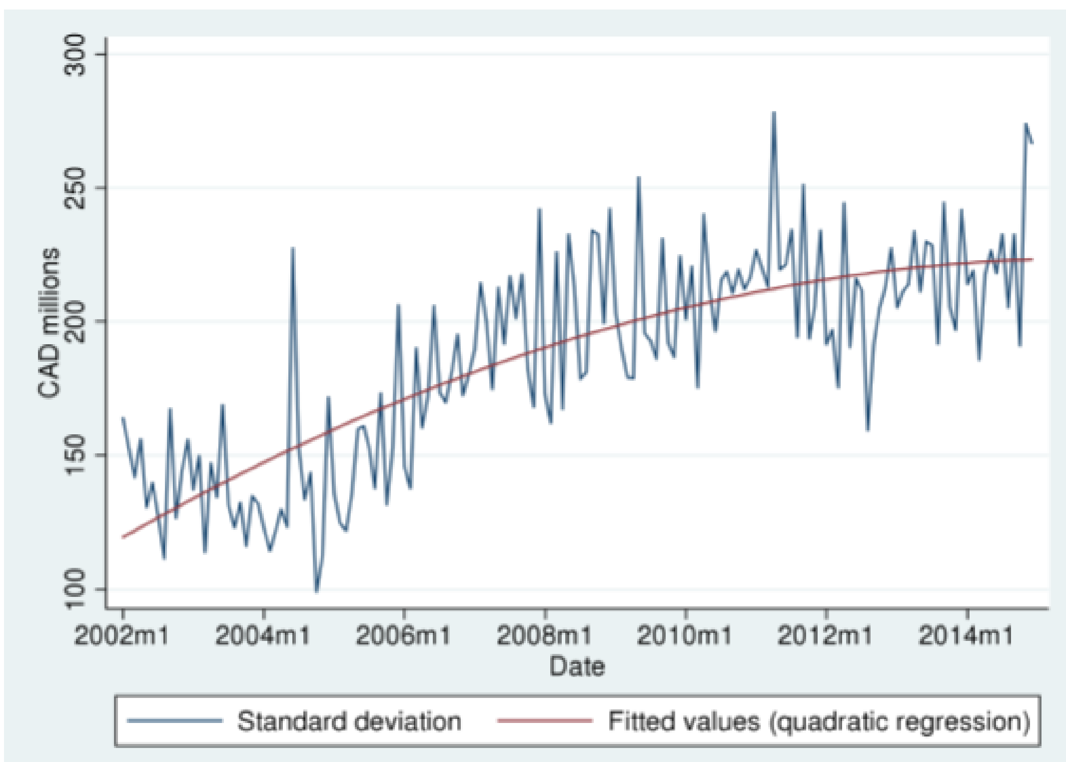
Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Figure 3: Evolution of net settlement obligations in the ACSS

This figure reports the evolution of key statistics for the period 2002-14. Mean and standard deviation of net settlement obligations across participants for every month are caluclated and fitted linear and quadratic regressions are included. Source: Bank of Canada calculations using Payments Canada data.



(a) Mean of net settlement obligations across participants for every month



(b) Standard deviation of net settlement obligations across participants for every month

Figure 4: LVTS Intraday Positions

This figure shows intraday position of a participant in the LVTS on a single day in October of 2014. Source: Bank of Canada calculations using Payments Canada data.

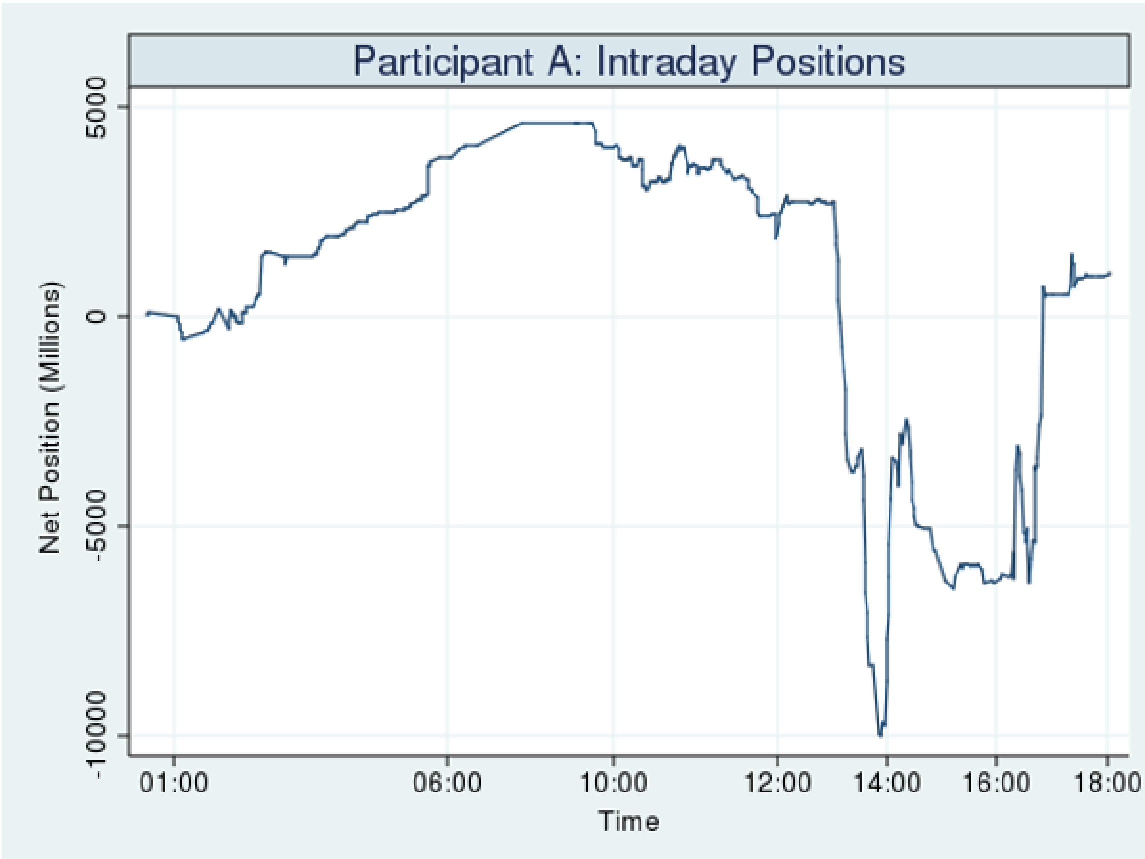


Table 2: Characteristics of LVTS Payments

This table represents the average daily characteristics of total LVTS payments . Source: Bank of Canada calculations using Payments Canada data.

	Tranche 1	Tranche 2	Total
Value of Payments Sent	\$ 43B	\$ 127B	\$ 170B
Volume of Payments Sent	399	31,559	31,958
Value of Collateral Pledged	\$ 12B	\$ 5B	\$ 18B
Value of Collateral Pledged per Dollar of Payment Sent	\$ 0.23	\$ 0.04	\$ 0.01

Figure 5: ACSS Payments Comparison

This figure compares the distribution of actual and simulated payment flows for Participant A. Source: Bank of Canada calculations using Payments Canada data.

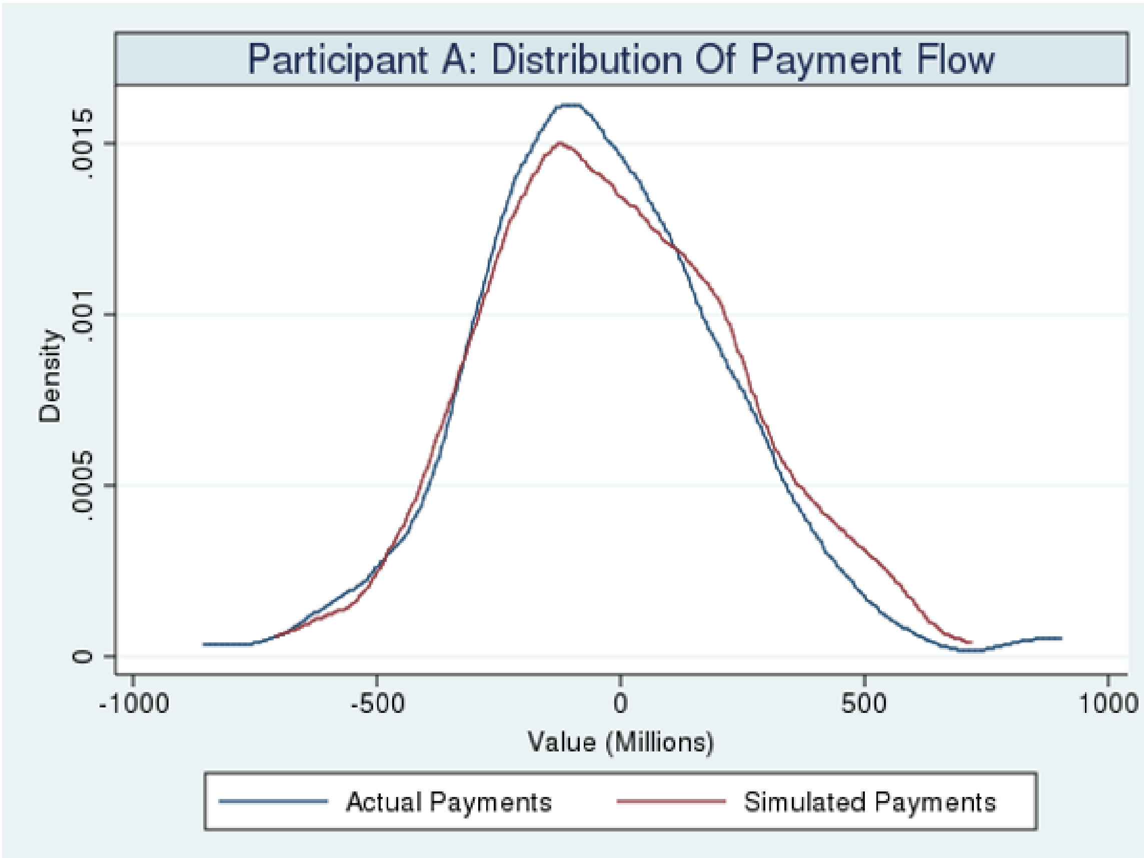


Table 3: Key Statistics of ACSS Payments

This table compares descriptive statistics of the simulated and actual ACSS payments (between 2004-2014). The columns 'observed' and 'simulated' denote the skewness and percentiles of observed and simulated payments values per participant respectively

	Observed vs Simulated ACSS Payments (2004-2012)					
	Skewness		90th percentile		1st Percentile	
	Observed	Simulated	Observed	Simulated	Observed	Simulated
Bank :						
P1	0.1	0.0	248.8	257.4	-601.5	-613.3
P2	-0.2	0.2	225.6	258.9	-702.1	-644.6
P3	0.5	0.1	485.6	510.6	-918.1	-976.5
P4	-0.3	-0.1	380.6	403.0	-825.3	-776.6
P5	-1.3	-0.9	136.9	143.6	-353.4	-348.3
P6	0.3	-0.1	250.7	269.2	-587.1	-568.5
P7	-0.4	-0.3	94.3	94.8	-175.9	-214.0
P8	-1.5	-1.4	25.3	31.5	-192.5	-183.9
P10	-1.3	-0.7	15.1	20.0	-145.3	-138.0
P11	0.6	0.2	116.9	130.8	-223.1	-206.2
P12	0.3	0.2	134.9	138.1	-239.1	-223.0

Table 4: Characteristics of Daily Average LVTS and ACSS Batch Payments

This table compares Daily Average LVTS payments and ACSS batch payments (between 2010 and 2014). Values are denominated in millions and Volumes are denominated in units.

	Period 2010-2014 (Payment Statistics)															
	LVTS		1 Minute		5 Minute		15 Minutes		30 Minutes		2 Hours		4 Hours		6 Hours	
	Value	Volume	Value	Volume	Value	Volume	Value	Volume	Value	Volume	Value	Volume	Value	Volume	Value	Volume
Bank :																
P1	12,678	2,486	4.4	1,677	21.8	8,382	65.5	25,140	131.0	50,263	523.0	200,640	1,043.2	400,188	2,072.6	795,409
P2	10,020	1,566	4.7	1,427	23.4	7,133	70.2	21,394	140.3	42,773	560.1	170,743	1,117.1	340,556	2,219.8	676,885
P3	44,279	4,996	8.1	2,929	40.5	14,645	121.4	43,925	242.8	87,820	969.1	350,559	1,932.8	699,209	3,840.4	1389740
P4	15,657	3,382	6.5	2,040	32.4	10,199	97.1	30,589	194.2	61,156	775.1	244,124	1,546.1	486,918	3,071.8	967,793
P5	6,279	498	2.1	698	10.6	3,489	31.7	10,463	63.4	20,919	253.2	83,505	505.1	166,555	1,003.4	331,044
P6	24,448	3,038	4.6	1,663	23.0	8,313	69.0	24,935	138.0	49,852	550.9	199,000	1,098.8	396,917	2,182.7	788,907
P7	3,504	1,040	1.7	403	8.5	2,017	25.6	6,050	51.1	12,096	204.1	48,287	407.1	96,310	808.7	191,425
P8	223	168	0.9	85	4.3	423	13.0	1,270	26.1	2,539	104.1	10,134	207.5	20,212	412.4	40,173
P10	402	119	0.8	166	4.2	831	12.6	2,493	25.3	4,985	100.9	19,897	201.2	39,686	399.7	78,880
P11	2,458	218	2.0	558	9.8	2,790	29.5	8,369	59.0	16,732	235.5	66,790	469.8	133,217	933.5	264,780
P12	519	281	2.0	641	10.1	3,204	30.3	9,608	60.6	19,210	242.1	76,683	482.8	152,949	959.2	304,000

Figure 6: Rolling Window

This figure represents the rolling window methodology applied in our analysis. As is evident, the size of rolling window A is smaller than that of rolling window B. Source: Bank of Canada calculations using Payments Canada data.

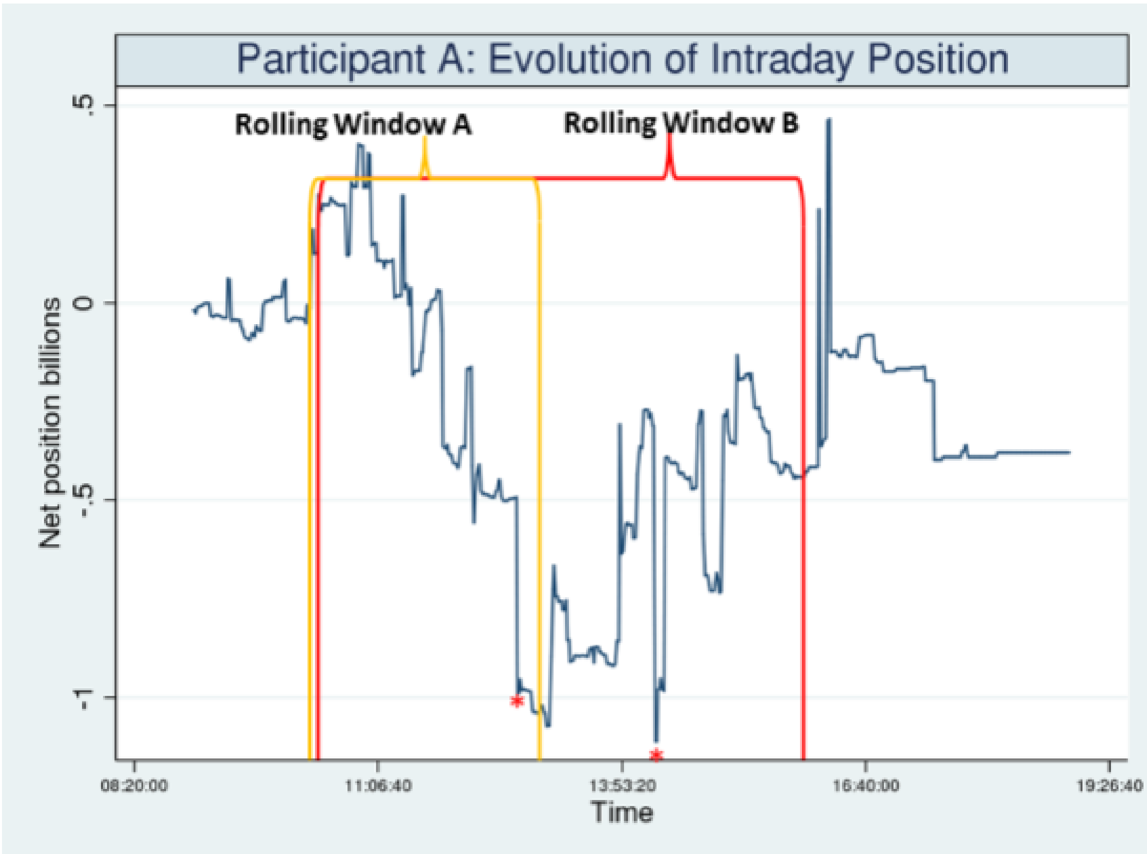


Figure 7: Participant Size Effects

This figure shows the relationship between participant size and the effects of combining retail and wholesale payments. Source: Bank of Canada calculations using Payments Canada data.

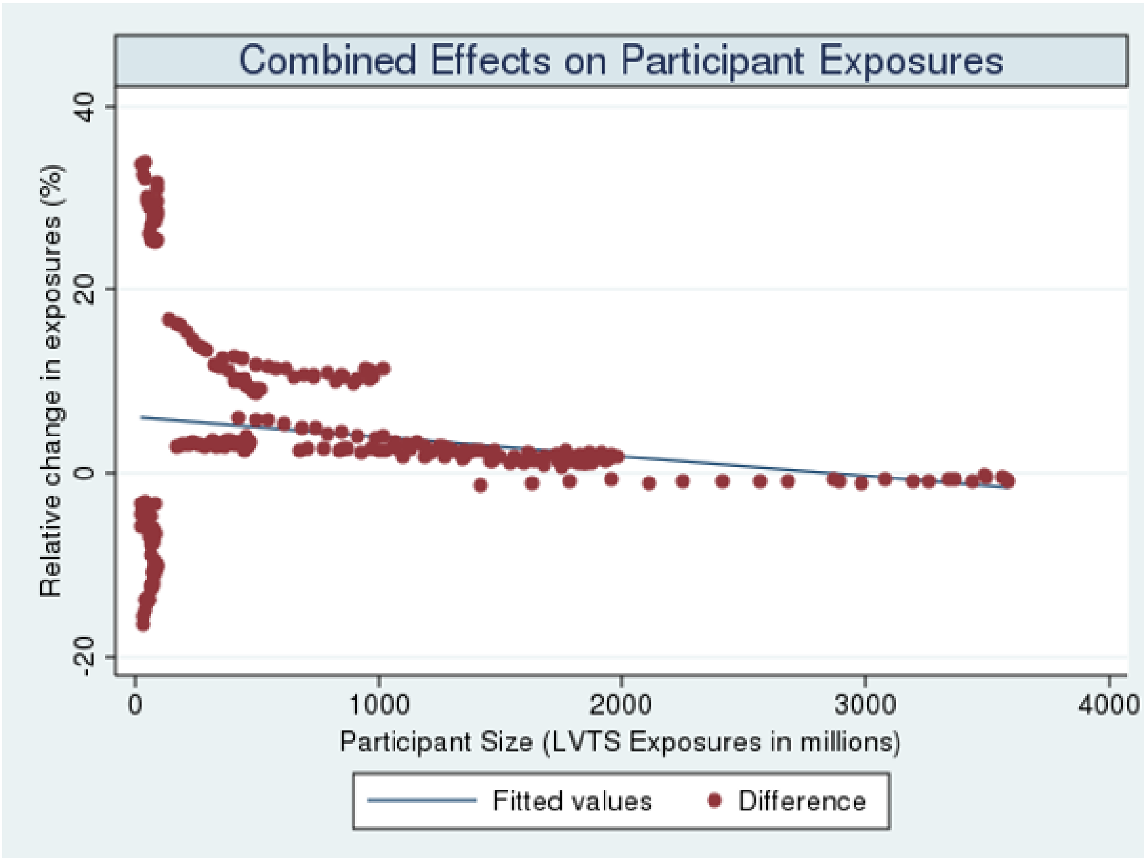
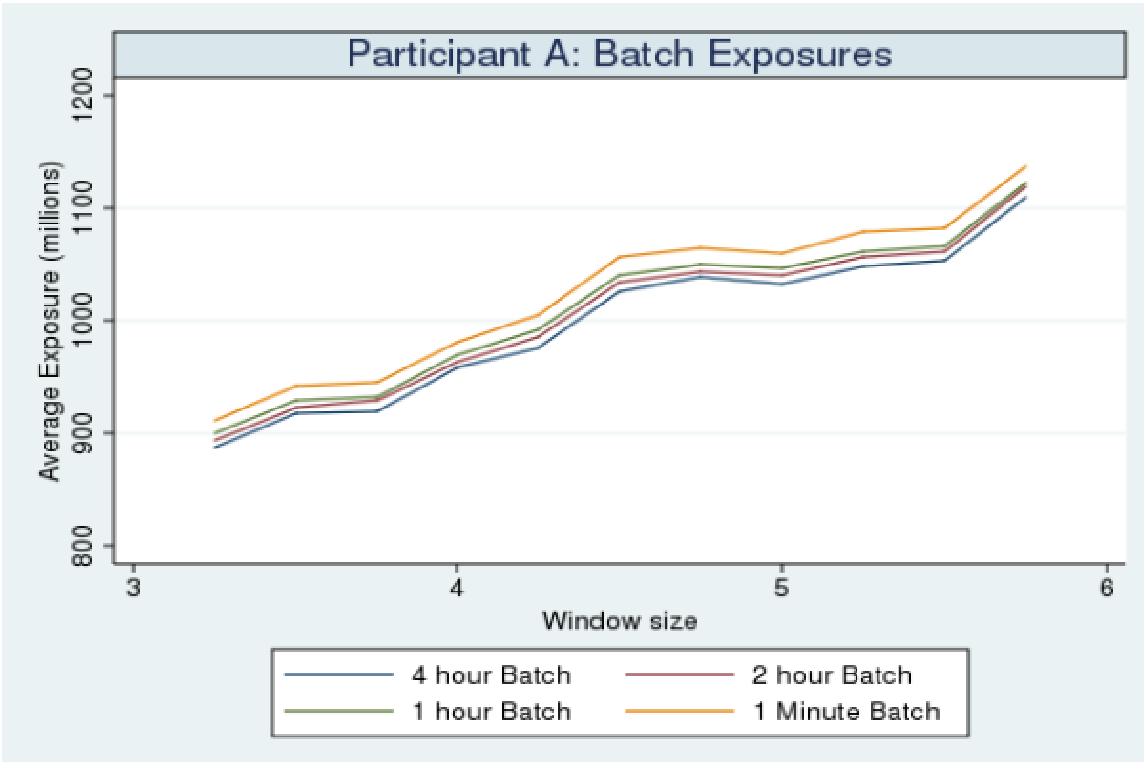
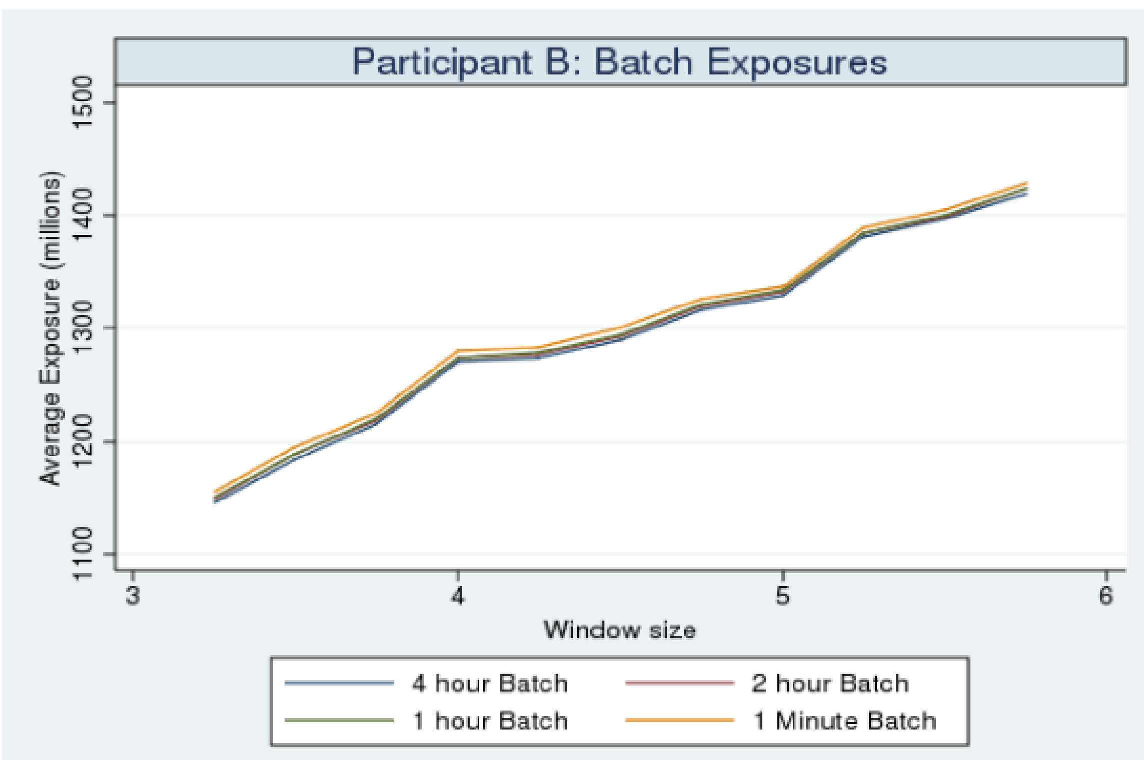


Figure 8: BatchExposure

This figure shows effects on participant exposures due to batches of combined payments. Source: Bank of Canada calculations using Payments Canada data.



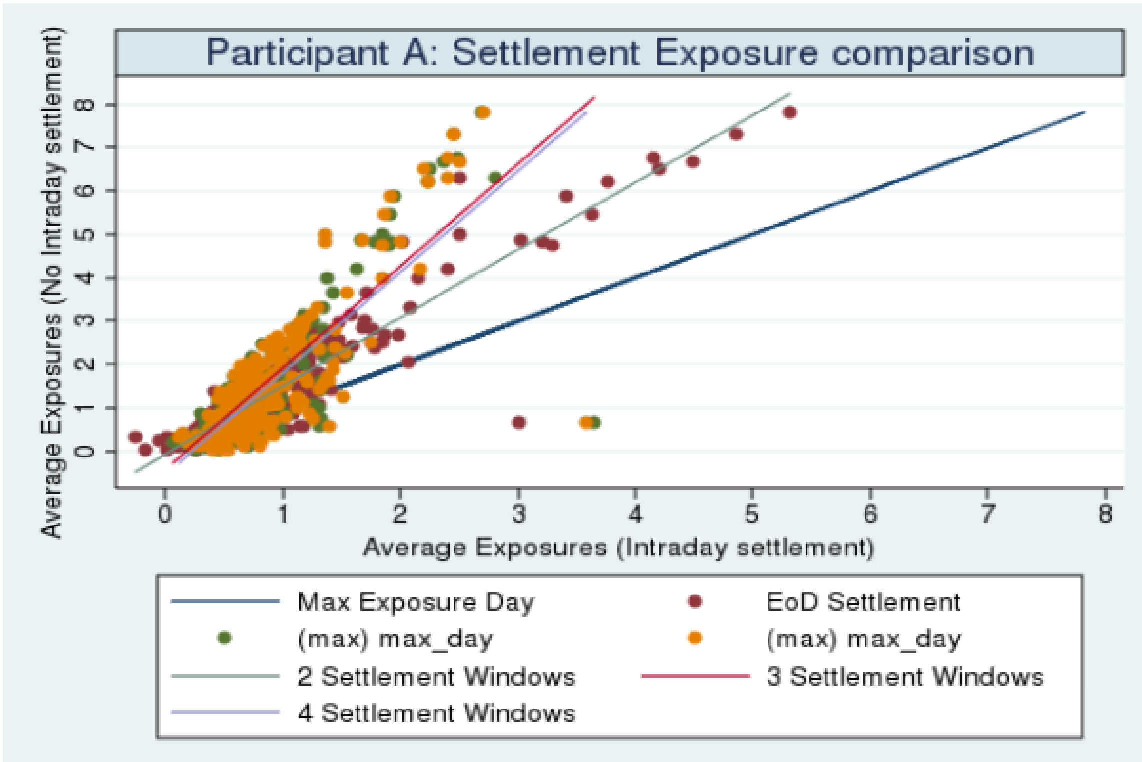
(a) **Net settlement obligations for Participant A**



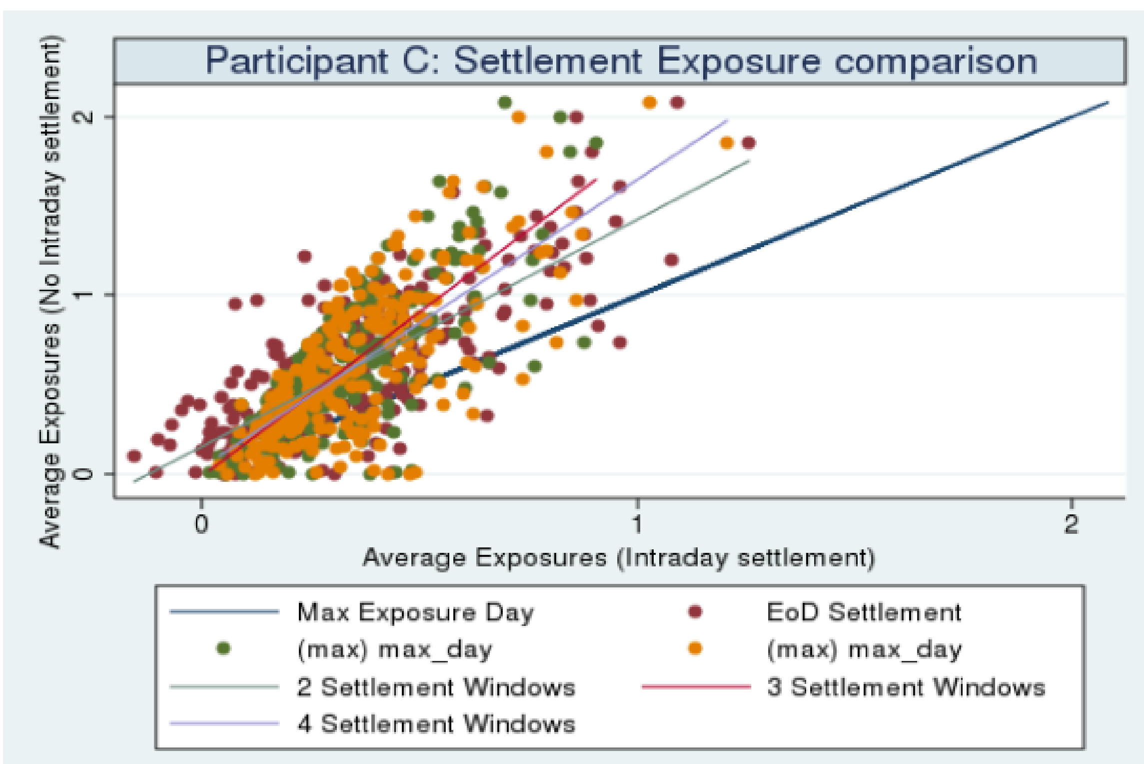
(b) **Net settlement obligations for Participant B**

Figure 9: Settlement Exposures

This figure compares exposures under various settlement stops. Source: Bank of Canada calculations using Payments Canada data.



(a) **Settlement Exposures for Participant A**



(b) **Settlement Exposures for Participant B**

Figure 10: Netting Efficiency

This figure demonstrates the trade-offs between credit and liquidity risks at various settlement hours. Source: Bank of Canada calculations using Payments Canada data.

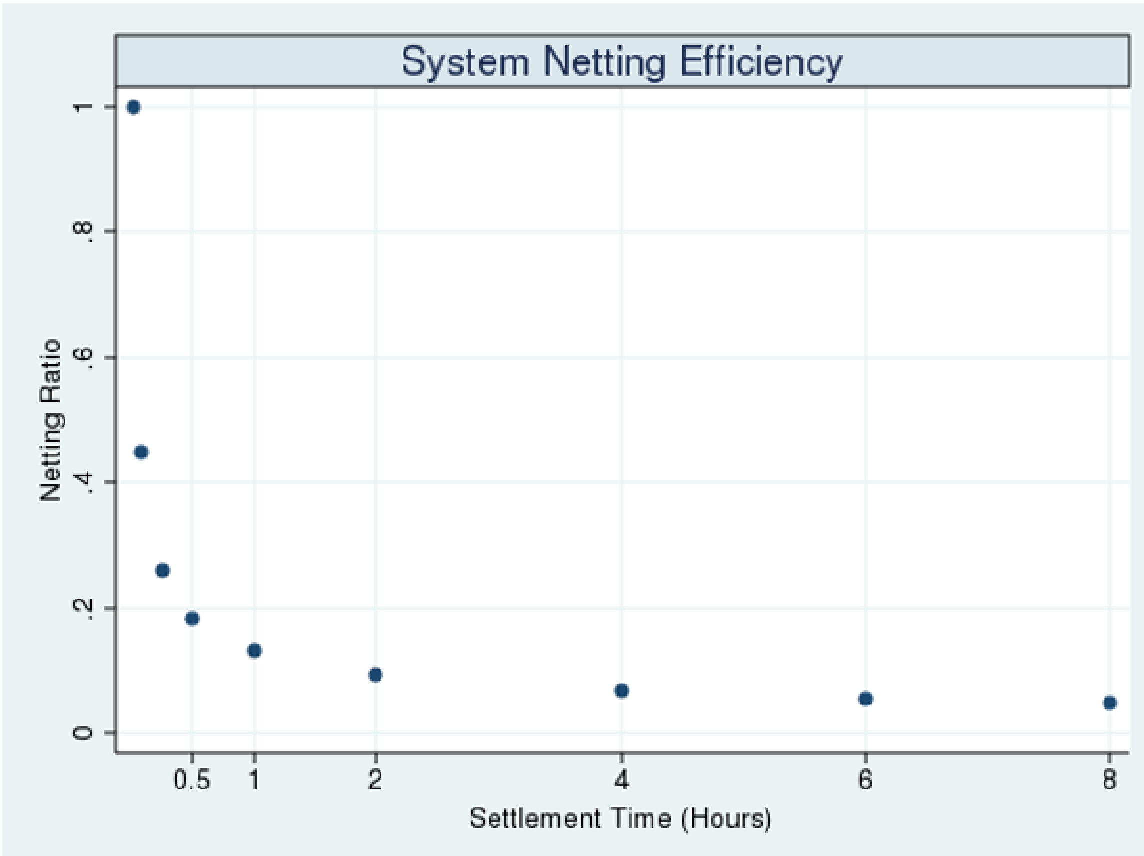


Figure 11: End of Day vs Multiple Settlement

This figure compares the evolution of intraday credit risks under multiple and EoD settlement stops. Source: Bank of Canada calculations using Payments Canada data.

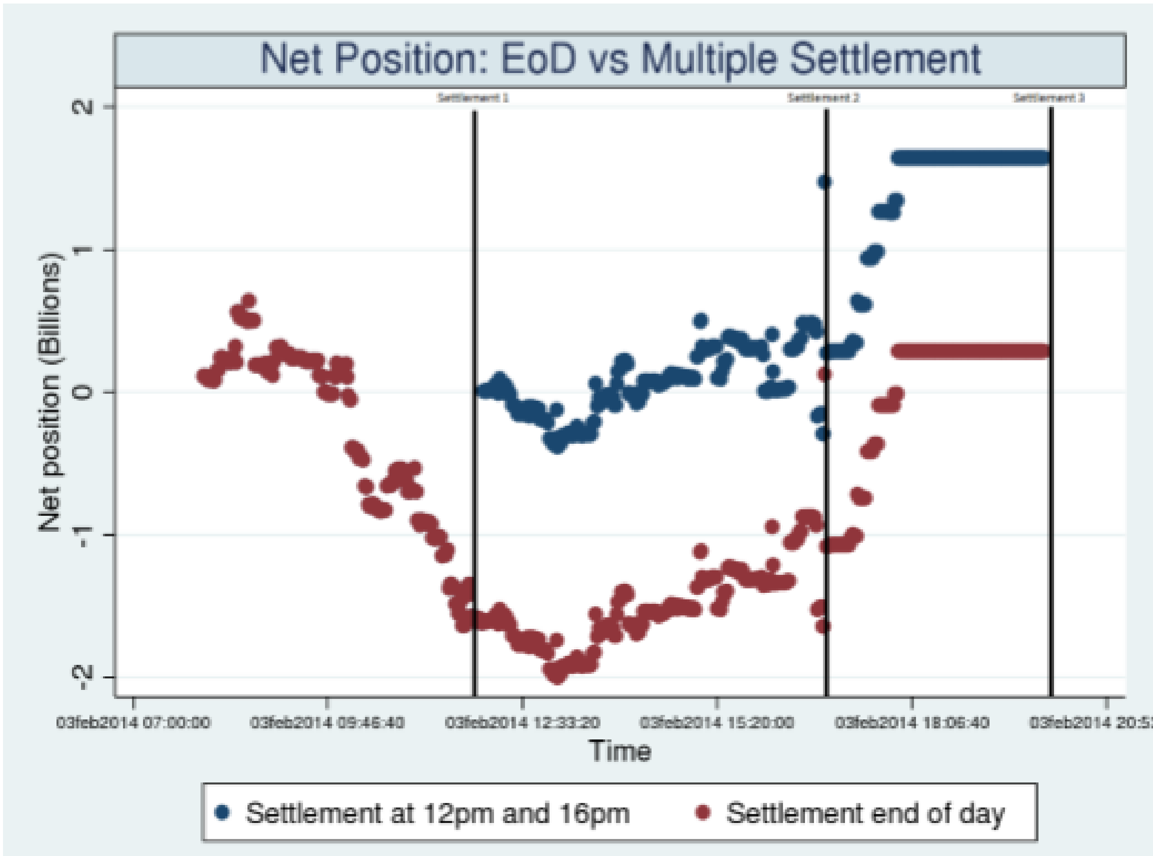


Table 5: Percentage of Days with higher exposures

This table shows the percentage of days with worse exposures under multiple intraday settlement than an end-of-day settlement stop. Source: Bank of Canada calculations using Payments Canada data.

	Percentage of days with worse exposures		
	2pm and EoD	12pm, 2pm and EoD	11am, 2pm, 4pm and Eod
P1	98.8%	97.2%	95.6%
P2	74.4%	65.0%	60.0%
P3	94.8%	87.6%	87.2%
P4	89.2%	90.4%	93.2%
P5	88.9%	90.0%	76.9%
P6	56.7%	21.3%	27.3%
P7	69.4%	68.5%	59.9%
P8	85.0%	83.7%	78.7%
P10	80.1%	63.9%	48.8%
P11	74.2%	56.7%	43.5%
P12	54.3%	51.5%	39.2%