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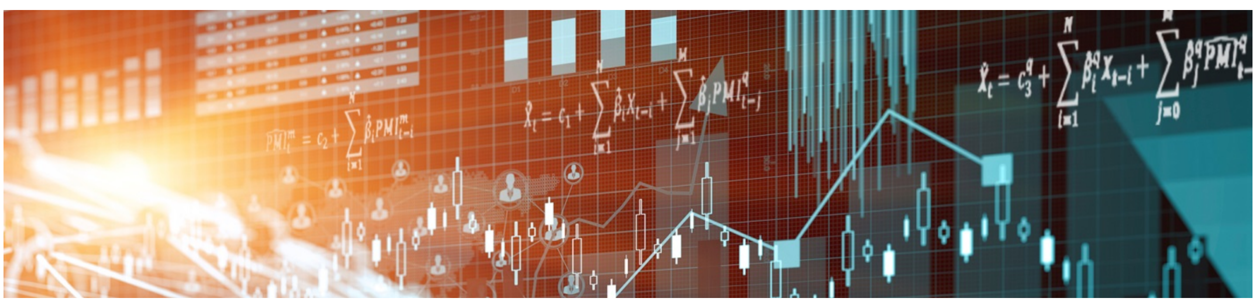
Credit Risk and Collateral Demand in a Retail Payment System



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Credit Risk and Collateral Demand in a Retail Payment System

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Abstract

The recent financial crisis has led to the development of new regulations to control risk in designated payment systems, and the implementation of new credit risk management standards is one of the key issues. In this paper, we study various credit risk management schemes for the Canadian retail payment system (ACSS) that are designed to cover the exposure of a defaulting member. We consider schemes that use a collateral pool calculated using a rolling time window. Our simulations show that the size of the window has a very significant effect on the average level of collateral and its variability day to day, creating an interesting trade-off. Collateral levels and variability may be important for ACSS participants because they could affect the opportunity costs of pledging collateral, and also the costs of managing it over time. Our results contribute to understanding the practical implementation of risk management schemes in the current and future generations of payment systems in Canada.

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

Résumé

La récente crise financière a donné lieu à l'élaboration de nouvelles règles visant à contrôler les risques dans les systèmes de paiement désignés, et la mise en œuvre de nouvelles normes de gestion du risque de crédit revêt à cet égard une grande importance. Nous étudions dans le présent document plusieurs méthodes de gestion du risque de crédit pour le système canadien de paiement de détail, à savoir le Système automatisé de compensation et de règlement (SACR), qui sont conçues pour couvrir l'exposition au risque de crédit pouvant résulter de la défaillance d'un participant. Nous examinons des méthodes faisant appel à un fonds commun de sûretés calculé sur une période mobile dans le temps. Nos simulations montrent que la longueur de la période a une incidence très significative sur le niveau moyen de sûretés et sur sa variabilité d'une journée à l'autre, produisant un arbitrage intéressant entre ces deux éléments. Les niveaux de sûretés et leur variabilité peuvent s'avérer importants pour les participants au SACR, car ils pourraient influer sur les coûts d'opportunité de la mise en gage des sûretés, ainsi que sur les coûts de gestion de ces sûretés au fil du temps. Nos résultats permettent de mieux comprendre l'application pratique de méthodes de gestion du risque au sein des générations actuelles et futures de systèmes de paiement au Canada.

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

1 Introduction

Payment systems are at the core of every country's financial system. They facilitate the clearing and settlement of retail and wholesale payments that are used by consumers, businesses and every financial institution. Because of their importance to the financial system, they are regulated and overseen by various authorities. The recent financial crisis has led to the development of new risk management guidelines and standards for major payment systems, such as the Principles for Financial Market Infrastructures (PFMIs), and the Bank of Canada has recently introduced risk management standards for prominent payment systems in Canada. These new requirements may introduce changes in the demand for collateral with unclear and potentially unexpected consequences. Our paper is one of the first attempts to study the possible effects of these new collateral requirements on a retail payment system. This paper focuses on Canada's retail payment system, the Automated Clearing Settlement System (ACSS).

We examine the implications of several credit risk management schemes that impose collateral requirements on ACSS participants to control credit risk in the event of a single participant default. We are interested in the effects of these schemes on the average collateral costs, the variability of the level of required collateral from day to day, and the shortfall in the case of a default. These three variables impact the opportunity costs faced by participants when they pledge collateral, the operational costs of managing the collateral, and the safety and soundness of the system. Acquiring, moving, processing and transforming collateral is costly and financial institutions may face adjustment costs and operational challenges when there are drastic and unexpected changes in the collateral requirements imposed in payment systems and other financial market infrastructures. The shortfall of financial resources in event of a default is also a key parameter considered by regulators when examining the safety and soundness of a system, as this represents a financial loss that is not covered by the pledged collateral.

We study two different collateral schemes. First, we consider a cover-all scheme that fully collateralizes the daily exposure of a retail payment system to the default of any of its participants. This is a defaulter-pays scheme, because any exposure created by the default is fully covered with the collateral pledged ex ante by the defaulter (shortfall is zero). This case is used as a benchmark for comparison. The cover-all case may not be desirable in practice because of the lack of intra-day coverage, as collateral must be pledged at the end of the day after net positions of every participant have been fully determined. This may be too late to fulfill the objective of controlling credit risk intra-day and overnight.

In the second scheme, we consider a cover-one method that uses a collateral pool with contributions from all participants. This collateral pool is designed to cover the exposure of the single largest default of a participant in the system. Therefore, this is also a survivor-pays scheme. In this scheme, the pool size is determined by calculating the largest exposure within a rolling time window and is adjusted at predefined time intervals. Participants' contributions to the pool are calculated at the beginning of the day using weights obtained from the largest participant's exposure within the time window. We use two different methods for calculating the weights. The first considers the maximum exposure that every participant incurred in the time window, whereas the second considers the average exposure of every participant within the same time window.

We use simulation techniques to understand the implications of using these two collateral schemes in the ACSS. The ACSS is used in Canada to clear retail (small value) payments. It does not currently impose any ex ante allocation of collateral on its participants to control credit risk, but this will change as a result of new proposed risk management standards for prominent payment systems. For our analysis, we use a sample of 13 years with daily participant data for the period 2002-14 and find a set of interesting results.

First, we analyze the statistical patterns of the daily payment flows in the ACSS. These payment flows can be categorized as multilateral net payment obligations of the participant with the ACSS (net debit position of the participant, positive sign), or net payment obligations of the ACSS with the participant (net credit position of the participant, negative sign). Following this sign convention, daily payment flows of every participant can be well approximated as independent random draws from a bell-shaped distribution with mean approximately equal to zero. The variance of this distribution is not constant over the period considered. We observe a significant positive trend in variance for the period 2006-12 due to economic growth and the substitution of cash payments with other electronic means of payment.

Second, we conduct simulations to show how the window size and the frequency of adjustment of collateral affects the average level of collateral required, and the variability of this collateral day to day in the cover-one scheme. Our simulations show that collateral levels and variability reach relatively stable values for relatively small window sizes (e.g., one year or more). Also, the confidence interval of having enough collateral to cover the shortfall because of a default reaches very high levels with relatively small window sizes. Regarding the two alternatives considered to calculate weights of every participant in the collateral pool, we find that the two methods differ significantly in the distribution of collateral pool contributions across participants.

Our results show that the window size creates a clear trade-off between average level of collateral required and variability of this collateral day to day for the cover-one scheme. A larger window size captures a wider range of observations through time and therefore higher net debit positions, leading to higher collateral requirements. Also, when the window is large, there is a greater persistence of these high debit positions, decreasing the variability of collateral day to day. In contrast, we find that the frequency of adjustment has a relatively irrelevant effect on these two variables.

Contrary to the cover-one scheme, the cover-all scheme is designed to fully cover the overnight credit risk created by every participant to ACSS, therefore there are no shortfalls from defaults occurring overnight. However, it does not account for intra-day credit risk. Also, because payment flows are random and independent from day to day, collateral requirements are very volatile from day to day, which can create financial and operational challenges when system participants manage their collateral pledged in the ACSS.

On the other hand, in a cover-one scheme, variability can be reduced when the window size is large enough. A greater window size identifies large extreme values from the historical distribution of payment flows that are used to determine the pool size. As a consequence, the average value of collateral is relatively large, but variability is low. This may be costly for participants, but collateral may also be easier to manage because the amount required is relatively stable for a long period of time.

Our results show that the design of a collateral scheme in a payment system requires a careful analysis of the implications for collateral demand and financial stability. Certain risk management schemes may significantly affect the incentives of the payment system participants and their behaviour in equilibrium. We provide some evidence of interesting behaviour of financial institutions in a payment system closely related to the ACSS, the Large Value Transfer System (LVTS).[1] The LVTS is a large value payment system used to clear and settle large value payments in Canada. Some key risk management variables are voluntarily determined by LVTS participants. We find that LVTS participants tend to choose key risk control variables that increase the average level of collateral pledged with a significant fraction of it unused on a daily basis, but significantly decrease its variability over time. This result is robust when considering different measures that are related to the cost of pledging collateral. Interestingly, we observe large heterogeneity of these measures across participants.

These results have implications that could be valuable for financial market infrastructure (FMI), participants, regulators and policy-makers. Currently, there is a set of risk management standards being implemented by central banks and regulators that are designed to improve the safety and soundness of payment, clearing and settlement systems in order to improve the resiliency of the financial system. Specifically, the PFMIs from the Committee on Payments and Market Infrastructures (CPMI) of the Bank of International Settlements (BIS, 2012) serve as important risk management principles for systemically important FMIs. Among other issues, the PFMIs discuss the importance of measuring, monitoring and managing credit risk exposures in payment systems. Interestingly, the PFMIs also discuss the need of having stable collateral requirements that are not procyclical.[2] The existence of abrupt changes of collateral requirements during a period of financial stress could trigger margin spirals and other effects, which may create additional stress and exacerbate the effects of a financial crisis.[3]

Our results may contribute to the understanding of the effects of different collateral schemes on the demand for collateral and the cost of holding and managing it for financial institutions. Additionally, different collateral schemes in payment systems that are substitutes to some degree can

[1] An interesting feature of the LVTS is that most participants are also ACSS participants, which could be helpful to understand better the implications of future collateral schemes used in the ACSS.

[2] They state that *"In order to reduce the need for procyclical adjustments, an FMI should establish stable and conservative haircuts that are calibrated to include periods of stressed market conditions, to the extent practicable and prudent."* (Principle #5, BIS 2012).

[3] For instance, financial institutions, in an effort to meet collateral requirements, may liquidate some of their assets, causing further price declines that might trigger additional collateral requirements (Brunnermeier and Pedersen, 2009; Raykov, 2014).

create arbitrage opportunities between the different payment systems, which may impact the distribution of payments that are being cleared and settled by every system in equilibrium. Therefore, our paper should provide important insights to be considered in the practical implementation of risk management schemes in the ACSS and other payment systems, including the next generation of payment systems in Canada, and the effects on the payments system risk to the financial system.

This paper follows a relatively large and recent literature on payment systems. The efficiency, safety and soundness of payment systems has been at the centre of the policy interest in most central banks for several decades (Berger *et al.*, 1996; Chapman *et al.*, 2015). There is a relatively large body of theoretical and empirical literature and much of it focuses on the study of systemic large value payment systems, as they are at the core of the financial system. The ACSS has received limited attention compared with the LVTS.[4] Researchers have studied such topics as network topology (Embree and Roberts, 2009; Bech *et al.*, 2010; Chapman *et al.*, 2011) or efficiency effects (Allen *et al.*, forthcoming). The issue of excess collateral in LVTS has also received significant attention by policy-makers and has been briefly discussed in McPhail and Vakos (2003) and Allen *et al.* (2011).

During the past years, there has also been a greater interest in understanding the effects of the new regulations in collateral demand (see Cruz Lopez *et al.*, 2013). Heller and Vause (2012), Sidanius and Zikes (2012) and Duffie *et al.* (2015) study this issue in the context of central counterparties (CCPs). Also, in a series of articles, Singh (2011) has studied in more detail aspects such as the use, velocity and rehypothecation of collateral by large global dealers in over-the-counter (OTC) markets. To our knowledge, our paper is the first to study this issue for retail payment systems in the context of the new financial regulations.

The rest of the paper proceeds as follows. In the next section we describe the main features of the ACSS, including the observed statistical patterns of retail payments. Section 3 discusses the issue of collateral demand and other costs of managing collateral, and some empirical evidence using data from the LVTS. Section 4 presents the two risk management methods considered, and Section 5 shows the results of our simulations. Section 6 concludes.

[4] Labelle and Taylor (2014) wrote one of the few studies available for the ACSS. They consider the exposures in case of a default of a participant, and compare them with the participants' capital and liquid assets. Northcott (2002) offers an early discussion on the considerations of ACSS designation.

2 The ACSS

2.1 Description

The ACSS, introduced in 1984, is owned and operated by Payments Canada and was designated by the Bank of Canada on 2 May 2016 to be overseen as a prominent payment system.[5] The ACSS is an uncollateralized deferred net settlement system. The majority of retail payment items in Canada are cleared through the ACSS (approximately 24 million items on average each business day). Each day payment items are exchanged between direct clearers, and data is entered into the ACSS to track the total volume and value of items in a particular stream (payment instrument). At the end of the daily exchange process, these entries are used to determine the multilateral net position of the direct clearers. The ACSS is used to clear a high volume of lower value, less time-sensitive payments that do not require intra-day finality provided by the LVTS. Settlement for the ACSS takes place on the direct clearers' settlement accounts on the books of the Bank of Canada via LVTS payments, on a deferred (next-day) multilateral net settlement basis after final positions are determined.

2.2 Regulatory Environment

Oversight and regulation responsibilities for payment systems in Canada are shared between the Bank of Canada and the Minister of Finance. The Minister of Finance has broad responsibility for the financial system in Canada, including payment systems, and also has regulation-making authority. The Bank of Canada has responsibility for the oversight of payment, clearing and settlement systems it has designated as having the potential to pose systemic or payments system risk to the Canadian financial system. Systemically important payment systems are subject to a set of international risk management standards based on the PFMIs, which were developed by the CPMI and the Technical Committee of the International Organization of Securities Commissions (IOSCO) at the BIS. Systems with payments system risk are of prominent importance but not systemically important, and therefore are subject to a set of standards that adopt aspects of the PFMI. For

[5] Prominent payment systems, while not systemically important, are critical for economic activity. In these systems, disruptions or failures could have the potential to pose risks to the economic activity and affect general confidence in the payments system.

this study, we focus on the proposed standard for credit risk, which states: *"A [prominent payment system] PPS should effectively measure, monitor and manage its credit exposures to participants and those arising from its payment, clearing and settlement processes. A PPS should maintain sufficient financial resources to cover its credit exposure arising from the default of the participant and its affiliates that would generate the largest aggregate credit exposure for the PPS."*[6]

2.3 Payment flows in the ACSS

Before we describe the methodology of each collateral scheme, it is important to briefly describe the nature of the data we are working with. The key variable being examined for this study is the final multilateral net obligation of each participant at the end of each cycle (day).

Participant-specific patterns Figure 1 shows the distribution of the final net obligation for each participant for the entire sample period. 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 largest observed debit and credit positions larger than one billion dollars. In this sense, the distribution can be approximated as one with unbounded support because very large values are at least, in theory, possible every day. The shape of the distribution also depends on if the participant tends to be a net receiver or a net sender. If the participant tends to be a net sender, the distribution will be skewed to the right (meaning more often there is a net debit settlement obligation), and if the participant tends to be a net receiver then the distribution will be skewed to the left (meaning 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. However, there are some exceptions, such as payroll or pre-authorized payments, but these make up a small portion of payments and thus have little impact on the overall distribution of payments. We test this hypothesis

[6] For more information about proposed criteria for PPS, see http://www.bankofcanada.ca/wp-content/uploads/2016/02/criteria-risk-management-standards.pdf.

by regressing the daily net flows of every participant on the lagged daily net flows and we control 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 R^2 coefficient is also very small. This suggests that 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 We also analyze the evolution of the distribution of net settlement obligations over the years. We consider all net obligations in a given month for every participant and obtain two key statistics: The mean of net flows does not change across years and is centred around zero (see Figure 3a). However, the variance of net flows increases from 2006 to 2012 before levelling off (see Figure 3b). This is likely because total value of payments increases over the years as a result of the steady economic growth in Canada. More interestingly, during the last decades there is a clear trend of substitution of cash payments with other electronic means of payment (e.g., automatic funds transfers or debit and credit cards), which should increase the usage of the ACSS and widen the distribution observed over the years (see Arango *et al.*, 2012).

2.4 Overnight exposures in the ACSS

The motivation for this analysis stems from the credit risk exposures in the system, specifically, the overnight credit risk. Credit risk in this situation can be described as the FMI not collecting sufficient financial assets from the participants to manage current and potential exposures in the system, leading to possible losses to participants and/or the system. With the current configuration of the ACSS, net settlement obligations that are incurred at time T are not settled until T+1 with no collateral pledged to cover these obligations. This delay in settlement increases the potential for a participant to default on its net settlement obligation and exposes the other participants to credit risk.

In the ACSS rules, an additional net settlement obligation (ASO) is required in the event of a default. The ASO is used if there is a remaining shortfall from the defaulting participant. All surviving participants are required to cover the shortfall and the required contributions depend on their activity in the ACSS vis-a-vis the defaulter. The issue here is that there are no financial resources available ex-ante to back up the ASO. To mitigate the credit risk that arises, it is proposed that participants pledge collateral to the system. Therefore, in this article we propose possible schemes for collateralizing this exposure to mitigate the credit risk that exists in the system based on the current design.

We define a net settlement obligation, $np_{b,t}$, as the end-of-day net settlement obligation of participant b in period t with the ACSS with the following sign convention: $np_{b,t} > 0$ if participant b owes money to the system (debit position), and $np_{b,t} < 0$ if the ACSS owes money to participant b. Since we are concerned with the exposure of the ACSS to the default of a participant, we define the exposure of the ACSS to the default of a participant b in period t, $e_{b,t}$, as

$$e_{b,t} \equiv \max(np_{b,t}, 0). \tag{1}$$

Therefore, a participant in a credit position has $e_{b,t} = 0$ and may not need to pledge collateral for that day, in some cases. The objective of this paper is to understand the effects of different risk management methods that use collateral from participants to reduce or eliminate $e_{b,t}$ in case one or more participants defaults on their settlement obligations.

3 Existing trade-offs in collateral management

3.1 Demand for collateral

The impact of recent regulatory reforms relating to collateral demand is a key concern for policy-makers and financial institutions. Collateral is a scarce resource and after the introduction of new regulations such as Basel III or the Dodd-Frank Act, there is a larger demand for high quality collateral. The extensive use of collateral to mitigate credit risk has not only increased the opportunity costs faced by financial institutions when they pledge it, but also the operational costs of managing it and the risks of procyclicality. Collateral must be allocated efficiently and it may be transformed, re-used or rehypothecated to fulfill various needs. At certain times, there can be shortages of certain types of collateral and this can be very stressful for financial institutions. Because of increasing needs, financial institutions are adopting sophisticated technological platforms to manage collateral (see Capel and Levels, 2014) and this is an issue that has also received significant attention from regulators (BIS, 2014). For instance, CCP participants often have a precautionary stock of unencumbered assets ("pre-funded" variation margin) ready to be transferred in case of variation margin changes (see Duffie *et al.*, 2015). This precautionary stock can be related to the underlying traditional theories of precautionary liquidity demand for money.

Based on this evidence, we could conjecture that participants' profits are affected not only by the opportunity cost of pledging collateral (r_p), but also by the cost of adjusting the collateral (r_a), which is higher when collateral requirements are adjusted more frequently. A simple profit function for financial institution i could be written as

$$\pi_i(K, \Delta K) = -r_i^p \cdot K - r_i^a \cdot (\Delta K)^2, \tag{2}$$

where K is the average level of collateral per unit of time, and ΔK is the per cent change of collateral from day to day, r^p is the opportunity cost of pledging collateral, and r^a is the cost of adjusting collateral. Therefore, profits would depend linearly on the collateral cost, and quadratically on the variability. The relative difference between r_i^a and r_i^p would determine the preference of participants for certain types of collateral management. Participants that have $r_i^a \gg r_i^p$ may be such that they operate in business lines with high collateral requirements and their access to collateral markets may be limited. Therefore, they face great challenges to move, pledge and transform very different amounts of collateral from day to day and can be particularly concerned with collateral variability rather than with the average costs of collateral.

3.2 Some empirical evidence from the LVTS

We provide some interesting empirical facts about the behaviour of the LVTS participants regarding the use of collateral. Although this system settles mainly large value payments as opposed to retail payments, we believe that studying participant behaviour in the LVTS can provide interesting evidence that could be useful when considering potential risk management schemes in the ACSS.

First, all participants in the ACSS are also participants in the LVTS, therefore the behaviour may be similar. Second, large value payments can be considered random to some extent, and follow a similar distribution as those in the ACSS.[7]

The LVTS provides two types of payment streams: Tranche 1 (T1) and Tranche 2 (T2). T1 is a fully collateralized payment stream; that is, a participant can send a T1 payment as long as its net owing position is no greater than the collateral it has pledged to the Bank of Canada for Tranche 1 activity. For this reason, T1 payments are known as "defaulter-pays," in other words, it is a cover-all scheme.

In Tranche 2, each participant i grants voluntarily a bilateral line of credit (BCL) to every other participant. This line of credit is defined as the largest net exposure that participant i can accept from another participant on that day (i.e., the largest net amount that participant i can receive). In addition, each participant has a multilateral net debit cap used for sending payments, calculated as the sum of all bilateral lines extended to it, multiplied by a factor called the system-wide percentage (SWP).[8] Each LVTS participant pledges to the Bank of Canada an amount of collateral equal to the largest bilateral line of credit it has extended to any other participant multiplied by the SWP. All losses not covered by the defaulting participant's collateral are allocated pro-rata among the survivors on the basis of the BCLs established by survivors vis-à-vis the defaulting participant. For this reason, T2 has been described as a "survivor-pays" scheme.[9]

We use three different indicators to measure the usage of collateral by participant in the LVTS. First, we study the BCLs set by each participant. Second, we consider the multilateral debit cap. Finally, we consider the excess collateral. Figure 4 provides a summary of the results.

Using the BCL data in LVTS, we calculate the unused portion of BCLs as a percentage to determine how much of the BCL granted to the receiving participant is unused. In panel (a) of Figure 4 we observe that the distribution of the unused portion of BCLs is relatively large, and

[7] There is a caveat here because LVTS settles many other different payments from other FMIs such as CDSX and CLS, so this is not completely true.

[8] The system-wide percentage is established by the President of Payments Canada in consultation with the LVTS Management Committee.

[9] Total collateral pledged is designed to cover a default of the largest participant in LVTS. In the exceptionally remote event of multiple participant defaults, and where total collateral pledged is still not sufficient to cover the value of the final net debit positions of the defaulting participants, the Bank of Canada will provide a guarantee of settlement.

in about 40 per cent of the cases the largest intra-day net debit position is close to zero or much lower than the BCL. This shows that on average, the BCLs granted are much larger than required. This can be for a number of reasons, for instance, to reduce the costs and operational burden of adjusting BCLs on a daily basis to account for additional payments being sent. We then examine in panel (b) the excess collateral that is not being used for LVTS purposes. Participants pledge a portfolio of collateral to the Bank of Canada for LVTS use and then apportion a percentage of that collateral to T1 or T2. The amount not apportioned to a tranche is known as excess collateral. We consider how much excess collateral is left relative to how much collateral is apportioned for LVTS purposes. Average excess collateral across days and participants is about 200 per cent and we observe a relatively large tail in the distribution with values of excess collateral above 600 per cent. One possible reason for this high level of excess collateral could be that it is at the LVTS for quick use when needed, and thus it could prevent the participants from the costs and operational challenges of pledging additional collateral. Lastly, in panel (c) we consider T2 multilateral net debit caps and determine the percentage of utilization for this limit. Average level is about 60 per cent, which shows that the multilateral net debit caps are left with a lot of room and perhaps participants set high limits to ensure they do not have to adjust their collateral frequently to account for more payments they plan to send. When examining these three pieces of information from the LVTS, we can conclude that overall, participants are pledging more than enough collateral than required for everyday use.

4 Collateralizing overnight risk exposures in the ACSS

4.1 Cover-all case

To begin our analysis, we take a look at collateral requirements in a simple cover-all scenario, in which each and every net settlement obligation for each participant is collateralized each and every day. We analyze this case to form a base for comparison to the cover-one case, which is explained later. We propose that the collateral requirement is determined after all payment stream deadlines have passed in the ACSS. Once the deadlines have passed, the net settlement obligation for each participant is determined, and shortly after, the required collateral is pledged to the system by each participant. A pledge of collateral will be required only if the participant is in a net debit obligation. If the participant is in a net credit position, then no collateral is required. In mathematical terms,

$$K^A_{b,t} = d_{b,t} \equiv \max(np_{b,t}, 0), \tag{3}$$

where $K^A_{b,t}$ is the collateral of participant b in day t in the cover-all case, $np_{b,t}$ is the net settlement obligation and $d_{b,t}$ is the debit position of the participants with the ACSS. This level of collateral will be pledged after the payment stream deadline has passed every day.

Of course, the cover-all case is not very reasonable or desirable in practice. Since collateral is pledged at the end of the day, the objective of controlling credit risk is distorted to some extent because collateral is pledged too late in the day, once the final net position is known by all participants.

Based on the nature of payment flows and net settlement obligations in the ACSS, we can assume that collateral required from day to day in Eq. (3) will be random and unpredictable from day to day. It will follow a normal distribution truncated at zero, and in a large fraction of days there will be no collateral pledged by a certain participant.

4.2 Cover-one case with collateral pool

Next we look at the cover-one case with the use of a collateral pool. In this case, only the highest net debit obligation across all participants in a rolling window W is covered. The highest net debit obligation that is incurred in the given window W determines the size of the collateral pool. The idea of the rolling window is that as time progresses, the rolling window moves and will capture the highest net debit obligation that falls within that time frame (see Figure 5). This will determine the size of the collateral pool. Once the collateral pool size is determined, the contribution of each participant is then determined. Each participant in the system that incurs a net debit obligation during the given window must contribute collateral to the pool. The contribution for each participant will be determined by the highest net obligation that each participant incurs in the given window.

In more mathematical terms, collateral can be expressed as follows, where $\overline{K}^{1,\max}(W)$ is the collateral pool size in period t in the cover-one case for some window W, where the following definition is used:

$$\overline{K}^{1,\max}(W) = \max_{b,\ t\in W} d_{b,t}. \tag{4}$$

Collateral is distributed among participants using weights that are calculated as follows:

$$\omega_b^{\max} = \frac{\overline{K}_b^{1,\max}(W)}{\sum_j \overline{K}_j^{1,\max}(W)}, \tag{5}$$

where

$$\overline{K}_b^{1,\max}(W) = \max_{t\in W}\ d_{b,t}. \tag{6}$$

The collateral pledged by every participant is

$$K_b^{1,\max}(W) = \omega_b^{\max} \cdot \overline{K}^{1,\max}(W). \tag{7}$$

Since the collateral pool is obtained as the maximum of i.i.d. draws from a quasi-normal distribution, the distribution of the collateral pool from Eq. (4) follows the well-known extreme value distribution.[10]

Alternatively, we can calculate the weights using the average net debit obligation in the window for every participant, rather than the maximum debit obligation as in Eq. (6). In this case, the weight ω_b^{mean} is obtained by calculating $\overline{K}_b^{1,\text{mean}}(W)$ for every participant,

$$\overline{K}_b^{1,\text{mean}}(W) = \frac{1}{W_T}\sum_{t\in W} d_{b,t}, \tag{8}$$

where W_T is the length of the window in number of days. We can use $\overline{K}_b^{1,\text{mean}}(W)$ to calculate

[10] See http://ocw.mit.edu/courses/civil-and-environmental-engineering/1-151-probability-and-statistics-in-engineering-spring-2005/lecture-notes/app11_max.pdf

ω_b^{mean} as in Eq. (5) and the collateral pledged by every participant is equal to

$$K_b^{1,\text{mean}}(W) = \omega_b^{\text{mean}} \cdot \overline{K}^{1,\max}(W). \tag{9}$$

5 Results

5.1 Cover-all case

In the cover-all case, our simulations show that, as expected, the collateral requirements have a high variability day to day (see Figure 6). This is because of the randomness of the net settlement obligations. Since these are collateralized each day, and since each net settlement obligation is a random variable, the collateral required has a high variability day to day. For instance, the collateral required is very often close to zero (approximately 60 per cent of the time, see Figure 7); this can be explained by the distribution of net settlement obligations being approximately bell-shaped and centred around zero. Also, there is a wide range of possible values, as shown by the tail of the distribution. Based on the design of this scheme, there will be no shortfalls in the event of a default as every net settlement obligation is covered, but as we discussed before, this scheme does not cover intra-day exposures.

5.2 Cover-one case

5.2.1 Collateral levels

For the cover-one case, the size of the collateral pool and the collateral per participant may depend on the size of the window, the number of days between adjustments and the weights used to calculate this collateral.

Table 2 shows these variables by considering different window sizes. The window size is one key variable that affects the main characteristics of the cover-one scheme. We first study how the average size of the pool changes with the window size. As the window size increases in the cover-one case, we exhibit the size of the collateral pool increasing but at a decreasing rate. This is an intuitive result because of the fact that a larger window size will capture a wider range of observations through time, thereby capturing higher net debit positions that may be missed with a smaller window size, leading to higher collateral requirements. On average, we find that with a window size of approximately 15 days, the collateral pool will become larger than the sum of all collateral pledged on 1 day in the cover-all case. We can also observe in Figure 8 that the average pool size as a function of window size experiences a strictly concave function.

In addition, Figure 8 shows that the number of days between adjustments does not have a significant effect on the average pool size. Since the pool size approximately follows an extreme-value distribution, the average pool size is determined by that distribution, and the adjustment rate has a secondary effect, which may be due in part to small sample bias.

Table 2 shows collateral values per participant by considering two different methods to calculate the weights. The column "Max" shows the case where weights are calculated using the maximum debit position within the window, while the column "Mean" shows the case where weights are calculated using the average debit position within the window. We observe significant differences between the two methods. Some participants tend to have higher collateral levels in one case, whereas others have higher collateral levels in the other case. This result is driven by the distribution of payments of every player. Participants that have on average low debit positions but occasionally have some high debit positions within the window tend to be better off when weights are calculated using averages.

To study how collateral levels depend on the method used to calculate the weights, we consider Figure 9. In this figure, we plot collateral levels for every bank and window size against the maximum and average debit position of every participant in the window. We also plot a linear regression line and a 45-degree line to show any possible statistical pattern. By comparing the two cases in Figure 9a and Figure 9b, we observe that on average, participants contribute less collateral as a function of their debit obligation when using weights that are calculated using the maximum debit position within the window. From Figure 9a we observe that for every additional dollar obligation incurred, the participant has to contribute a lower fraction of collateral, whereas in Figure 9b we observe that for every additional dollar of obligation incurred, the participant contributes an additional dollar plus some fraction of collateral. From these results, it can be inferred that in the mean calculation case there is a disincentive to incur larger payment obligations which may alter the behaviour of the participants by preventing larger exposures in the system.

5.2.2 Variability of collateral

Another important outcome to consider when choosing the window size and the number of days between adjustments is the variability of collateral from day to day. As we discussed before, this is important for the participants, as it will bring operational challenges and may bring higher costs for managing this variability of collateral. We define variability as the absolute value of relative change (in per cent) of pool size from day to day. Some results are shown in Table 3. At a window size of one day, the variability of required collateral will be similar in both cases, as the net position that is used for both the collateral pool and individual contributions will change each day. From the random nature of net positions, we can see that with a one-day window size, the variability is as high, just as it is in the cover-all case. As the window size increases, we show that the variability of collateral between days decreases–a convex function, see Figure 10. The variability decreases drastically as the window size increases, but at a decreasing rate as the window size gets larger.

When looking at the rate of adjustment, the results show that for a smaller window size, the adjustment rate matters but becomes less relevant as window size increases. The adjustment rate directly affects the variability. When looking at Figure 10 it is clear that an adjustment every one day has a much higher variability than an adjustment every eight weeks. Nevertheless, the variability between days of adjustment eventually converges as the window size increases. When the window is large enough, it eventually reaches extreme values of the distribution of debit payments that are likely to determine the pool size, and because the window size is large, it is valid for a long period of time. Therefore, a higher rate of adjustment does not affect this outcome.

Another key variable considered is the confidence interval. We define the confidence interval as the per cent of days (over the entire sample) where the pool size is enough to cover the maximum debit position in a given day. The number of shortfalls that will occur as a result of a default decreases as the window size increases. This can be seen in Figure 11. Clearly, it is a concave function. However, the number of days between adjustment is not relevant for the shortfall found.

5.3 Discussion

These results show that the parameters used for the design of a collateral scheme in a retail payment system require careful analysis because of the implications for collateral demand coupled with the possible incentives faced by the participants. Figure 12 shows the combination of average daily variability of collateral and average collateral levels in the cover-one case for different window sizes. Points located in the bottom-right region in the figure correspond to the smallest window size: variability is the highest, and average collateral level is the lowest. We plot the set of all points for every possible window size and we obtain a "production possibilities" (PP) curve that represents the different combinations of collateral level and variability that can be obtained for a participant depending on the size of the window selected. This figure combines the results of Table 2 and Table 3 but with a larger set of window sizes.

We plot two different examples in Figure 12a and Figure 12b for several participants. In Figure 12a, we show the case of two participants that have two PP curves with considerable differences. By examining Figure 12a we notice that P8 tends to be in a net credit position more often than P7. This affects the weights calculated in the collateral pool, and creates large differences in the two curves shown. On the other hand, Figure 12b shows the case of two participants (P1 and P2) that have similar distributions of payments, and therefore the two frontier curves are very similar. Hence, the specific characteristics of the participants in terms of their distribution of payments determine the collateral requirements imposed to ACSS participants in the cover-one case.

In addition, we can assume that participants' costs are affected by collateral levels and variability, as shown in the profit function in Eq. (2). If participants had the opportunity to select a window size, they would select a value that maximizes their payoff conditional to the existing PP curve. Figure 12a plots two different indifference curves for participants P1 and P2. These are the combination of collateral levels and variability such that every participant is indifferent in terms of payoff. In this example, we assume that participant P2 tends to give a relatively higher weight to low collateral variability, whereas P1 values the average collateral level relatively more. This could be justified based on the observed behaviour of these participants in the LVTS that we have analyzed previously. At the optimum, they would each select a different window size based on these preferences.

This discussion implies that heterogeneity plays an important role in our model. Participants have different distributions of net settlement obligations with the ACSS. In addition, they may have different preferences for different risk management schemes. The simple cover-one case that we consider with a single window size may create challenges to accommodate the heterogeneous preferences of the various participants. An optimum design of the window size could consider the heterogeneous preferences so the aggregate payoff for all participants is maximized, conditional on minimum safety and soundness requirements.

6 Conclusion

In this paper we have studied the effects of new regulations on collateral demand that are intended to increase the safety and soundness of prominent payment systems. We have focused on three dimensions: the average cost (level) of collateral, the variability (stability) of collateral requirements, and the existing shortfalls from a default. We believe that the level and variablity are very relevant for financial institutions, and we have provided evidence that this is the case in an existing system in Canada. Our results will help us understand the key incentives for collateral management that financial institutions face when they participate in a payment system, and what the unintended effects of these regulations can be. These results should be useful for a more efficient design of the future generation of payment systems in Canada and in other countries.

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A Figures and tables

Figure 1: Distribution of net settlement obligations

This figure shows the distribution of net settlement obligations for every participant in the ACSS for the period 2002–14. Some few extreme values have been eliminated from some participants for confidentiality reasons. A positive sign means a net payment obligation of the bank with the ACSS (debit position of the bank). A negative sign means a net payment obligation of the ACSS with the bank (credit position of the bank). Source: Bank of Canada calculations using Payments Canada data.

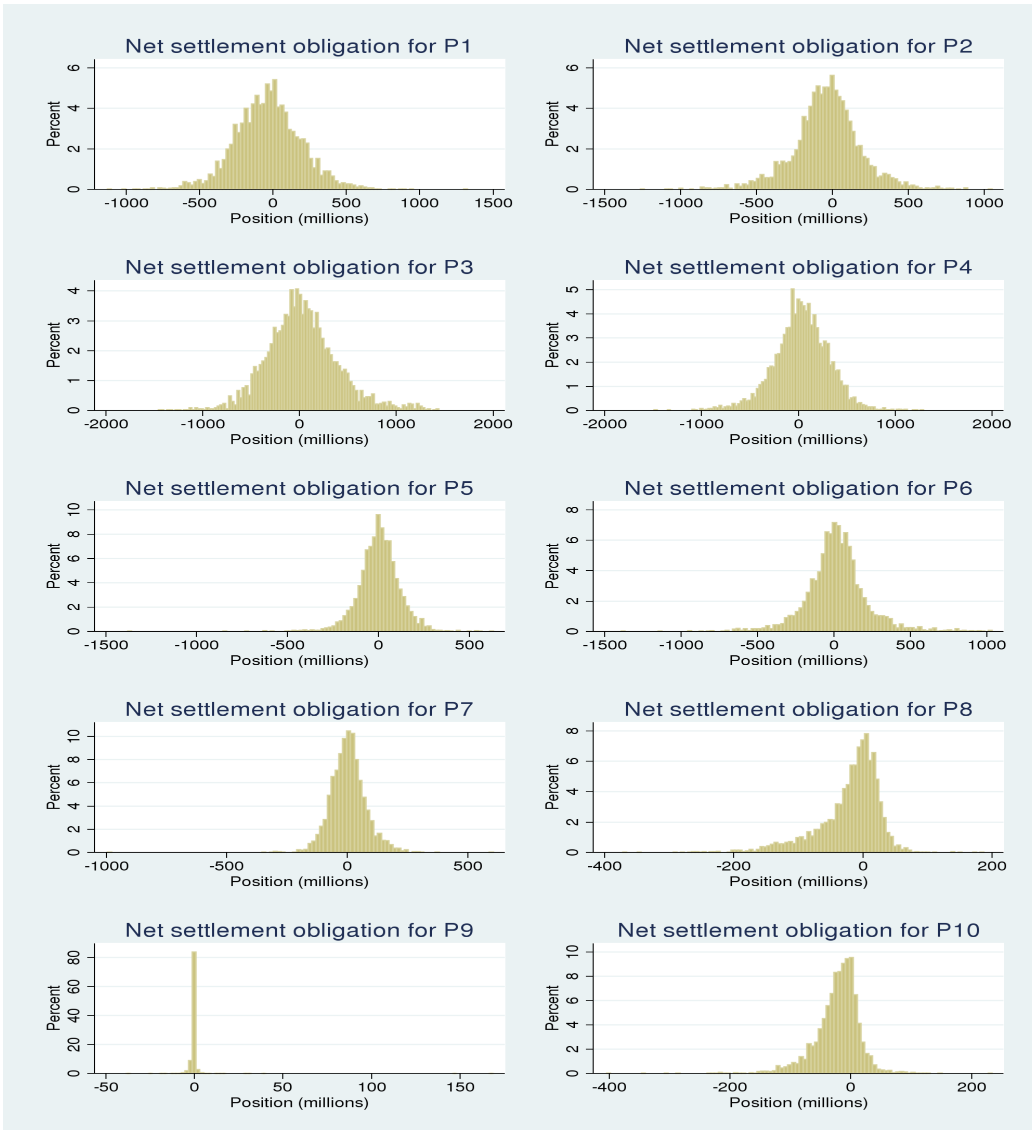


Figure 2: Net settlement obligations of some participants during a generic month

This figure shows the daily net settlement obligations with the ACSS of six participants during a generic month. A positive sign means a net payment obligation of the participant with the ACSS (debit position of the participant). A negative sign means a net payment obligation of the ACSS with the participant (credit position of the participant). Source: Bank of Canada calculations using Payments Canada data.

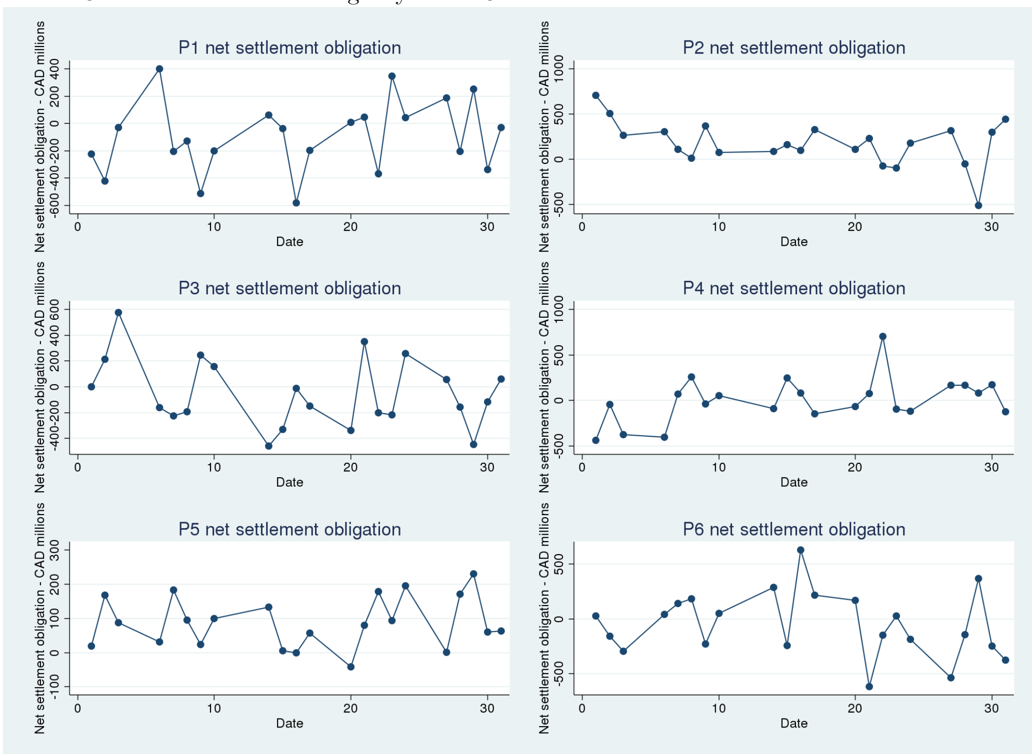
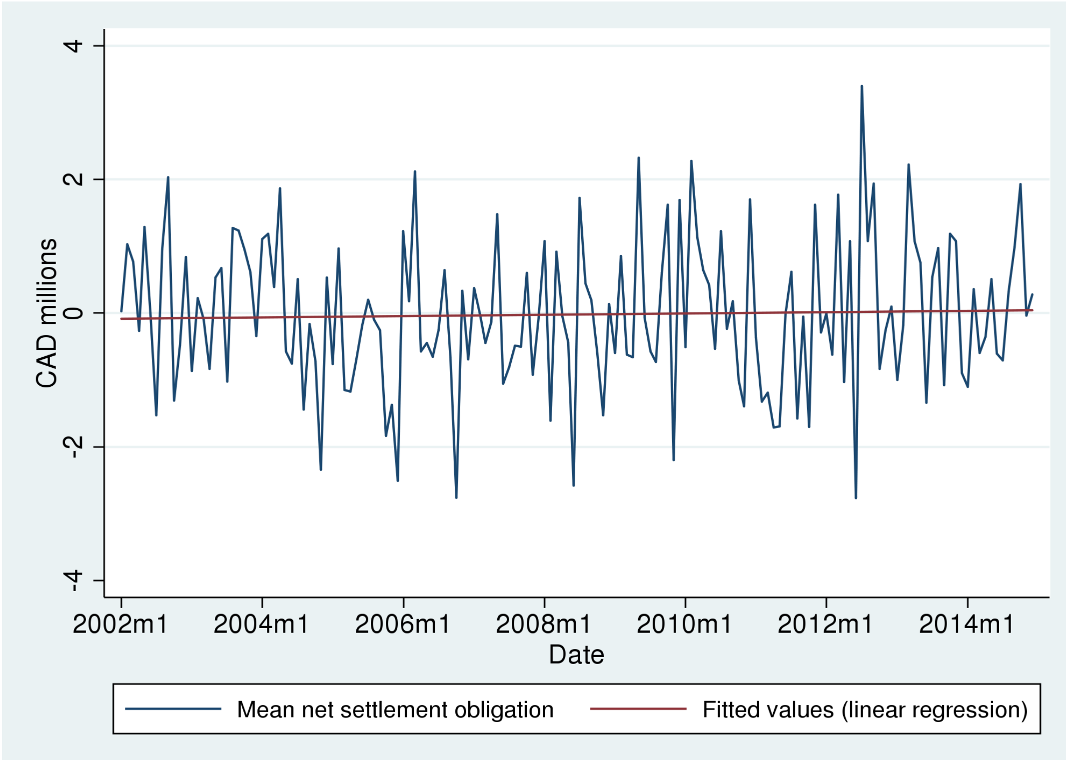
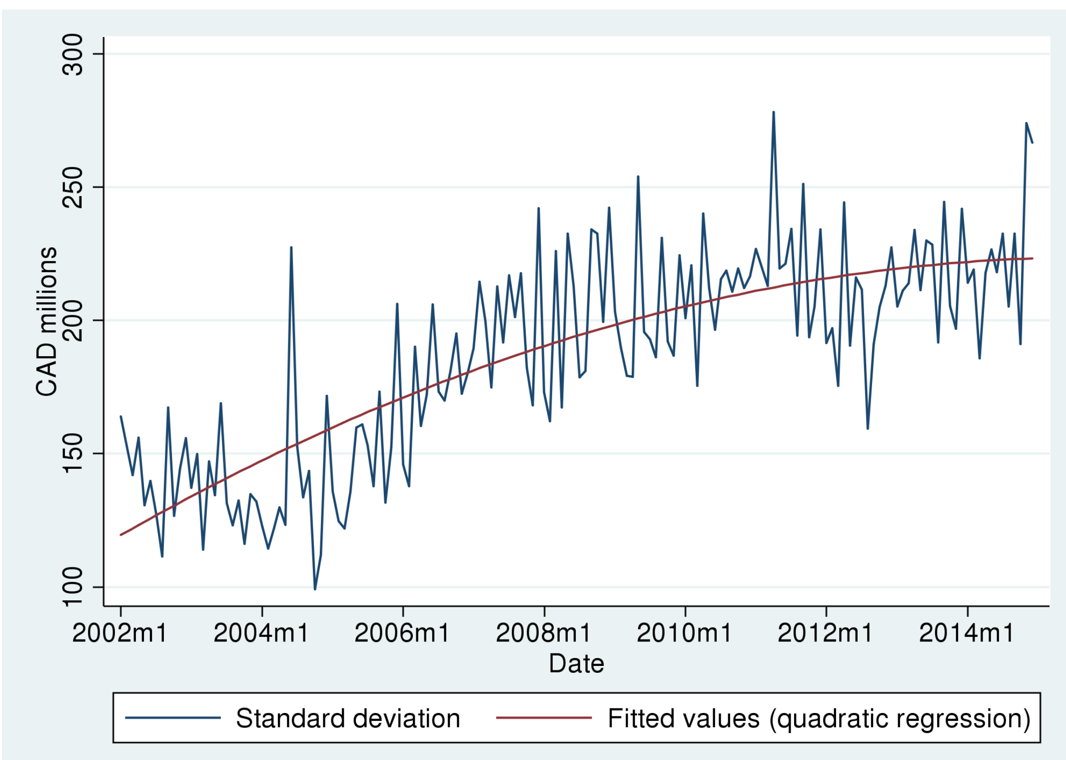


Figure 3: Evolution of net settlement obligations in the ACSS

This figure reports the evolution of key statistics for the period 2002–14. We calculate mean and standard deviation of net settlement obligations across participants for every month and we include fitted linear and quadratic regressions. Source: Bank of Canada calculations using Payments Canada data.



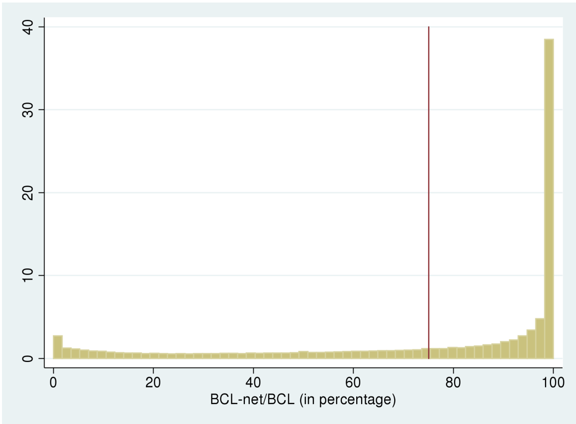
(a) Mean of net settlement obligations across participants for every month



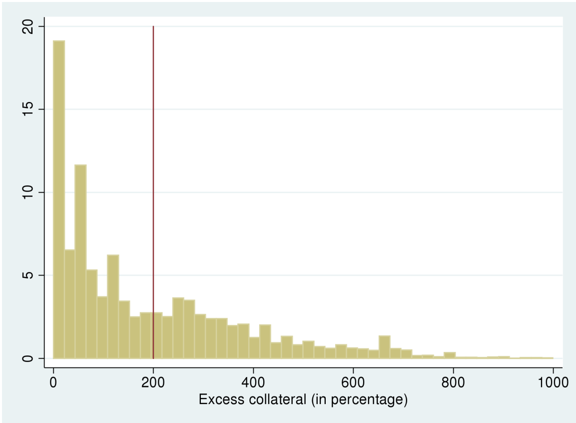
(b) Standard deviation of net settlement obligations across participants for every month

Figure 4: LVTS collateral utilization

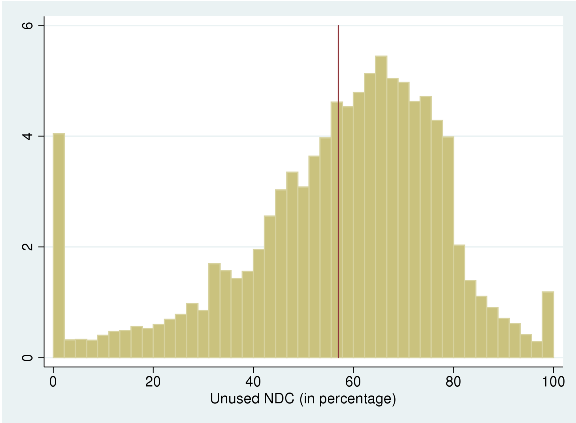
This figure shows histograms across days and participants of key variables related to LVTS utilization. The vertical line represents the mean of the distribution. The BCL figure shows statistics for the difference between the BCL and the largest intra-day net debit position (in percentage over BCL). The excess collateral figure shows the daily value of excess collateral per bank, divided by the collateral apportioned to LVTS in T1 and T2 (in percentage). The net debit cap figure shows the daily unused percentage of multilateral net debit caps (in percentage over net debit cap). Source: Bank of Canada calculations using Payments Canada data.



(a) BCL utilization across days and participants



(b) Excess collateral across days and participants



(c) Net debit cap utilization across days and participants

Figure 5: Cover-one case methodology

This figure shows an example of how to calculate the pool size and the individual collateral of every participant using a rolling window of size W, and a frequency of adjustment of size F.

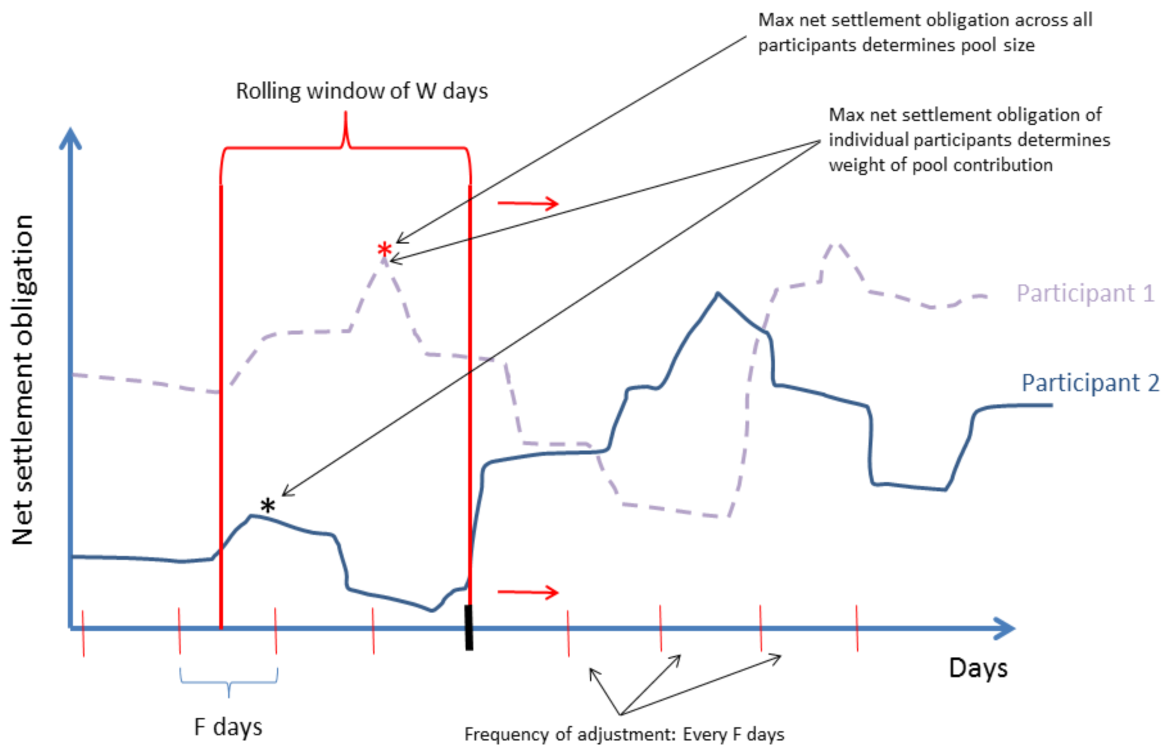


Figure 6: Collateral required for cover-all case

This figure shows the required collateral for six ACSS participants during a generic month in the cover-all case (in millions of CAD). Source: Bank of Canada calculations using Payments Canada data.

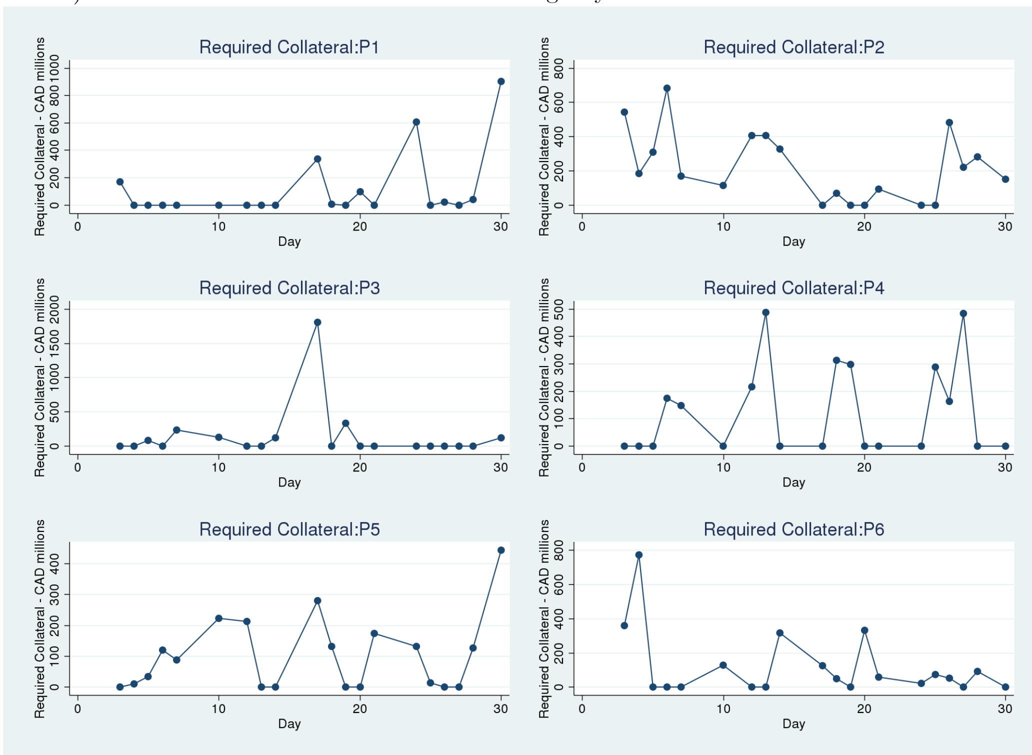


Figure 7: Collateral required for cover-all case

This figure shows the histogram of required collateral across days and participants for the cover-all case. Source: Bank of Canada calculations using Payments Canada data.

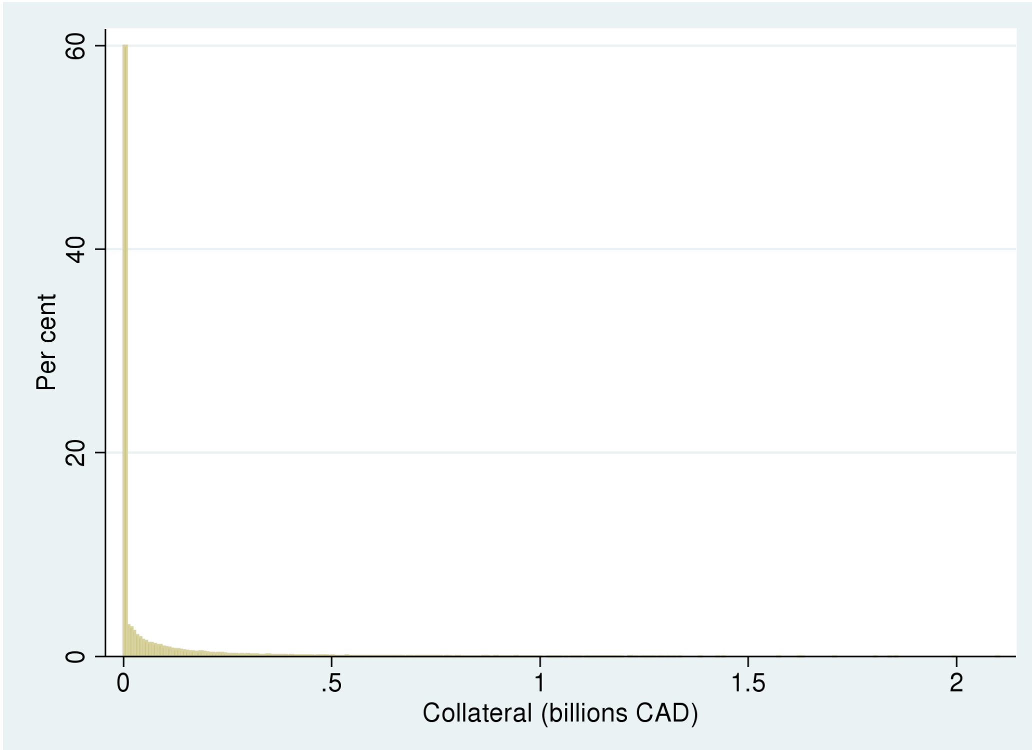


Figure 8: Average pool size as function of window size and the frequency of adjustment for cover-one case

This graph shows the average pool size for the cover-one case as a function of the window size (in number of days) and the frequency of adjustment. Source: Bank of Canada calculations using Payments Canada data.

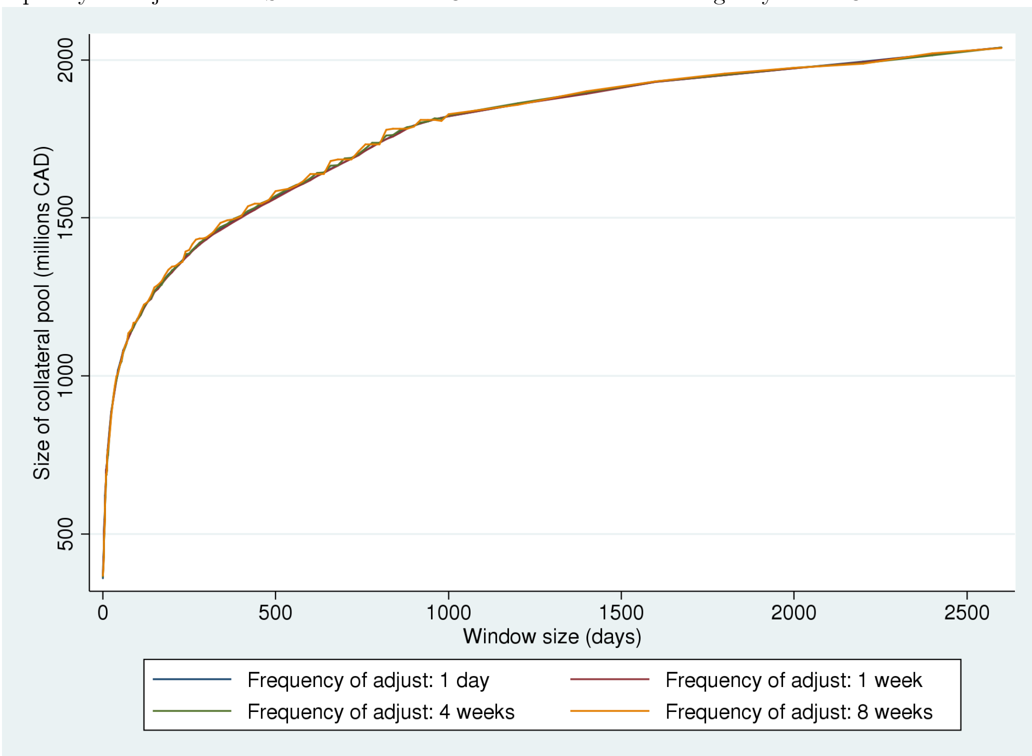
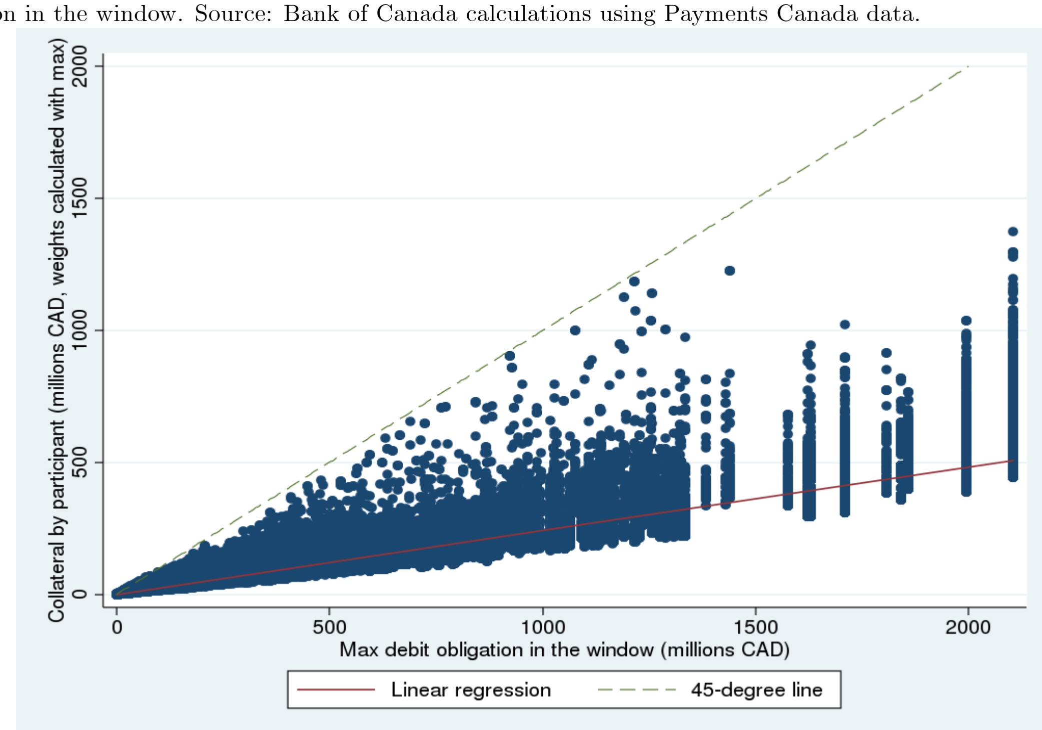
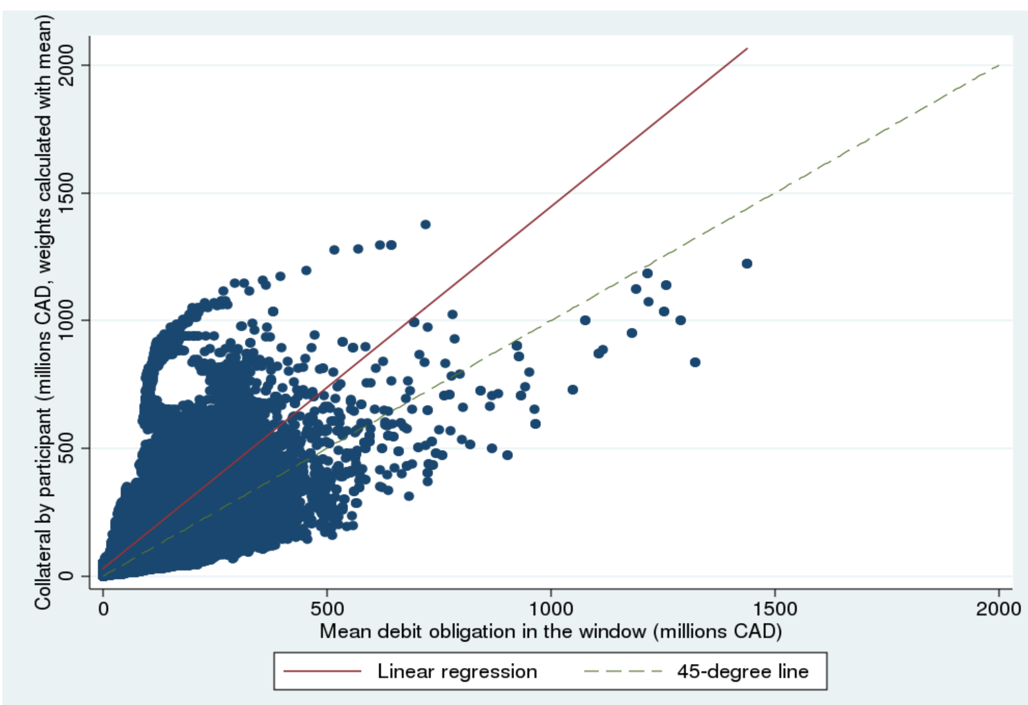


Figure 9: Collateral per bank vs. debit obligations for cover-one case

This figure plots collateral per participants for the cover-one case for different window sizes and the average or maximum debit obligation in the window for the period 2002–14. The first case shows the collateral per participant where participants' weights have been calculated using the maximum debit obligation in the window. The second case shows the collateral per participant where participants' weights have been calculated using the average debit obligation in the window. Source: Bank of Canada calculations using Payments Canada data.



(a) **Weights using maximum debit position within the window**



(b) **Weights using average debit position within the window**

Figure 10: Variability of pool size from day to day as function of window size and frequency of adjustment for cover-one case

This graph shows the variability of the pool size, measured as the per cent of the absolute change of pool size between days as a function of the window size (in number of days) and the frequency of adjustment. Source: Bank of Canada calculations using Payments Canada data.

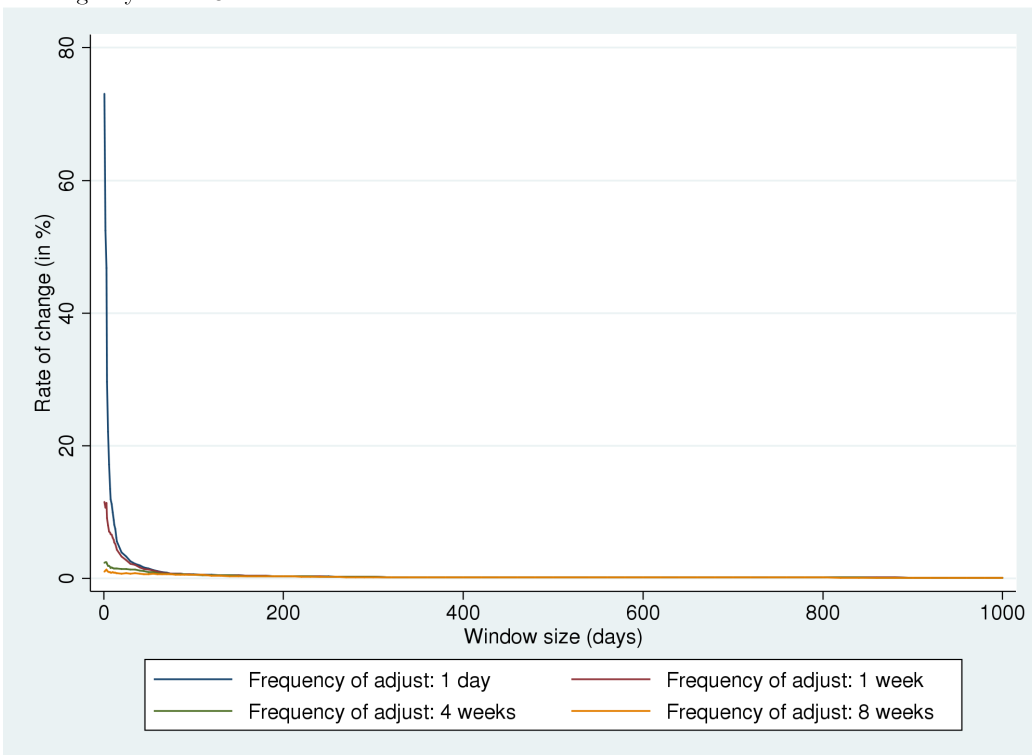


Figure 11: Confidence interval as function of window size and frequency of adjustment for cover-one case

This graph shows the confidencial interval, measured as the per cent of days (over the entire sample) where the pool size is enough to cover the maximum debit position in a given day. We show how confidence interval changes as a function of the window size (in number of days) and the frequency of adjustment. Source: Bank of Canada calculations using Payments Canada data.

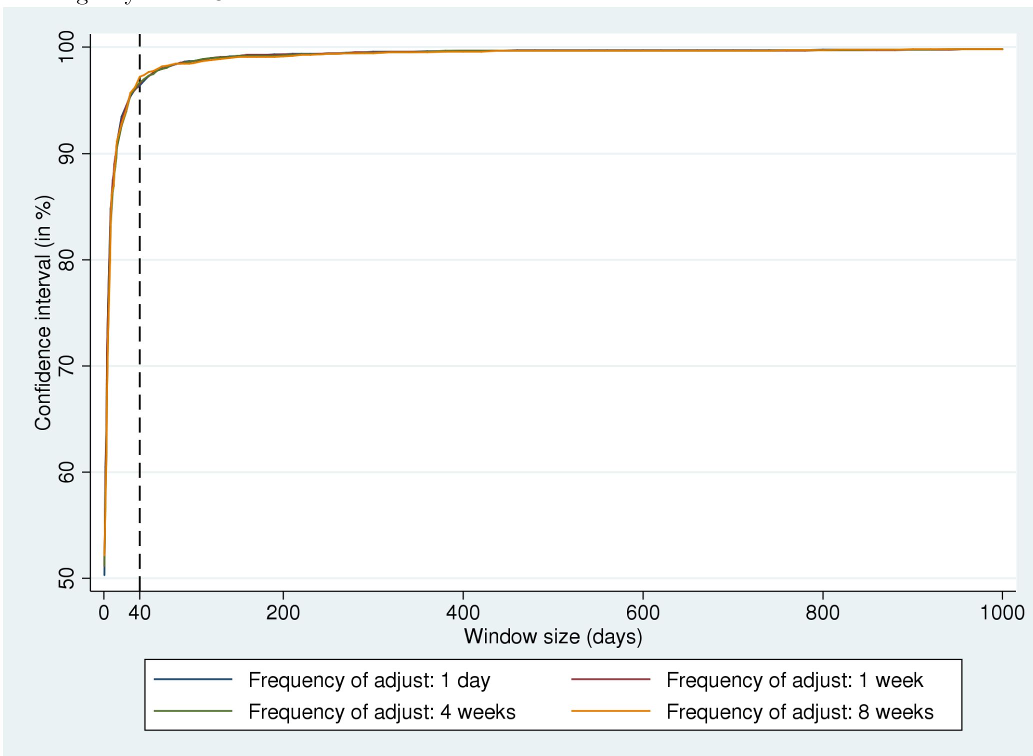
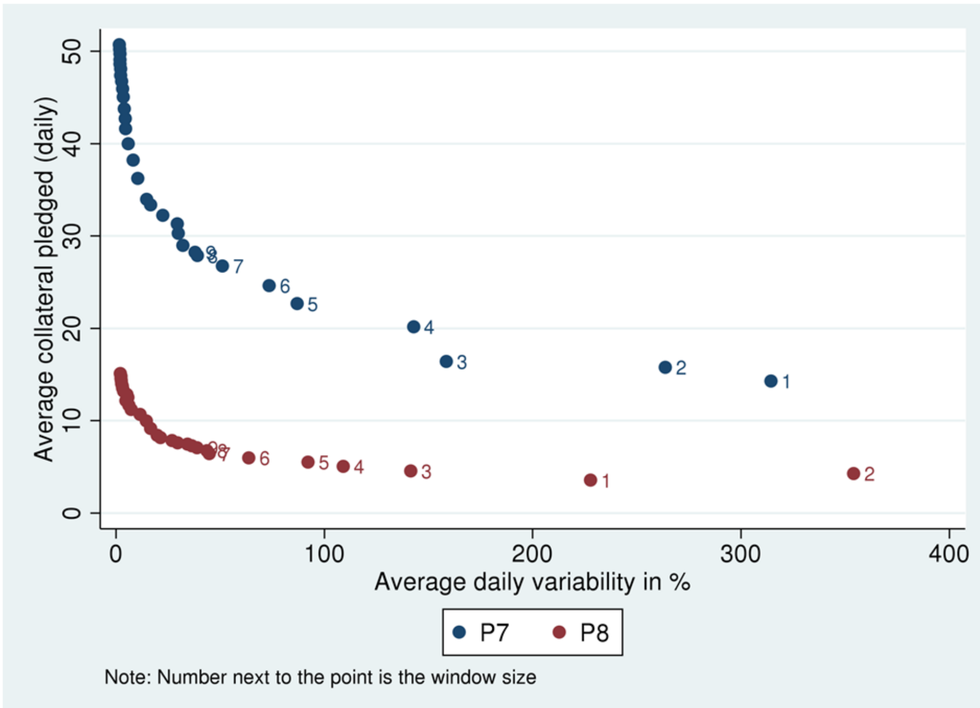
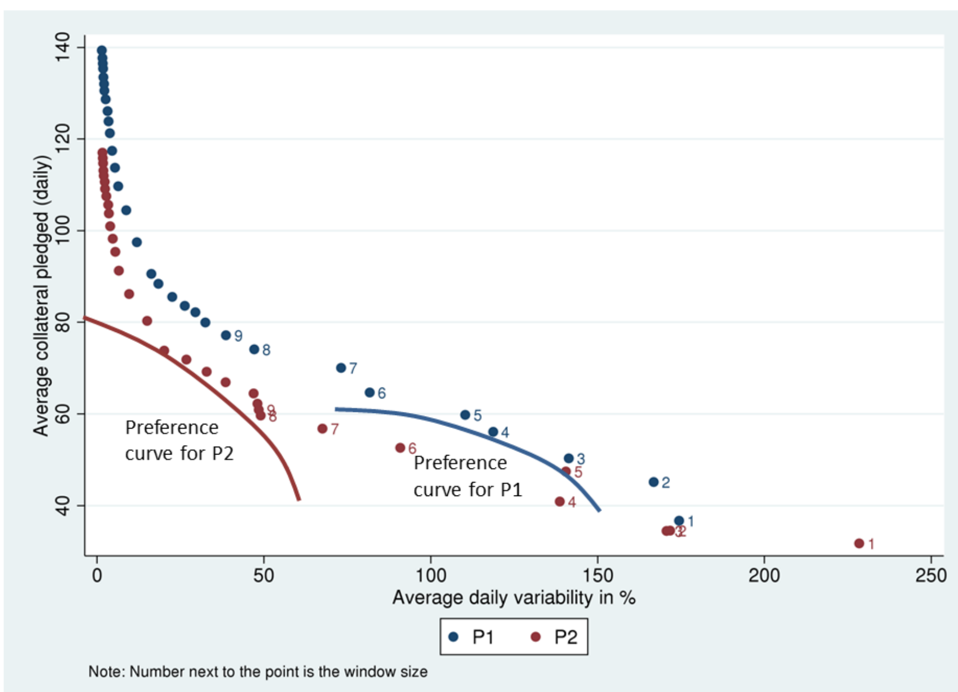


Figure 12: Average collateral pledged vs. variability (for different window sizes) for cover-one case

This figure shows the average level of collateral and variability for different ACSS participants and window sizes. Frequency of adjustment used: One day. We show two different examples: Heterogeneous and homogeneous participants. Source: Bank of Canada calculations using Payments Canada data.



(a) Example I: Heterogeneous participants



(b) Example II: Similar participants

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

Table 2: Key statistics of collateral pool (in millions CAD) for cover one case

This table shows key statistics about the size of the collateral pool, the collateral pledged per participant, and the weight in the collateral for period 2002-2014 in the cover one case. Column 'Max' shows the collateral per participant where weights are calculated using the maximum debit position in the window. Column 'Mean' shows the collateral per participant where weights are calculated using the average debit position in the window. Frequency of adjustment: 1 day. Source: Bank of Canada calculations using Payments Canada data.

	Cover 1 case, window size									
	1 day		10 days		100 days		500 days		1000 days	
	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean
Pool size:	359.9	359.9	693.8	693.8	1,179.0	1,179.0	1,563.8	1,563.8	1,821.3	1,821.3
Collateral:										
P1	36.7	36.7	80.0	73.4	140.5	127.8	178.7	172.7	204.5	203.0
P2	31.7	31.7	62.2	60.2	118.0	106.8	155.5	131.4	174.4	142.8
P3	102.4	102.4	182.4	183.6	291.0	291.5	378.2	394.2	437.5	464.6
P4	68.9	68.9	119.3	127.2	183.0	222.9	231.6	297.6	266.0	347.6
P5	20.6	20.6	42.5	42.4	71.7	74.1	98.0	96.6	115.2	112.4
P6	42.0	42.0	86.6	84.1	157.4	142.5	207.5	185.8	246.4	218.1
P7	14.3	14.3	29.0	28.7	51.1	52.9	72.5	70.9	87.8	84.0
P8	3.5	3.5	7.3	7.3	15.4	12.6	27.5	18.1	35.3	22.2
P10	2.1	2.1	6.1	4.2	16.4	7.4	26.5	9.5	32.1	11.0
P11	17.5	17.5	38.1	39.1	66.9	63.9	88.9	81.0	103.6	92.3
P12	20.0	20.0	39.9	43.2	65.5	76.1	94.7	105.5	111.2	122.8

Table 3: Variability of collateral between days for the cover one case

This table shows key statistics about the variability of pool size between days and collateral per participant for cover all and cover one for period 2002-2014. Column 'Max' shows the case where weights are calculated using the maximum debit position in the window. Column 'Mean' shows the case where weights are calculated using the average debit position in the window. Frequency of adjustment: 7 days. Source: Bank of Canada calculations using Payments Canada data.

	Cover 1 case, window size									
	2 days		10 days		100 days		500 days		1000 days	
	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean
Pool size:	10.65%	10.65%	6.13%	6.13%	0.56%	0.56%	0.12%	0.12%	0.04%	0.04%
Collateral:										
P1	32.96%	32.36%	16.01%	24.14%	1.20%	1.38%	0.28%	0.32%	0.11%	0.15%
P2	34.65%	32.56%	24.13%	32.23%	1.23%	1.58%	0.28%	0.36%	0.11%	0.19%
P3	44.05%	48.72%	24.31%	34.50%	1.45%	1.45%	0.36%	0.32%	0.10%	0.14%
P4	36.87%	39.82%	14.11%	18.52%	1.14%	1.22%	0.24%	0.27%	0.11%	0.12%
P5	27.72%	29.24%	13.61%	18.52%	1.24%	1.36%	0.31%	0.30%	0.13%	0.13%
P6	37.33%	38.93%	17.35%	19.08%	1.34%	1.41%	0.28%	0.33%	0.15%	0.15%
P7	47.42%	51.28%	13.52%	17.27%	1.34%	1.29%	0.32%	0.29%	0.16%	0.13%
P8	29.27%	36.86%	21.51%	22.09%	1.66%	1.82%	0.41%	0.42%	0.18%	0.21%
P10	56.10%	58.86%	41.67%	58.48%	1.98%	2.12%	0.34%	0.43%	0.16%	0.20%
P11	39.85%	37.54%	15.79%	20.77%	1.24%	1.44%	0.31%	0.33%	0.15%	0.16%
P12	35.85%	38.01%	15.39%	21.95%	1.16%	1.46%	0.34%	0.35%	0.11%	0.16%