Participant Consolidation in Canada's LVTS: A Simulation Study

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Abstract

This study examines how the risks and costs of participation in a large value payment system can be influenced by consolidation. The study will also demonstrate the usefulness of simulation analysis as a tool for addressing this issue. In order to demonstrate the usefulness of simulation four example merger scenarios using Canada's Large-Value Transfer System (LVTS) will be simulated. The findings indicate that the impact of a merger is sensitive to the size of the merged participant. That is, it is not necessarily the case that a merged participant realizes an improvement with respect to LVTS cost and risk and that non-merging participants are always worse off. In cases where a very large institution is created, liquidity costs are found to improve for this participant while declining for most, if not all, non-merging participants. Operating costs, as measured by share of LVTS annual fees, are also found to decrease for the merged participant while increasing for non-merging participants. Moreover, a merger can impact system-wide (operational) risk implications based on the resulting size and centrality of the consolidated entity. Additional simulations reveal that participants can reduce their liquidity costs through behavioural adjustments following a merger. However, while behavioural changes help to alleviate liquidity costs, higher payments delay could occur as a result. Suggested areas for further study are also discussed.

1.0 Introduction

The pace of consolidation among global financial institutions has increased over the past decade as intermediaries seek greater economies of scale and scope in an effort to improve profitability. In Canada, the issue of large bank mergers continues to be debated in political and academic circles.[1] This paper contributes to the discussion by focusing on a relatively less-studied area of financial intermediation. Specifically, it seeks to understand how financial sector consolidation might impact the level and distribution of cost and risk within and, to a certain extent, outside of a country's large-value payments system (LVPS).

LVPS are a critical component of the financial system. They are used by participating financial institutions to meet payment obligations stemming from their own business activity and that of their customers. Moreover, LVPS are often utilized to meet time-sensitive funding obligations related to other clearing and settlement infrastructure and, in addition, provide the environment for daily monetary policy implementation. This important role, coupled with the high value of payments flowing through these systems each day, means that LVPS have potential to act as a conduit for the transfer of risk to other parts of the financial system. For this reason, central banks are typically charged with oversight responsibility for LVPS that operate within their jurisdiction with a view to promoting their safe and efficient operation.

The different types of risk and cost associated with LVPS, and the potential tradeoffs existing between them, are well understood by central bank policymakers.[2] Risks in LVPS typically include funding, operational, legal and credit risk. Costs incurred by participants in these systems may include fixed costs, such as start-up investment and admission fees imposed by the system operator, and also variable costs including annual participation fees and the implicit cost of holding high-quality collateral to secure intraday credit. These risks and costs are not insignificant. For example, Engert (1993) estimates the cost of collateral in Canada, i.e., the spread between a bank's cost of funds and the rate of return on securities pledged as collateral, to be between 10 and 15 basis points. Moreover, D'Souza (2008) estimates that approximately 15 per cent of the total liquid assets held by the six largest financial institutions in Canada correspond to their LVPS business.

Although it is perhaps unlikely that the costs and risks of participation in an LVPS will serve as the main motivation behind a financial merger, such an event could significantly impact this aspect of the merging banks' business. At the same time, given the network characteristics of LVPS, this impact could extend to other participants as well. Subsequent changes in the behaviour of these other participants in response to the merger could cause the overall level and distribution of risk and cost in the LVPS to be affected further. Central banks, in their oversight of LVPS and also in promoting a stable and efficient financial system, maintain an interest in understanding how the level and distribution of risk and cost in the system might change

[1] A recent contribution to this debate is the report of the Competition Policy Review Panel (June 2008). The report recommends the removal of the *de facto* ban on bank, insurance and cross-pillar mergers of large financial institutions in Canada, subject to regulatory safeguards. Koeppl and MacGee (2007) summarize the arguments for and against financial sector consolidation in Canada, while a more general treatment can be found in Berger, Demsetz and Strahan (1999) and Northcott (2004). Allen and Lui (2005) and McIntosh (2002) employ an empirical approach and find potential scale economies in both traditional and non-traditional business areas of the Canadian banking system, suggesting that efficiency improvements could be realized if banks were allowed to merge.

[2] See BIS (1998, 2005) for a description of these risks and costs.

following consolidation and, in addition, how the tradeoff between these risks and costs could be altered at both the participant- and system-level. Moreover, they may be interested in knowing to what extent, if any, such a development could affect the safe and efficient processing of payments within its jurisdiction more generally. This paper sets out to explore these issues in more detail.

A second intention of this paper is to demonstrate the usefulness of simulation analysis as a tool to quantify the impact of consolidation, by applying it to a hypothetical merger scenario involving participants in Canada's Large-Value Transfer System (LVTS). This method of analysis is growing in popularity among central bank practitioners given its ability to capture the technical design characteristics and also the key interdependencies observed in these systems. However, simulation analysis exhibits some drawbacks relative to other modeling approaches, as will be discussed.

Further clarity on the scope of the project is useful at this point. In addition to the risk and costs in LVPS, it is understood that a merger in the financial sector has potential to impact the competitive structure of other closely related markets, such as securities lending and the provision of correspondent banking services. Moreover, post-merger outcomes in these other markets could have feedback effects on LVPS risk and cost. This paper does not address the impact on these other markets; however, this is recommended as a topic for future research.

The paper will proceed as follows. Section 2 raises several issues for consideration regarding how the risk and costs in LVPS could be affected by financial sector consolidation. Section 3 discusses simulation analysis as a research tool, and how it can be applied to the study of consolidation in an LVPS. The results of simulation exercises involving hypothetical mergers of participants in Canada's LVTS are presented in Section 4. Section 5 provides a sensitivity analysis of the results in Section 4 by considering alternative behavioural responses to consolidation in the LVTS. Section 6 concludes and suggests several areas for future research.

2.0 The Impact of Financial Consolidation on LVPS: Issues for Consideration

This section discusses how consolidation between LVPS participants might impact the level and distribution of cost and risk within and, to a certain extent, outside of the system. Several broad issues for consideration will be raised, creating a general framework that is useful for thinking through this topic. It will be argued that the impact of consolidation on LVPS risk and cost is not clear-cut. Instead, various potential outcomes exist, and the actual outcome will be influenced by a number of factors. Among these factors are the size of the merging participants, and also the policies of central banks and/or LVPS operators, as discussed below.

Although the discussion is intended to be general in nature, specific attention is devoted to discussing Canada's LVTS in certain areas to help set the stage for the simulation analysis that follows. Further information on the LVTS is provided in Box 1 at the end of this section.

Issue for Consideration #1: How could liquidity costs at the system-wide and participant-level change due to consolidation?

The concept of liquidity encompasses various definitions in the economics and finance literature. In the context of LVPS, liquidity is generally defined as the ability of a participant to meet its payment obligations in a timely manner. There are generally two sources of liquidity available to participants during the day. These are: (1) incoming payments from other participants, which may include funds borrowed as part of a term lending arrangement; and (2) the ability to draw on an intraday credit facility, which is typically operated by the central bank. Intraday credit is an important source of liquidity for participants in LVPS since it is used to help smooth over timing gaps which may exist between the receipt of incoming payments and the need to send outgoing payments. That is, intraday credit serves to expedite the rate at which payment finality is achieved.[3] This is important, since some payments settled through LVPS are time-sensitive, where the cost of delay can be significant.

As with any borrowing arrangement, central banks as lenders of intraday credit face risk exposure vis-à-vis borrowing participants. Leaving this risk uncontrolled is not desirable from a public policy perspective. Thus, intraday credit provision is often subject to limit caps, collateral requirements (which typically entail an opportunity cost because eligible securities must usually be of high quality) and, in some cases, an interest charge. It follows that maintaining liquidity in the system can be costly for participants.

It is argued that consolidation could either increase or decrease the demand for intraday credit, and therefore the liquidity costs of system participants. Moreover, this impact may not be uniform across all participants. For instance, non-merging participants may be impacted differently depending on their size (in terms of payments throughput) and interactions with the merged participant. Moreover, the overall impact of consolidation on liquidity cost will be influenced by the size of the merging participants and their influence on intraday LVPS payment flows.

On the one hand, consolidation could raise liquidity costs in the LVPS by increasing the degree of volatility in payment flows between participants. In turn, this may generate greater reliance on intraday credit as a source of liquidity. Using the LVTS T2 payment stream as an example, collateral must be pledged by each participant in proportion to the largest bilateral credit line (BCL) that it extends to any other participant. A BCL is granted based on the largest bilateral net credit position that the grantor expects to incur vis-à-vis the recipient at any point in the day, perhaps allowing for some margin of error in forecasting.[4] A merger of LVTS participants could result in a new entity that has the ability to incur very large intraday net debit positions vis-à-vis other participants. In turn, accommodating these incoming payments from the merged participant may cause non-merging participants to have to raise the value of their largest extended BCL, where further collateral would need to be posted to the system. Of course, a merger between two very small participants is unlikely to have the same impact on collateral requirements since the merger is not expected to significantly impact daily payment flows, nor is the merged bank likely to represent non-merging participants' largest BCL in the case of the LVTS.

On the other hand a merger could also reduce participants' demand for intraday credit in the LVPS. Lasaosa and Tudela (2008), in a study of the U.K. CHAPS payments system find a non-

[3] For an analytical demonstration of this see, for example, Freeman (1999) and Zhou (2000).
[4] Other factors will also influence the value of a BCL granted, including potential credit risk implications stemming from the LVTS loss-allocation procedure in the event of a participant default.

linear decline in system-wide collateral requirements as the degree of consolidation (through tiering) among participants is increased. Using simulation analysis, the authors find that CHAPS collateral requirements can be reduced by close to 40 per cent with a very high degree of tiering; however, these collateral-saving results are not reported separately for merging and non-merging participants. Liquidity savings are driven by two factors in the CHAPS study: internalization and liquidity pooling. Internalization refers to the settlement of payment obligations across internal business-line and/or client accounts of the new entity. That is, the merging banks will no longer need to settle obligations with each other through the LVPS which has potential to significantly reduce their reliance on intraday credit from the central bank. Of course, this also means that settlement activity in the system will decline holding all other factors constant which could add to the volatility of intraday payment flows. The degree of internalization achieved will ultimately depend on the size of the merging participants, and the nature of their bilateral payment flows prior to consolidation. Liquidity pooling is based on the premise that, as the degree of consolidation in the system increases, the greater the probability that a settlement bank's incoming payments can be used to finance its outgoing payments in which case less intraday credit in the LVPS will be needed.[5] It follows that the benefits of internalization and liquidity pooling could occur in other LVPS, including the Canadian system, in the event of a horizontal merger between participants.[6]

<u>Issue for Consideration #2: How might the level of payments delay in the system change as a result of consolidation?</u>

One way of thinking about participation in a LVPS is that banks will aim to minimize their cost of participation in the system, subject to a requirement that they meet all of their payment obligations when due. It was discussed above that participants' intraday credit requirements (and therefore liquidity costs) could increase or decrease following a merger. If liquidity costs do increase for one or more participants, they might try to reduce this cost by delaying outgoing payments until incoming payments arrive. However, there may also be a cost associated with this delay, especially if the payment is time-sensitive.[7] Bech and Garrett (2003) demonstrate that a participant's decision to send a payment under a regime of collateralized intraday credit will depend on the relative cost between delay and liquidity. That is, if liquidity costs are high

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[5] In addition to thinking about liquidity pooling from a LVPS liquidity perspective, one can also think about this concept in terms of intraday balance sheet liquidity. That is, a settlement bank that receives funds on behalf of a client during the day, but does not post this amount received to the client's account until end-of-day will be able to use these funds as a source of liquidity to meet its own payment obligations throughout the day. In the Canadian LVTS, for example, banks are generally required to make received funds available to their clients by the end of the payments cycle and by no later than the start of the next business day.

[6] The following example illustrates how a participant may benefit from liquidity pooling in the context of a horizontal merger in the LVTS. Consider a three-bank case (A, B, and C). For demonstration purposes, discussion of these participants' T2NDC is left out. Suppose that the only two daily payments involve C sending $50 to B in the morning and A sending $100 to C in the afternoon. In this case, C needs to extend a T2 BCL of $100 to A, and B must extend a BCL to C of $50 in order to receive the payments. Given a system-wide percentage of 0.30, this means that total collateral pledged would amount to $45. However, following a horizontal merger between A and B, settlement of the same two payments would require the merged bank extending a BCL of $50 to C while C must extend a BCL to the merged bank of $50 in order to complete the same payments. Thus, total T2 collateral requirements would be reduced to $30. Moreover, even though C was not involved in the merger, it still benefits in terms of lower collateral requirements. It follows that the benefits of liquidity pooling described here could easily extend to both merging and non-merging participants alike.

[7] For example, this cost could come in the form of explicit fines imposed by a payments system operator, or an implicit loss of reputation vis-à-vis other participants and/or the bank's own clients.

relative to delay costs, optimizing participants will choose to delay payments, and vice versa. The nature of the relative costs facing a participant is likely to be influenced by its individual characteristics, e.g. its size and role in securities markets.

Angelini (1998) argues that, although the decision to delay a payment may bring private benefit, it could have negative implications for the system. That is, in addition to possibly causing other participants to hold back their payments due to lack of incoming funds, frequent delay in a LVPS will hinder informational efficiency in the system, affecting participants' ability to forecast liquidity needs throughout the day. This may prompt participants to maintain higher levels of precautionary collateral to meet unforeseen payment demands, which entails additional cost and compromises profitability.

Returning to the LVTS T2 payments stream example, suppose that, following a merger, payment flows are affected in such a way that a participant requires an increased BCL from another participant to meet all of its bilateral payment obligations when due. Given that there are both counterparty credit risk implications and liquidity costs associated with granting bilateral credit in T2, the receiving participant may be unwilling to grant such a limit thus causing some payments to fail the risk control test upon intended submission. The sending participant in this example has two options. First, it can choose to delay sending its payments until it gathers sufficient T2 bilateral liquidity (through incoming payments) for the payment to pass the T2 risk control test.[8] Second, it can choose to send the payment via the more collateral-intensive T1 payments stream, possibly by incurring additional liquidity cost. It is anticipated that a participant's decision among these two options will depend on the relative cost between delay in T2 and liquidity in T1 for each payment.

Issue for Consideration #3: What are the potential operational risk implications of consolidation?

Increased delay of payments also has important operational risk implications for the system. This is because an operational outage may delay the settlement of payments for even longer than anticipated, causing participants to incur unexpected cost. It follows that the severity of an operational outage faced by one or more participants, or the system as a whole, is likely to be higher when more payments remain to be settled when it occurs. Consider, for example, a wide-spread disruption that occurs late in the day when there is still a large amount of volume that remains to be settled through the LVPS on that day. In this case, participants' internal systems and/or the central payments processing mechanism may not have sufficient time to recover for some or all remaining payments to settle. Payments delay in this case could extend to the next business day (which would be longer than anticipated), potentially affecting activity in the real and financial economies and resulting in additional cost for participants and their clients. This effect will be greater the more payments that are delayed beyond their anticipated settlement time due to the outage.

Consolidation could also bring greater operational risk to the LVPS by way of increased concentration of activity among fewer institutions. With more payments flowing in and out of a participant's operation, the greater is that participant's capacity to act as a liquidity trap and/or

[8] Note that it too may have to increase its BCL to the sender and incur higher liquidity cost in order to accommodate receipt of these incoming payments.

drain in the event that it experiences an operational outage. Moreover, regardless of its share of payments activity in the system, the merged entity could become even more 'central' to the system relative to each individual merging participant prior to the merger, meaning that its role as an important conduit for the smooth intraday flow of funds is increased. Centrality is discussed further in Section 3.

At the same time, it could be argued that consolidation has potential to reduce operational risk in the system where it results in payments throughput being distributed more evenly across participants. For example, a merger of two small- or medium-sized participants could create a participant that is capable of drawing existing business away from the larger participants in the system, perhaps as it becomes more competitive in the provision of correspondent banking services. Thus, it follows that consolidation may lessen the influence of one or more large participants in the system.

Issue for Consideration #4: How might consolidation affect risk outside of the LVPS?

As discussed above, a merger between LVPS participants will result in some payments being removed from the LVPS and settled privately across accounts of the merged entity. This has potential to increase risk outside of the LVPS in the following ways. First, if the internal settlement mechanism of the merged bank does not operate in accordance with the same internationally-recognized risk management principles that govern most central LVPS[9], then settlement risk outside of the system could increase following consolidation. It is not clear that a commercial bank will seek to employ the same level of (potentially costly) risk protection in its own operation as would the operator of a centralized interbank system that must comply with international Core Principles (Lasaosa and Tudela (2008); Group of Ten (2001)). It follows then that such systems may not be able to achieve intraday finality since an account holder's failure to settle due to insufficient funds could result in an unwinding of client positions.[10]

Second, banker risk will increase where an increased amount of payments throughput is settling across the accounts of a private institution that is relatively more vulnerable to failure than a central bank. Such risk could be exacerbated where the private institution does not provide legally-robust intraday finality on payments processed on behalf of its clients internally. Third, and related to the first point, the merged bank will be subject to credit risk where it chooses to grant overdraft funds to its clients to facilitate intraday settlement. This risk may not appropriately controlled, for example, where overdraft is provided on an unsecured basis. This issue is studied by Lasaosa and Tudela (2008), who find that credit risk of the settlement bank rises as tiering increases in the case of U.K. CHAPS, although the increase in risk is found to be small relative to capital.

On the other hand, internalization of payments activity across the accounts of the merged institution could reduce settlement risk in the financial system because it helps to spread activity across more than one system (Lasaosa and Tudela 2008). Payments could therefore continue to be settled through the proprietary system when an operational event prevents settlement through

[9] This is referring to the CPSS Core Principles for systemically-important payments systems. See BIS (2001).
[10] The provision of intraday finality may also not be desirable from the perspective of a private settlement bank, particularly where it seeks to take advantage of liquidity pooling on its balance sheet during the day. This concept of liquidity pooling was discused in footnote 5.

the central system, and vice versa. However, it is not clear that the greater risk discussed above will be outweighed by this benefit.

Issue for Consideration #5: How might participants' operating costs be affected by consolidation?

The LVPS operating costs of all participants could be impacted by consolidation. First, the merging participants may benefit from lower average cost by bringing together their back-office payments processing operations.[11] Research by Hancock, Humphrey, and Wilcox (1999) suggests that there are economies of scale in the provision of wholesale payments services. The authors cite the experience of the Federal Reserve between 1979 and 1996, during which time the number of Fedwire payment processing sites was reduced. In combination with a reduction in customer service offices occurring over the same period, the authors find that consolidation led to a significant improvement in cost-efficiency. The authors suggest that these findings shed light on the incentives that private banks may have to centralize their back-office payment processing operations following an expansion due to internal growth or through a horizontal merger.

Second, in many LVPS including Canada's, each participant contributes to the annual operating costs of the system based on its share of payments volume. It follows that any removal of payments from the LVPS due to internalization will cause non-merging participants' share of operating costs to rise, assuming that no change takes place in their own payments activity following the merger. On the other hand, the operating costs of the merged participant will fall relative to the combined pre-merger share of the two merging banks.

Note: The potential changes in operating and liquidity costs mentioned above will influence the business case for participation in the LVPS. For example, consolidation could increase the cost of participation in the LVPS to the extent that some participants might deem direct participation to be too costly. Thus, further participant consolidation – through either tiering or mergers – could follow an initial merger.

Issue for Consideration #6: What influence can central bank and/or payment system policy have on the effects of consolidation?

The above issues for consideration offer various possible outcomes as a result of consolidation – both negative and positive from the perspective of policymakers. It is important to understand how the policies of central banks and/or LVPS operators might influence which of these outcomes emerges, and how policy could be used as a tool to mitigate or eliminate those outcomes deemed to be undesirable. This section explores this issue. It is important to note that this discussion is not meant to be prescriptive, but rather is intended as a brief survey of available tools.

[11] On 11 August 1998, preceding a merger proposal involving four of Canada's major banks in the same year, John Cleghorn, then Chairman and CEO of Royal Bank of Canada wrote to the Globe and Mail that, "... As rivals, Royal Bank and Bank of Montreal spend about $1.4 billion a year on largely identical technology systems. Imagine if we could eliminate some of the duplication and use these savings to improve our products, prices and services. …" (The Globe and Mail, Metro section, page A12)

Liquidity Cost and Delay: Central banks and LVPS operators have the ability to impact the relative cost of liquidity and delay in the system. For reasons outlined earlier, policymakers typically agree that the achievement of payments finality earlier in the day is desirable from a risk perspective. LVPS policy can be designed to encourage this outcome, by reducing (increasing) the relative cost of liquidity (delay). For example, the acceptance of a wider range of securities as eligible collateral could lower the cost of acquiring intraday credit in the system. However, by accepting a wider range of collateral central banks as lenders of intraday credit are exposed to greater risk. Nonetheless, central banks may still choose to accept a wider range of securities if they deem the overall benefit to be greater than the increase in risk.

Policymakers also have the ability to increase the relative cost of delay by introducing policies to encourage earlier submission of payments. Such policies include throughput guidelines, where participants are required to complete a pre-determined portion of their payments activity by certain times of the day. This is the case in Canada. Alternatively, the fee structure imposed by the LVPS operator for payments processing could reward participants for earlier submission of payments. Either of these policies may also result in the added benefit of lower intraday collateral needs if they induce improved coordination of payment activity between participants. McAndrews and Rajan (2000) explore payments synchronization among participants in the U.S. Fedwire system.

Where the cost of delay is still viewed as cheaper than the cost of liquidity, some payments may continue to be delayed by participants in anticipation of incoming funds. Policymakers may therefore choose to equip the LVPS with a centralized queuing facility, complete with some version of optimization algorithm (see BIS (2005); Arjani (2006)). The implementation of such a mechanism is a key advantage of centralized queuing, and will help to expedite finality of queued payments.

Continuity of Operations: Given their critical role in the financial system, LVPS are typically designed with a view to promoting operational resiliency and minimizing the potential impact of a system-wide or participant outage. In Canada, for example, both the system operator and participants are required to maintain operable back-up facilities which they can revert to on short notice. Participants are also expected to be fully operable 98 per cent of the time within a 30-day period. Failure to do so may result in a penalty imposed by the Canadian Payments Association (CPA). Contingency arrangements are also in place to facilitate the settlement of time-critical payments in the event of a participant or central outage. A more thorough discussion of LVTS contingency measures can be found in Embree and Millar (2008).

Participation Criteria: Access criteria in most LVPS, including Canada's, do not include restrictions relating to size or transaction volume of individual potential entrants. Such equitable system-access policies could help to encourage greater participation rates, and reduce concentration in the system.

<u>Box 1</u>: Brief Summary of Canada's LVTS

The LVTS began operation in 1999 and is owned and operated by the Canadian Payments Association (CPA). Final settlement of the LVTS occurs on a net basis at the end of the business day and is guaranteed under all circumstances, thus virtually eliminating systemic risk. This is facilitated by the system's real-time risk controls (net debit caps), collateral requirements, and a residual guarantee provided by the Bank of Canada. Guaranteed settlement enables immediate intraday finality on all processed payments.

The LVTS consists of two payment streams — Tranche 1 (T1) and Tranche 2 (T2). Each stream has its own risk controls and collateral requirements. Participants may use either stream to send payments. T1 is a defaulter-pays stream, since any T1 net debit position incurred by a participant must be fully secured with eligible collateral pledged by that participant. In T2, a survivors-pay collateral pool is used to facilitate settlement in the event that one or more participants defaults on their settlement obligation, and where the value of collateral they have pledged to the system is insufficient to cover this loss. At any time, there is sufficient T2 collateral pledged by participants to cover the largest possible T2 net debit position of any participant. The T2 payment stream greatly economizes on participants' collateral requirements relative to T1. As a result, the majority of daily payment activity in the LVTS is conducted in T2.

In T2, participants have the ability to draw on a T2 line of credit. Specifically, LVTS participants grant bilateral credit lines (BCLs) to each other. The value of a BCL represents the maximum bilateral T2 net debit position that the grantee may incur vis-à-vis the grantor at any time during the daily payment cycle. A participant's T2 multilateral intraday credit limit, known as its T2 net debit cap (T2NDC), is calculated as the sum of all BCLs granted to it multiplied by a system-wide parameter (SWP), which was equal to 0.24 at the time of the study. As of 1 May 2008, the SWP was increased to 0.30. A participant's T2NDC represents the maximum multilateral T2 net debit position that it can incur during the daily payment cycle. A payment submitted to T2 is processed if it does not result in the sending participant incurring a net debit position exceeding either its BCL vis-à-vis the receiver or its T2NDC. Participants are required to pledge eligible T2 collateral equal to the value of the largest BCL that they grant to any other participant, multiplied by the SWP. Collateral pledged to T2 by each participant is referred to as its Maximum Additional Settlement Obligation, or MaxASO, which represents the maximum credit loss that it can incur in the event that another participant defaults.

The LVTS contains a central queuing mechanism. Designated T1 and T2 payments failing the risk control test are stored in the queue and are re-tried for settlement whenever a participant's liquidity is increased. In addition, an optimizing algorithm is run every 15 minutes which tries to settle as many payments as possible subject to the applicable risk controls for each tranche. A queue expiry algorithm also runs at regular intervals removing payments that have been queued for longer than a pre-specified amount of time.

More information on the LVTS is available in Arjani and McVanel (2006).

3.0 Using Simulation Analysis to Study the Impact of Consolidation on LVPS

The previous section raises several issues relating to the impact that consolidation could have on the level and distribution of LVPS costs and risk. A second intention of the paper is to demonstrate how simulation analysis can be used to quantify this impact.

3.1 Simulation Analysis as a Tool for LVPS Research

The Bank of Canada has adopted a simulation software application originally developed by the Bank of Finland and, in conjunction with other central banks, has augmented it to exactly replicate the LVTS.[12] The application - called the Bank of Finland Payment System Simulator (BoF-PSS2) - is a complex calculation tool which uses historical and/or artificially-generated payments system data to produce output statistics based on a particular system specification, i.e., the "system rules" as specified by the user. In assessing the impact of financial sector consolidation on LVPS, several metrics can be calculated using these output data to facilitate a comparison between the current environment and a merger scenario. These include measures of concentration and centrality, collateral requirements and system-wide payments processing efficiency.

The benefit of simulation analysis relative to other modeling techniques is described by Leinonen and Soramaki (2006). These authors suggest that simulation models are advantageous when dealing with large amounts of high-frequency data (as is the case with most empirical LVPS studies), and where model outcomes may be sensitive to abstraction from the level of technical detail and inter-connectedness typically observed in LVPS. Traditional theoretical and empirical models may fall short in this respect, since they usually require some degree of abstraction for tractability purposes.

A key drawback of some payments simulation techniques, such as the one proposed in this paper, is that they lack a behavioural underpinning. That is, these applications are typically not embedded with behavioral models that can generate participants' optimal reaction to a user-imposed change.[13] Instead, behavioural changes are pre-determined by the user and specified in the input data prior to simulation. It follows then that simulation outcomes *may* not reflect optimal behaviour on the part of participants. A second drawback of these models is that they present only partial outcomes. The volume of payments settling through LVPS is derived from agents' transaction activity in the real and financial economies, and is also influenced by developments in closely related markets such as securities lending, interbank lending, and correspondent banking. Current simulation techniques do not capture the interaction between LVPS and these external markets.

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[12] The Bank of Canada is appreciative of the efforts of the Bank of Finland in spearheading development of the most recent version of the BoF-PSS2 and allowing other central banks to use it. For a complete overview of the BoF-PSS2 and its contribution to payments research, see Leinonen and Soramaki (2003).

[13] In LVPS, for example, a key decision variable is the time a participant chooses to submit payment instructions to the system, which is likely to depend on the participant's own risk-cost profile, the design characteristics of the system, and also the decisions made by other participants. Any change to one of these variables has potential to impact a participant's optimal payments submission decision.

In recognition of the above shortcomings, it is important to note that the intention of simulation analysis is not to make precise predictions about how things *will* change, but rather to provide an indication of how things *could* change following a shock to the environment under study. As noted above, the Bank of Canada has chosen to adopt simulation analysis as one of many tools it uses to carry out payments system policy and research. In recent years, simulation analysis has proven useful to the Bank in studying, for example, the risk implications of participant default (McVanel 2005; Engert and Ball 2007); the impact of system design changes on the tradeoff between risk and efficiency (Arjani 2006; Chapman, O'Connor and Millar 2008); and, the critical interlinkages between settlement infrastructures (Embree and Millar 2008).

3.2 Application to Canada's LVTS: Framework, Metrics and Data

The typical elements involved in conducting a simulation exercise involving the merger of LVTS participants with the BoF-PSS2 are described below. These elements include questions to be answered and choice of output metrics to be used for comparison, as well as the simulation steps and a description of available data.

Based on the issues raised in Section 2, the questions to be addressed as part of the simulation exercise are as follows:

- As a gauge of potential risk outside of the LVTS, what value of payments activity could be removed from the system as a result of a merger and settled internally across client accounts of the merged bank?

- How could consolidation impact the distribution of annual LVTS operating costs among participants?

- How could participants' collateral requirements (and related costs) change as a result of a merger? For the system as a whole? Is liquidity recycled through the system more or less efficiently following a merger?

- What might be the implications for operational risk following a merger? Will payments activity become more concentrated? Could the central role played by one or more participants in recycling liquidity through the system change after a merger?

3.2.1 Simulation Framework and Data Description

Based on the discussion in Section 2, it is hypothesized that the size of the consolidated participant (in terms of its relative payments throughput) will factor prominently in the impact of a merger on LVPS cost and risk. Therefore, in conducting the simulation exercise, a starting point is to separate LVTS participants into three categories based on their average share of daily payments value (Table 1). This facilitates the comparison of alternative merger scenarios using various participant combinations both within and across these categories. In this analysis, four merger scenarios are considered, reflecting both a desire for robust outcomes while also being appreciative of the time and effort involved in carrying out each simulation exercise. Analyses such as this can be resource-intensive, especially where a long time horizon is being considered.

Table 1: Categorization of Participants by Size (January – June 2007)		
Category	**Number**	**Share of Daily Payments Value**
Small	6	Less than 3%
Medium	6	Greater than 3%; less than 10%
Large	3	Greater than 10%

Further comment on choice of merger scenarios is warranted. First, only mergers involving two banks are considered and, in an attempt to optimize on resource use, no mergers involving two small participants are simulated. The impact of such a merger is anticipated to be negligible, given that the average daily payments share of the six LVTS participants in the small-size category is around 1 per cent. Second, one scenario involves a dual merger. That is, two mergers are assumed to occur in the same scenario where there is a significant size difference between these two merged participants. Third, aside from the above-noted restriction on small participant mergers and also the Bank of Canada being left out as a merger candidate, merger participants have been chosen arbitrarily. Thus, the same participant could be included in one or more merger scenarios.

Table 2 provides additional information on each merger scenario by outlining the combined *pre-merger* share of daily payments value for the merging institutions in each case. The variation in these shares is intended to facilitate the confirmation or rejection of the hypothesis regarding participant size and the impact of a merger. The actual size of each merged entity (in terms of its payments throughput) will of course depend on the degree of payments internalization achieved through consolidation. Also note that the second scenario involves a double merger, as described above.

Table 2: Pre-Merger Payments Throughput of Merging Participants	
Merger Scenario	**Combined Percentage Share of Participants' LVTS Daily Payments Value**
1	49.74
2	(A) 44.19 (B) 24.68
3	35.67
4	20.06

Historical LVTS payments and bilateral and multilateral credit limits data have been provided for use in the simulations, courtesy of the CPA. The payments data include the date and time that each transaction was submitted to the LVTS, as well as the value of each payment and the identity of the sending and receiving participants. These data reflect only those payments that settled through the LVTS on each day. Data on credit limits include the value of the bilateral or multilateral limit available to each participant, as well as its effective date and time. These data represent the period between 2 January 2007 and 29 June 2007, for a total of 127 business days. This period includes several calendar events, including two Canadian national holidays, two United States national holidays, and some Canadian provincial holidays. Each of these calendar events have been found to significantly influence daily and intraday LVTS payment flows.[14]

The simulation methodology, which will be carried out for each merger case, consists of two broad steps. This methodology is described below. Metrics used for comparison between the base-case and each merger scenario are described in the next section.

1. Determination of base-case results.
   A simulation is run using actual LVTS payments and credit limits data. The BoF-PSS2 is specified to exactly mimic the LVTS, e.g., risk-controls, queuing, etc. Simulation output data are then used to generate the base-case metric values for comparison with each merger case. The metrics are calculated for both the Tranche 1 (T1) and Tranche 2 (T2) payments streams.

2. Determination of merger-case results for each of the four scenarios.
   To generate the comparison metrics for each merger scenario, certain assumptions must be made. Key assumptions include (1) participants' timing of payment submission does not change;[15] and (2) T2 BCLs between non-merging participants are also unchanged. The payments dataset is altered in light of the new merged participant, i.e., internalized payments are separated from those processed by the LVTS. An initial simulation is run to determine the T2 BCLs to and from the merged participant, as well as the T2NDC necessary for all payments between these participants in the revised dataset to be passed without delay.[16] Using these BCL values, each participant's T2 MaxASO can be calculated and compared against the base-case.

   The T2 BCLs generated above are also used to determine the BCL granted by the Bank of Canada to each participant. The Bank of Canada's policy is to grant each participant a BCL equal to 5 per cent of the summed value of all BCLs granted to the participant. In each

[14] Arjani (2003) uses an econometric approach to assess the impact of various calendar events on LVTS activity. For example, on U.S. holidays daily LVTS settlement value is expected to decline by close to 70 per cent.

[15] It is also implicitly assumed that participants' clients do not change following the merger.

[16] In some cases, the BCL necessary for all payments to be received from the merged entity upon submission, combined with the existing BCLs between non-merging participants and the system-wide parameter, did not produce a T2NDC that would allow all T2 payments to pass upon submission. This was not a surprising result, since the T2NDC is often found to be a more binding constraint than BCLs (Arjani 2006). In these cases, an adjustment was made to the BCL granted by the merged participant to bring the T2NDC up to the value required so that all payments would be able to be processed (excluding some Bank of Canada payments, as discussed). This allowed for the preservation of existing BCL values between non-merging participants.

merger case, this may result in some original T2 payments intended for the Bank of Canada failing the bilateral risk control test. It is assumed that these failed payments are instead settled at their same time of submission in the T1 payments stream, and participants' minimum necessary T1NDC (i.e., T1 collateral required) is calculated to reflect this. Note that the assumption of no payments delay will be relaxed in Section 5.

3.2.2 Metrics for Comparison

The metrics for comparison between the base-case simulation and each merger case are as follows. These metrics coincide with the questions posed in the previous section.

Average Daily LVTS Payments Value and Volume

As a starting point, the average daily value and volume of payments settled through the LVTS will be ascertained for each simulation scenario. In comparison with the base case, this information can be used to determine how much activity is removed from the LVTS as a result of a merger and is instead settled across accounts of the merged entity.

Participants' Share of LVTS Volume

A comparison of participants' individual share of settled LVTS payments between the base-case and each merger scenario is useful for two reasons. First, since annual LVTS operating cost is distributed among participants based on their share of payments activity, this facilitates an understanding of how this (largely fixed) cost could be re-allocated among participants as a result of consolidation.[17]

At the same time, and from a risk perspective, it was suggested earlier that an operational event affecting a larger participant (in terms of payments throughput) could have more severe repercussions relative to the same event affecting a smaller participant. This is because a participant responsible for sending and/or receiving a large amount of payments volume and value has the ability to act as a significant liquidity trap and/or drain on the system in the event of an operational outage. By gaining an understanding of how much more or less concentrated LVTS activity becomes as a result of a merger, the system-wide operational risk implications of consolidation will be clearer.

The calculation of individual payments share is straightforward. For each participant i, the daily payments share (in terms of volume) over the sample period will be calculated as follows.

$$S_i = \left(\frac{PS_i^t}{PS_N^t} \right)$$

S represents the daily payments share of participant i, where t = (1,…,127 days). PS_i^t and PS_N^t represent the number of T1 and T2 payments sent by participant i and by all N participants on day t, respectively. For reporting purposes, this figure will be averaged over the sample period.

[17] Limitations with respect to the data prevent an understanding of how costs associated with internal staffing and administration, and also IT costs will change, particularly for the merging entities. Moreover, there is no way of identifying the up-front cost of having to consolidate proprietary payment systems.

Network Centrality
A participant deemed central to the system from a network topology perspective is viewed as a crucial conduit for the smooth intraday flow of liquidity. Thus, any disruption to the daily operation of this participant could have negative funding consequences for others in the system. To complement the measure of payments share in understanding the operational risk implications of consolidation, a measure of centrality is also employed to understand which LVTS participants are currently deemed central, and how this might change following a merger. This second measure is useful since the correlation between payments share and centrality in the system may not be perfect.

In particular, a measure of centrality put forth by Bonachich is employed in the analysis.[18] This measure is calculated using a matrix that summarizes payments sent between participants. The matrix is standardized so that each element represents the share of payments sent by one participant to another. Using this matrix, the most central participant can be identified. Participants are ranked according to their average daily centrality over the sample period. The lower a participant's centrality rank, the more important the institution is as a conduit for the flow of liquidity through the system, i.e., the participant with a centrality rank of 1 is the most central in the system. More information regarding this centrality measure can be found in Appendix 1.

Collateral Required and Liquidity Efficiency
These measures will be important for understanding how a merger affects the need for liquidity and, more specifically, collateral requirements in the system, as well as the efficiency of collateral usage at both the participant- and system-level. Recall that the need for intraday credit in the LVTS could either increase or decrease following a merger, depending on the size of the merging participants, the resulting bilateral flows that emerge between participants, and the ability for incoming and outgoing payments to offset each other. As mentioned, this impact may differ across participants, so it is important to also calculate this effect by participant.

In comparing collateral required between the base-case and each merger scenario, participants' median daily T2 MaxASO and median largest daily T1 net debit position (to reflect its minimum necessary T1NDC) will be calculated over the sample period. Each participant's median daily total LVTS collateral requirement is found by adding these values together. Moreover, summing across all participants allows for comparison of collateral required at the system-level. Note that this metric will be directly influenced by some of the assumptions made, and these assumptions could have opposing effects. First, the decision to leave original payment submission times unaltered may overestimate the collateral required in each tranche, since participants may find a better way to coordinate incoming and outgoing payments following consolidation and thus will rely less on intraday credit. This possibility is explored in Section 5. Second, the calculation of participants' T1 collateral requirement is likely to be an underestimate, since it does not take into account precautionary collateral holdings maintained by participants to meet unforeseen obligations. McPhail and Vakos (2003) analyze LVTS participants' decisions to hold excess collateral in the T1 payments stream. Finally, the decision to move certain payments intended

[18] See Bonachich (1987). For a comprehensive overview of centrality measures see Borgatti (2005).

for the Bank of Canada to the T1 payments stream will also affect collateral requirements in that stream.

To understand how the efficiency of collateral usage may change following consolidation, the median daily turnover ratio is compared at both the participant- and system-level. The turnover ratio is a gauge of the value of settled payments activity supported by each pledged dollar of collateral. An increase in this variable means an efficiency improvement, where each dollar of collateral supports a greater value of payments compared to before the merger. It follows that the calculation of the daily turnover ratio (TR) is different for T1 and T2 given the difference in the collateralization of intraday credit in these two streams (see Box 1).

For T2, the turnover ratio for participant i on day t is calculated as follows:

$$TR_{it}^{T2} = \frac{PVR_{it}^{T2}}{C_{it}^{T2}}$$

For T1, the turnover ratio for participant i on day t is calculated as follows:

$$TR_{it}^{T1} = \frac{PVS_{it}^{T1}}{C_{it}^{T1}}$$

In the above equations, PVR and PVS represent payments value received and payments value sent, respectively, while C refers to collateral required (as calculated above). Superscripts are used to specify the applicable payments stream. A system-wide turnover ratio can easily be calculated for the T1 and T2 payments streams by summing the applicable PVR, PVS and C variables over all participants prior to calculating the above ratios.

Note that the sample median values of the above liquidity measures are reported in the findings instead of sample averages because, as mentioned earlier, several 'calendar events' occur during the period which could positively skew the sample distribution of these variables.

4.0 Simulation Results

This section summarizes the simulation results, which have been generated based on the framework and behavioural assumptions outlined in Section 3. Section 5 offers further simulation results using alternative behavioural assumptions

4.1 Summary of the Base Case

Table 3 presents aggregate value and volume statistics for the LVTS during the sample period. On average, over $170 billion settled through the LVTS each day in the form of approximately 20,000 payment instructions. The T2 payments stream accounts for 87 per cent and 98 per cent of LVTS value and volume, respectively, over the period.

Table 3: Average Daily LVTS Value and Volume (January – June 2007)				
	T1		T2	
	Value ($B)	Volume	Value ($B)	Volume
Mean	22.92	297	149.95	19,987
Min	7.49	162	48.33	10,494
Max	46.41	388	233.11	30,810

There are currently 15 participants in the LVTS, comprising 11 domestic institutions (including the Bank of Canada), two foreign subsidiaries, and two foreign bank branches. Table 4 illustrates the large heterogeneity among participants in terms of average daily LVTS payments throughput, as well as the high degree of concentration among large participants currently observed in the system.

Table 4: Distribution of LVTS Payments Activity by Participant Size (Daily Average, January – June 2007)			
	Number of Participants	Share of Value	Share of Volume
Small	6	6.35	6.02
Medium	6	31.79	35.72
Large	3	61.86	58.26

Table 4 shows that the three largest participants account for over 60 percent of payments value. Note that the six major Canadian banks account for more than 80 per cent of daily T2 value and more than 85 per cent of T2 volume sent through the system.

Table 5 displays information on total collateral required for all payments to successfully pass the risk controls in the base-case simulation.[19] Median daily values have been collected for each participant and are averaged among small, medium and large participant categories, excluding the Bank of Canada, since it does not pledge collateral to the system.

[19] That is, the T1NDC calculation excludes precautionary collateral holdings that may be pledged by participants (see McPhail and Vakos (2003)).

Table 5: Base Case Metrics (Based on Median Daily Values for Each Participant)				
	Average Small	**Average Medium**	**Average Large**	**System-Wide**
Total Collateral Required ($M)	210.62	590.16	1,547.00	8,856
- T1NDC	109.82	265.16	1,099.00	5,282
- MaxASO	100.80	325.00	448.00	3,574
T2 Turnover Ratio	11.80	22.65	67.36	38.49
T1Turnover Ratio	0.99	0.93	2.18	2.14

Table 5 shows that large participants are, on average, required to pledge a far greater amount of collateral to the LVTS in absolute terms (over $1.5 billion to T1 and T2, on average). However, each dollar of collateral pledged by large participants provides substantial benefits, particularly in the T2 payments stream. For each dollar of collateral pledged to T2, large participants receive close to $70 in payments. This is more than 3 times the amount for medium-sized participants, and more than 6 times the amount for small participants. Table 4 also shows that the efficiency of T1 collateral usage is far lower relative to that in T2. This is to be expected given the difference in intraday credit collateralization, and also that T1 payments are far fewer in number and often time-sensitive. This makes it more difficult to coordinate payment flows in this stream.

Although not shown in the above tables, the Bonachich measure of centrality reflects a close correlation between a participant's central role in the system and its relative payments throughput. For example, the largest 3 participants in terms of average daily payments value are ranked first, second and third in terms of centrality measured at the same daily frequency. However, this correlation breaks down slightly for the small participant category.

4.2 Summary of the Simulation Results

Below is a summary of the simulation results, which follows up on the questions raised earlier. Tables containing the full range of figures from the simulation exercise can be found in Appendix 2.

<u>What value of payments activity could end up being removed from the LVTS and internalized across client accounts of the merged bank?</u>

In the four scenarios considered, the average daily value of payments activity removed from the LVTS T2 stream and settled internally by the merged participant(s) is slightly over $15 billion, or about 9 per cent of the base-case amount. There is large variation, however, between scenarios. For example, approximately $30 billion of payments value is internalized in the first case, while around $2 billion is internalized in the fourth scenario. Moreover, the dual merger case results in a combined $22.5 billion being internalized by the consolidated entities. In T1 the amount internalized ranges from $43 million to $790 million. It is not surprising that there is less internalization in T1 than in T2, since fewer payments are sent through T1 and most are to and from the Bank of Canada. Recall that value removed from the LVPS and settled internally by participants reflects potentially greater risk outside of the LVPS.

How could consolidation impact the distribution of annual LVTS operating costs among participants?

Recall that participants' share of annual LVTS operating costs is based on their share of payments volume. In all of the merger scenarios, operating costs decline for the merged participant(s) and increase for non-merging participants. This result is not surprising, given the assumption that non-merging participants continue to send and receive the same volume and value of payments in the merger case. Thus, the removal of payments due to internalization will cause their share of LVTS activity to rise.

Merged participants realize a reduction in their share of operating costs of around 3 percentage points, on average. Once again, a high degree of variation is observed, where the largest reduction is found in the first case (9 percentage points) and the smallest reduction appears in one of the two mergers in the second case (0.58 percentage points).

How could participants' collateral requirements (and related costs) change as a result of a merger? For the system as a whole?

In each scenario, system-wide collateral requirements are found to increase following consolidation, by roughly 15 per cent on average. The largest increase is found in the first case (23 per cent), while the smallest is in the fourth case (8 per cent). Moreover, this result is driven by an increase in T2 collateral required in all merger cases, while total T1 collateral required is found to increase in only two of the four scenarios.

At the participant level, the change in collateral requirements is somewhat ambiguous both across and within scenarios. That is, it is not always the case that the merged participant's collateral requirement (and thus liquidity cost) is reduced by consolidation, nor do all non-merging participants experience an increase in their collateral requirement. Indeed, in one scenario some non-merging participants' collateral requirement actually falls following consolidation.

In three of the five mergers considered[20], the merged participant experiences a decrease in its total collateral requirement. This decrease amounts to 10 per cent on average, and ranges from 1.5 (third scenario) to 17 per cent (first scenario). In the other two cases, the merged participant's total collateral requirement is increased, by up to 32 per cent in the fourth case and by 2 per cent for the smaller of the two merged participants in the second scenario. This is driven by an increase in these participants' T2 collateral required. For example, the merged entity in the fourth scenario faces a rise of 80 per cent in its MaxASO, as it is required to grant a BCL of over $5 billion to a large participant. However, all five merged participants experience a decline in their T1 requirement, which is likely due to the benefits of internalization and liquidity pooling described earlier, as well as a higher degree of payments offsetting due to an increased number of T1 payments requiring settlement.

[20] Recall that two mergers were simulated in the second scenario.

For non-merging participants, total collateral required increases for all participant categories in all but the fourth merger scenario. The percentage increase in collateral required by non-merging participants in these three cases ranges from 28 per cent in the third merger case to 55 per cent in the first scenario, and is driven by a rise in both T1 and T2 collateral required. However, the results of the fourth merger scenario indicate a modest decline of 3 per cent in the total collateral requirement of small participants. This result stems from a decline in T1 collateral required, perhaps due to an increased number of payments settling through this stream based on the assumption regarding the treatment of certain Bank of Canada payments. It should also be noted that the percentage increase in T2 collateral required by all non-merging participants in this scenario is much less relative to the first three cases, since most participants' largest BCL remains unchanged from the base case. That is, the merged participant in the fourth scenario is typically not the recipient of the largest BCL granted by other participants. The relatively small size of this merged participant compared with the other cases is viewed as a major contributing factor to this result.

These results support the earlier hypothesis that the impact of a merger will depend on participant size. Collateral requirements for non-merging participants are found to unambiguously increase when the merged participant is large, i.e., in this specific study it has greater than a 30 per cent share of payments throughput. When this is the case, non-merging participants need to grant their largest BCL to the merged participant, and in most cases, this BCL is higher than their largest BCL prior to the merger. In turn, additional T2 collateral is required. At the same time, a merger that results in a relatively smaller participant (such as that described in the fourth scenario and also the second merger of the dual merger case) is not expected to have a significant impact on the collateral requirements of others.

Once again, these results are influenced by behavioural assumptions made earlier, specifically regarding payment submission times. An alternative submission specification may help to reduce volatility in bilateral payment flows between participants, thus lowering the minimum necessary BCLs between them as well as T2 liquidity costs. This possibility is explored in Section 5.

Is liquidity recycled through the system more or less efficiently following a merger?

The simulation analysis reveals a decline in the efficient recycling of liquidity at the system-wide level for T2, and an increase for T1. The T2 system-wide turnover ratio drops from around $38 in the base-case to between $24 (first scenario) and $31 (fourth scenario). This is not a surprising result, given that both an increase in collateral required and a decrease in the value of payments settled through T2 is observed in each merger scenario. The T1 system-wide turnover ratio is found to increase in each merger case, from $2.14 to between $2.19 in the third case and $2.96 in the first case. This result is intuitive, given that more payments value is being settled through this stream on average each day relative to the base-case (in three of the scenarios) and often the merged bank's T1 collateral savings are sufficient to bring total T1 collateral required below what was necessary for payments to settle in the base-case.

At the participant-level, the results for each of the merging participants are similar to those for the system as a whole. That is, all five merging participants realize a decline in T2 collateral efficiency, which ranges from 18 per cent to 49 per cent, and an increase in T1 collateral efficiency ranging from 7 per cent to 55 percent.[21] To reiterate, this is reflective of more payments settling through this stream and also reduced T1 collateral requirements for these participants.

For non-merging participants, the results for collateral efficiency are more mixed. Collateral efficiency in T2 falls for all participant categories in all merger scenarios; however, it falls only slightly (by less than 3 per cent, on average) for small participants in the fourth scenario. This finding is generally in line with the change in collateral requirements reported earlier. At the same time, large participants continue to experience greater T2 collateral efficiency compared with medium participants, and medium participants continue to experience greater efficiency relative to small participants. Collateral efficiency continues to be lower in T1 relative to T2 following a merger. Large non-merging participants experience a decline in T1 collateral efficiency for all merger scenarios, while the result for small- and medium-sized participants is more mixed across merger cases.

What could be the implications for operational risk following a merger? How much more concentrated could payments activity become? Could the central role played by one or more participants in recycling liquidity through the system change following a merger?

A merger between two LVTS participants could increase operational risk implications for the system. In three of the four merger scenarios, the merged participant's share of LVTS payments volume is found to be greater than that of any other single participant prior to the merger, reflecting a greater degree of concentrated payments activity with one institution. For example, in the first scenario the merged participant's share of LVTS activity approaches 40 per cent, while in the second scenario the combined share of the two merged participants' LVTS activity is around 70 per cent. As a result, the system-wide implications of an operational event occurring at one of these merged banks, i.e., relating to funding and other risks, could be significant. At the same time, the merged participant(s) are found to be the most central in both of these cases, and also in the third case.

The fourth merger scenario presents an interesting finding in this respect. In this case, a merger of two medium-sized participants has the impact of creating another large-size participant, which is ranked second in terms of overall payments share. As discussed in Section 2, this could contribute to reducing the high degree of concentration among one or more firms (and related operational risk) in this category by promoting greater competition in related markets, such as correspondent banking.

Perhaps most interesting with respect to centrality is the potential that a merger has to significantly change the central role of a participant in the system. For example, in the smaller of the two mergers in the second scenario, the merging participants are ranked second and fifth in terms of centrality; however, as a merged entity it is the most central participant in the system, even despite being the smaller of the two merged participants in that scenario.

[21] Note that, to facilitate this comparison, the weighted average of the pre-merger turnover ratios for the two merging participants was calculated. Each participant's pre-merger share of volume was used as to weight the individual turnover ratios.

5.0 Behavioural considerations

One drawback to simulation analysis, which was briefly discussed in Section 3, is that most of the current models (including the BoF-PSS2) lack a behavioural underpinning. That is, these models do not, on their own, *generate* outcomes based on the optimal reaction of participants to a shock to the environment. Instead, the user is required to make assumptions regarding how participants will react to the shock, and adjust the input data accordingly to be used in the simulation. In this sense, simulation models can be used to perform different sensitivity analyses, where one can determine how outcomes might change under a variety of assumptions regarding participant behaviour.

The findings reported above are generated based on specific assumptions regarding how LVTS participants might react to consolidation. Two of these assumptions pertain to payments submission and the granting of BCLs. That is, it was assumed that participants' payments submission times do not change following a merger, and that non-merging participants will choose to grant the consolidated entity a BCL sufficient for all payments to pass the T2 risk control test. In this section, two experiments are conducted where each of these assumptions is relaxed to better understand how sensitive the above results are to behavioural change. These experiments will also shed light on how liquidity cost may be traded for payments delay as a result of a merger in the LVTS.

5.1 Changes to Non-Merging Participants' BCL-granting Behavior

In the preceding simulations, it was assumed that non-merging participants would grant the merged bank a sufficient BCL to ensure that all bilateral payments sent from it would pass the T2 risk control test. The BCL provided by the merged participant to the others was calculated in the same way. However, as discussed in Section 2, given that there could be credit risk and collateral implications associated with granting such a BCL, this assumption may not hold. That is, non-merging participants may be unwilling or unable to grant such a BCL to the merged participant, and vice versa. A participant that wants to submit a payment through T2 but does not have sufficient liquidity to do so (due to the lower BCL) has two options. It can either choose to delay sending the payment until it gathers sufficient T2 bilateral liquidity for the payment to pass the T2 risk control test, or it can choose to send the payment via the more collateral-intensive T1 payments stream, possibly by incurring additional liquidity cost.

The purpose of this experiment then is to quantify the impact of a reduction in the BCLs granted following a merger where participants choose to delay any T2 payments that cannot initially pass the risk-control test. The experiment will be conducted for each of the four merger scenarios, where the merger results in Section 4 will act as the base case.

Some additional assumptions are needed. First, it is assumed that designated payments failing the T2 risk control test enter the LVTS central queue instead of being held back by participants internally (see Box 1 for information on the LVTS central queue). The functionality of the queue itself is unchanged. Second, two additional simulations will be run where it is assumed that all non-merging participants choose to reduce the BCL they grant to the merged entity by 10 per cent in the first simulation, and by 20 per cent in the second simulation. For simplicity, this reduction takes place regardless of whether the merged entity is granted a participant's largest BCL. The merged participant chooses to do the same in the opposite direction. The values of 10 and 20 per cent have been chosen arbitrarily. BCLs between non-merging participants continue to be unchanged, and each simulation is run as before using the same transactions dataset.

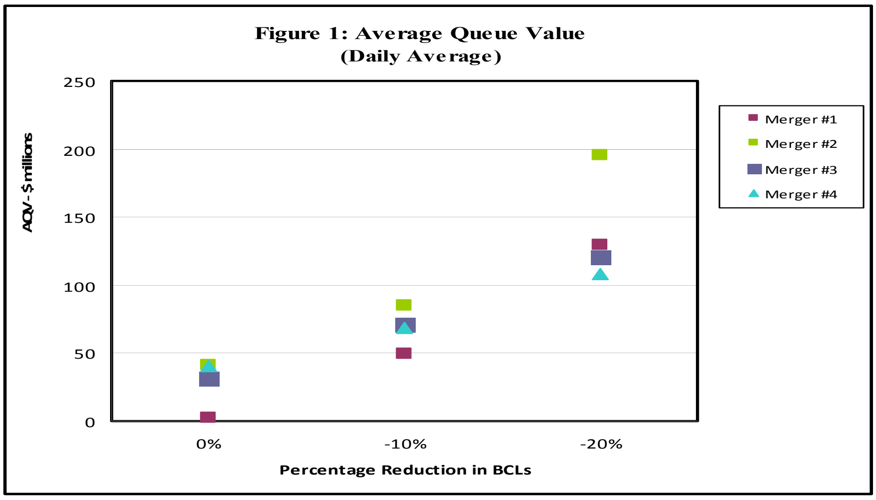
Two measures are used to capture payments delay. The first is Average Queue Value (AQV):

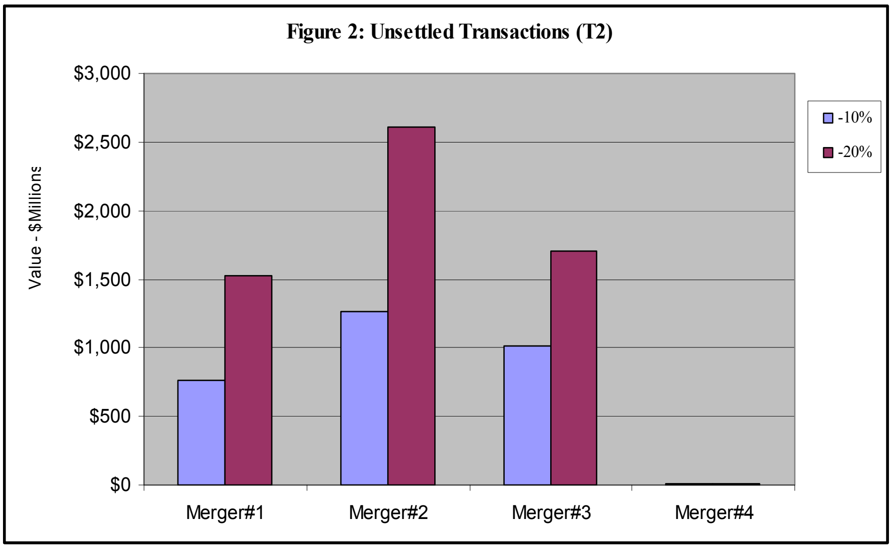
$$AQV_t^N = \left(\frac{\sum_{i=1}^{T} Q_i^N}{T} \right)$$

AQV is an aggregated measure, which calculates the average value of centrally queued payments each day. It is found by dividing the sum total of queued payments value (Q) in each one-second interval i on each day t by the number of one-second intervals per day (T = 64,800 seconds per day, based on the LVTS general payment exchange period). It follows that this indicator is influenced (weighted) by both the value and delay duration of each queued payment. Thus a drawback of this measure is that one cannot differentiate whether a small payment spends a long time in the queue or a large payment is in the queue for a short period of time. Nonetheless, the measure is still useful and relevant for purposes of this analysis.

The second measure is median daily value of unsettled transactions. The need for this second measure arises since only certain payments are queued following failure of the risk-control test, and further that payments are queued for a limited time. Hence, the AQV measure could, on its own, underestimate the true degree of payments delay following this behavioural change. The existence of unsettled transactions means that participants would have to find alternative (and possibly more costly) means to meet these obligations, such as sending the payments through T1. In the analysis we assume that any unsettled payments are not re-submitted to the LVTS.

Figures 1 and 2 below illustrate these measures for each of the merger scenarios following both a 10 per cent and 20 per cent reduction in BCLs. In Figure 1, “0%” refers to the original merger scenario. The values reported are for T2 payments only.





* Unsettled transactions value for the fourth merger scenario is non-negative, ranging from $8 million in the 10 per cent case to over $13 million in the 20 per cent case.

Figures 1 and 2 indicate that, generally speaking, this potential behavioral response to a merger could have significant system-wide risk ramifications in the form of greater delay in payments processing. Further, the result is non-linear. System-wide delay rises more quickly in each of the scenarios when moving from a 10 per cent to 20 per cent reduction in BCL values relative to the move from the base-case (0 per cent) to 10 per cent. This is the result of 'knock-on' effects, where the inability of the merged participant (which is typically very large) to circulate liquidity through the system causes non-merging participants to miss their own obligation timelines to each other. Indeed, many of the queued and unsettled payments observed in the first three merger scenarios are between non-merging participants.

These results are also influenced by the identity of the merging participants and current payment flow patterns in the LVTS. For example, in Figure 1 some delay is observed in each of the merger scenarios (at 0%) stemming from observed delay in the LVTS (recall that original BCLs granted between non-merging participants are used in the simulations).[22] However, a significant difference is noted in the base-case AQV between the first merger scenario and the others. The findings of Cheung (2008) help to explain this. Specifically, she observes frequent use of the LVTS queue to process payments between merging participants in the first scenario; however, with the merger, these payments are internalized and therefore no longer appear in the LVTS queue. This impact also carries forward in the case of a 10 per cent reduction, but 'knock-on' effects are found to be very large and outweigh this effect in the 20 per cent reduction case.

5.2 Change in Payments Submission Behavior

Often in the simulation results it was found that the merged bank is extended the largest BCL granted by non-merging participants, which could lead to a significant increase in the T2 collateral requirement of the latter. For example, in the first merger scenario, the merged bank received the largest BCL provided by all other participants leading to a rise in T2 collateral of around 80 per cent for non-merging small and large participants, and around 37 per cent for the medium participants. Using this scenario as an example, the analysis below examines whether a re-organization of payments submission between the merged and non-merging participants could lower the T2 collateral requirement of participants. The same analysis could, of course, be adapted to any of the merger scenarios considered.

Recall that the daily BCL granted to the merged participant in each scenario was defined as the non-merging participant's minimum intraday bilateral net debit position vis-à-vis the merged participant required to accommodate all payment flows. It is likely that alternative submission patterns could result in a lower BCL requirement. In this analysis, one possible alternative is tested to assess how collateral requirements could change – that being perfect coordination of payment flows where all payments between the merged entity and non-consolidating participants are assumed to be submitted virtually simultaneously.[23] Although perhaps not the most plausible alternative, this will provide a "best-case" scenario for each non-merging participant regarding the BCL that must be granted to the consolidated participant for all payments to pass without failing the bilateral risk control test. This is akin to the concept of the lower bound of (bilateral) liquidity as outlined by Leinonen and Soramaki (2003). For simplicity, it is assumed that payment flows between non-merging participants are unchanged. The results of the analysis for non-merging participants are provided in Table 6.

[22] Delay (i.e., use of the central queue) is typically observed on a daily basis in the LVTS (see Cheung (2008)). There are, of course, no unsettled transactions in any of the original merger scenarios since the dataset provided by the CPA only includes settled payments.

[23] It is also assumed that this simultaneous exchange of payments instructions takes place early in the day. The time at which this exchange of payments takes place will also influence payment flows relating to transfers between non-merging participants; however, the analysis does not seek to address this impact.

Table 6: Impact of payments re-structuring on non-merging participants' BCLs (Merger Scenario #1 Example; Dollar figures in $ millions)						
	Original Merger Scenario		**Revised Scenario With Re-Structured Payments**			
Participant	**BCL to merged entity**	**MaxASO**	**BCL to merged entity**	**Largest BCL**	**MaxASO**	**% Change in T2 Collateral Requirements**
(Column)	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Non-Merging Small	150,773	1,072	193	1,775	426	**-60.3**
Non-Merging Medium	8,990	2,157	141.74	4,200	1,008	**-53.3**
Non-Merging Large	2,731	655	190.61	1,000	240	**-63.4**

Column 1 of Table 6 reports the categorical sum of BCLs granted by non-merging participants to the merged institution from Section 4, while the second column shows the corresponding T2 collateral requirement. Column 3 shows the revised sum of BCLs granted to the merged participant based on perfect coordination of payments. Although not captured in Table 6, for some participants this value is zero meaning that, on at least 50 per cent of days in the sample, coordination of payments led to a net credit position for the non-merging bank. To calculate the revised T2 MaxASO, the new largest BCL granted by each participant is found (none of which are to the merged participant). This exercise yields a significant reduction in participants' T2 collateral requirement – by 60 per cent, 53 per cent and 63 percent for the small, medium and large participants, respectively.

The above simulation reveals that non-merging participants could reduce their collateral requirements through improved payments co-ordination with the merged participant. However, similar to the previous experiment, such an action could yield payments delay in the system. This is because any reduction in the BCLs granted to the merged participant (facilitated by better coordination of payments activity) will negatively affect its T2NDC, and possibly lead to payments to other participants being delayed. Indeed, the merged participant's T2NDC is reduced to $126 million based on the revised BCLs in Table 6, around 90 per cent less than its required T2NDC of $1.27 billion. The amount of delay is likely to be significant in this case based on how central the merged participant is, to the extent that severe payments gridlock (and possibly even deadlock) could occur. Worse still, if the merged entity also reduces its BCLs to non-merging participants as a result of improved payments coordination then all T2NDCs will be reduced, thus further exacerbating delay.

This exercise examines a situation where all payments with the merged participant were submitted simultaneously; however this is not necessarily plausible, in part because not all payments are known with certainty at the start of the day. Nonetheless, these results suggest that even a slight improvement in the coordination of payment flows between the merged participant and others could result in lower liquidity costs for both. However, this benefit is not likely to be realized without increased delay in the system.

6.0 Conclusions

The purpose of this paper was twofold. First, it sought to understand how financial sector consolidation might impact the level and distribution of cost and risk within and, to a certain extent, outside an LVPS. The second purpose was to demonstrate the usefulness of simulation analysis to quantify these impacts.

In addressing the first purpose, the paper raised several issues to be considered by policymakers. These issues included: the effect of consolidation on liquidity and operating costs, payments delay, operational risk, and also risk outside of the LVPS. The role of policy in influencing the outcome of consolidation was also discussed.

The BoF-PSS2 simulation application was used to empirically study certain of the above issues using a hypothetical merger scenario in Canada's LVTS. Simulation has both advantages and disadvantages relative to other research tools. A benefit of the simulation exercise is that it allows for the disaggregation of results in terms of the impact on the merged participants and on the non-merging participants.

Four hypothetical merger scenarios were simulated in this study, where the size of the merged bank was allowed to vary across each of the scenarios. Perhaps the most important finding in this study is that the size of the merged participant is a key factor in determining how consolidation will impact LVPS cost and risk. That is, liquidity costs and operating costs were found to generally decline for the merged participant and increase for non-merging participants; however, this was not always the case. Where a smaller merged participant was created, the opposite effect occurred. The simulation results also reveal that a merger can heighten operational risk in the system, depending again on the resulting size and centrality of the merged entity.

As mentioned, one shortcoming of simulation analysis is that it lacks a behavioural underpinning. In order to partially address this shortcoming additional simulations were conducted in which assumptions about participants' behaviour were altered. The objective of this sensitivity analysis was to understand whether changes in behaviour could result in lower liquidity costs for participants. Specifically, the analysis involved changes to earlier assumptions regarding the BCLs that participants grant, and the time that payments are submitted to the system. Indeed, in each of these two experiments participants' collateral requirements did fall, but only at the expense of higher payments delay in the system. Once again, participant size was highly relevant in terms of the simulation outcome. For the smaller merged participant, additional delay and the value of unsettled payments tended to be lower when BCLs were adjusted in the first sensitivity analysis.

Several areas for future research are identified, not least of which is to consider further merger possibilities using the same framework. Moreover, additional simulation analyses can be run to estimate the impact of either a technical- or solvency-related default of a merged participant in terms of the losses such an event could bring to the system.

It is recognized that financial sector consolidation will influence other areas related to the payment system, such as securities lending and provision of correspondent banking services. These external markets were outside the scope of this analysis, but warrant further study in order to understand the impact of consolidation on the area of banks' business related to payments services. Another suggested area of further study relates to the effects that consolidation will have on the collateral composition and related costs to a merged participant in the LVTS. Alterations in collateral composition may be necessary following a merger since (1) an issuer limit applies to some types of eligible LVTS collateral, and these limits could be breached following a merger; and (2) a participant is unable to pledge securities it has issued, which may affect the merged entity if the two consolidating institutions were pledging each others' collateral to the system prior to the merger. In either case, replacement of LVTS collateral securities to work around these rules could entail costs for participants.

Another area recommended to be studied in greater depth regards how central bank and payment system policy might alter the outcomes of consolidation. Finally, this analysis uses simulation; it could be worthwhile to compliment the knowledge gained through simulation by examining this same issue using other models of the payment system.

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Appendix 1: Centrality Measure

In this appendix we will explain the centrality measure and how it is calculated in more detail than was done in Section 3 in the main text. The centrality rank is used to indicate which participant is most important for recycling liquidity and the smooth functioning of the LVTS. Our centrality measure is Bonacich centrality, which is explained in Bonacich (1987) and Borgatti (2005). We weight our measure by value as described in Ballester et al. (2006). We will outline the process of calculating centrality in steps, explaining the interpretation as needed.

<u>Step 1: Generate an adjacency matrix (G)</u>

An adjacency matrix outlines the links that exist between participants. Each element of our adjacency matrix (g_{ij}) represents the share of participant i's outgoing payment value that are sent to j. This matrix summarizes how much each participant transacts with each of the other participants.

<u>Step 2: Discount based on path length</u>

Bonacich centrality weights longer path lengths less than shorter ones. The path length is the number of links that are needed to move from the starting point to the end point. A longer path length means that a dollar of liquidity sent out by one participant takes more links to move through the system (and return to them). Shorter path lengths mean that the liquidity is received back by the sending participant quicker than with longer path lengths. The discounting takes the time value of money into consideration. If a path contains many links, it takes more time for the liquidity to be recycled through the participants, and therefore we discount the value of the longer paths to account for the additional time required for the liquidity to be recycled.

Following O'Connor, Chapman and Millar (2008) we use a discount rate equal to (1/(1+target for the overnight rate)). Where the target for the overnight rate is calculated at a daily rate. The target for the overnight rate is 4.25 percent throughout our sample period. The weighted adjacency matrix will be denoted M.

<u>Step 3: Bonacich matrix manipulations</u>

We then calculate (I-M)^-1, where I is an identity matrix and M is the matrix representing the discounted shares of payments sent between participants.

<u>Step 4: Weight by value</u>

Ballester et al. (2006) propose a weighted centrality measure. We weight our centrality by the share of total daily value that is sent by each participant. Weighting the centrality matrix in this way accounts for the fact that some participants send much larger values than others. For example a small participant that sends 30 percent of its value to participant j is not the same as a large participant who sends 30 percent to j, because the large participant is sending much more value. Weighting by value in this way ensures that all participants are not treated as though they send the same amount. Thus we weight the adjacency matrix by the share of value and multiply with the result of step 3. Thus we have (I-M)^-1 * Gα.

<u>Step 5: Rank based on centrality</u>

Once we have calculated centrality values we translate these into rankings, where a participant with the ranking 1 is the most central participant and 2 is the second most central. Changing the centrality values into rankings allows us to more easily compare days in the sample. As well it allows for an easily interpreted result.

One caveat of Bonacich centrality is that if there are participants who do not hold on to liquidity from received payments, then this measure may bias towards these participants being more central, since the measure does not take into account how long a dollar stays with each participant. If we see participants moving up in the centrality rankings despite this bias towards some of the most central participants then we can be certain that centrality is being affected by the consolidation.

Appendix 2: Results Tables

Table 1: Internalization of Payments Value due to Merger

	Merger 1	Merger 2	Merger 3	Merger 4
T1 Value Internalized ($M)	424.1	(A) 790.2 (B) 163.8	75.7	43.6
T2 Value Internalized ($M)	29,460	(A) 17,686 (B) 3,891	6,541	1,837

Table 2: Value Settled Through the LVTS – System-wide and Merged Participant

	Merger 1		Merger 2			Merger 3		Merger 4	
	Total	Merged Bank	Total	Merged Bank (A)	Merged Bank (B)	Total	Merged Bank	Total	Merged Bank
Total Value Settled ($B)	143.0	56.2	150.3	57.9	38.8	166.3	55.2	171.0	32.7
T1 Value Settled ($B)	23.2	7.3	22.7	6.8	2.2	23.4	6.3	23.5	2.2
T2 Value Settled ($B)	119.8	48.9	127.6	51.1	36.6	142.9	48.9	147.5	30.5

Table 3: Volume Settled Through the LVTS – System-wide and Merged Participant

	Merger 1		Merger 2			Merger 3		Merger 4	
	Total	Merged Bank	Total	Merged Bank (A)	Merged Bank (B)	Total	Merged Bank	Total	Merged Bank
Total Volume Settled	17,352	6,520	17,207	6,810	5,115	19,869	6,644	19,783	3,702
T1 Volume Settled	302	66	301	62	12	297	63	301	8
T2 Volume Settled	17,050	6454	16,906	6,748	5,103	19,572	6,581	19,482	3,694

Table 4: Share of Volume Settled Through LVTS – Base Case vs. Merger Case
(Participant category averages reported. Results for merging participants reported separately.)

	Merger 1		**Merger 2**		**Merger 3**		**Merger 4**	
	Base Case	Merger	Base Case	Merger	Base Case	Merger	Base Case	Merger
Average Small (Non-merging)	1.00	1.17	1.00	1.18	1.00	1.02	1.00	1.03
Average Medium (Non-merging)	5.95	6.96	4.02	4.73	6.58	6.72	5.34	5.47
Average Large (Non-merging)	11.68	13.65	-	-	13.16	13.43	23.29	23.88
Merging Participants	46.58	37.57	(A) 43.62 (B) 30.28	(A) 39.53 (B) 29.70	34.75	33.41	20.72	18.72

Table 5: Total Collateral Required (System- and Participant-Level) – Base Case vs. Merger Case
(Participant category averages reported for participant-level. Results for merging participants reported separately.)
(All figures in $ millions)

	Merger 1		Merger 2		Merger 3		Merger 4	
	Base Case	**Merger**	**Base Case**	**Merger**	**Base Case**	**Merger**	**Base Case**	**Merger**
Total System-Wide	8,856	10,866	8,856	9,986	8,856	10,248	8,856	9,557
- T1NDC	5,282	6,242	5,282	4,990	5,282	5,630	5,282	5,202
- MaxASO	3,574	4,626	3,574	4,996	3,574	4,618	3,574	4,355
Total Avg. Small (Non-merging)	211	310	211	328	211	271	211	205
- T1NDC	110	130	110	117	110	117	110	102
- MaxASO	101	179	101	211	101	154	101	103
Total Avg. Medium (Non-merging)	590	911	556	755	651	797	562	598
- T1NDC	265	466	240	292	311	383	246	256
- MaxASO	325	445	316	463	340	414	316	342
Total Avg. Large (Non-merging)	749	1,233	-	-	734	986	1,946	2,008
- T1NDC	389	578	-	-	314	355	1,454	1,468
- MaxASO	360	655	-	-	420	631	492	540
Total Merging Participants	3,892	3,220	(A) 3,923 (B) 1,446	(A) 3,515 (B) 1,477	3,520	3,468	1,451	1,918
- T1NDC	2,908	2,550	(A) 3,059 (B) 606	(A) 2,740 (B) 377	2,752	2,690	731	628
- MaxASO	984	670	(A) 864 (B) 840	(A) 775 (B) 1,100	768	778	720	1,290

* Base-case amounts will vary by merger scenario, depending on which participants are chosen to merge. Recall that averages across participant categories are those for non-merging participants.

Table 6: T2 Turnover Ratio
(Participant category averages reported for participant-level. Results for merging participants reported separately.)

	Merger 1		Merger 2		Merger 3		Merger 4	
	Base Case	**Merger**	**Base Case**	**Merger**	**Base Case**	**Merger**	**Base Case**	**Merger**
System-wide	38.49	24.41	38.49	24.99	38.49	29.15	38.49	30.99
Avg. Small (Non-merging)	11.80	7.69	11.80	6.78	11.80	9.46	11.80	11.46
Avg. Medium (Non-merging)	22.65	17.21	21.04	15.17	23.73	19.95	20.01	15.69
Avg. Large (Non-merging)	49.89	29.46	-	-	52.90	37.00	76.10	65.74
Merging Participants	83.54	68.15	(A) 82.78 (B) 46.88	(A) 63.23 (B) 32.70	87.57	61.67	43.31	22.30

Table 7: T1 Turnover Ratio
(Participant category averages reported for participant-level. Results for merging participants reported separately.)

	Merger 1		Merger 2		Merger 3		Merger 4	
	Base Case	**Merger**	**Base Case**	**Merger**	**Base Case**	**Merger**	**Base Case**	**Merger**
System-wide	2.14	2.96	2.14	2.34	2.14	2.19	2.14	2.28
Avg. Small (Non-merging)	0.99	0.90	0.99	0.98	0.99	0.99	0.99	0.99
Avg. Medium (Non-merging)	0.93	0.78	0.84	0.90	1.00	1.05	0.89	1.00
Avg. Large (Non-merging)	2.18	1.45	N/A	N/A	2.32	2.23	2.36	2.30
Merging Participants	1.99	2.29	(A) 1.89 (B) 2.32	(A) 2.02 (B) 3.60	1.74	1.93	1.55	2.02

Table 8: Centrality Rank (Average Daily Rank)

	Merger 1		Merger 2		Merger 3		Merger 4	
	Base Case	Merger	Base Case	Merger	Base Case	Merger	Base Case	Merger
Merging Participants	1st and 2nd 1.00 & 2.03	1st 1.00	(A) 1st and 3rd (B) 2nd and 5th (A) 1.00 & 3.14 (B) 2.03 & 5.82	(A) 2nd (B) 1st (A) 1.98 (B) 1.05	1st and 7th 1.00 & 7.07	1st 1.00	3rd and 4/5th 3.14 & 4.50	2nd 2.06