Analyzing Default Risk and Liquidity Demand in Canada during the Financial Crisis*

PRELIMINARY DRAFT

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Abstract

We use detailed data from the Canadian banking sector to evaluate the impact of the 2007 financial crisis. We document that unlike the Euro zone, which experienced a sharp and persistent increase in demand for liquidity supplied by the central bank immediately after the outbreak of the subprime crisis in the summer of 2007, the Canadian banking system experienced distress only for a limited time, for two months immediately following the collapse of Lehman Brothers in September 2008, and settled back to its usual state thereafter. We further use these data to evaluate bank-specific riskiness. We classify the risk measures based on whether the data necessary for their construction are publicly available, are available only to participants of the Large Value Transfer System (LVTS), which is a payment settlement mechanism specific to Canada, or are available only to the central bank. We show that the publicly available risk measures based on prices of credit default swap (CDS) contracts, while indicative of initial problems of the financial system as a whole, do not seem to correspond to the cross-sectional heterogeneity in the behavior banks face from their counterparties in the short-term lending markets. Participation, strategies in and reliance on special liquidity-supplying tools provided by the central bank thus seem to potentially be important additional indicators of distress.

1 Introduction

The aim of this paper is to analyze risk and liquidity demand in the Canadian banking sector during the financial crisis. We begin by analyzing the demand for liquidity on an individual bank level by using data from liquidity auctions (auctions of term repo loans) run by the Bank of Canada and from the Insured

*We would like to thank... The views expressed here are those of the authors and should not be attributed to the Bank of Canada. Any errors are our own.

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Mortgage Purchase Program (IMPP) run on behalf of the Canadian government by the Canada Housing and Mortgage Corporation. The IMPP provided cheap liquidity to banks during the crisis in exchange for mortgages. We complement this analysis with several estimates of banks' risk which are based on publicly available prices of credit default swaps and on credit lines and flows on the Canadian interbank market. We argue that the CDSs do not seem to provide a good measure of risk during the crisis and that the direct participants of the Canadian payment settlement mechanism are likely to have an informational advantage over outsiders. Furthermore, contrary to anecdotal evidence, we argue that even the insured mortgages very likely carry significant risk-premia - possibly due a fraction of the risk being guaranteed by private insurers. We use the data to quantify the extent of the implied counter-party risk vis-a-vis the private insurer.

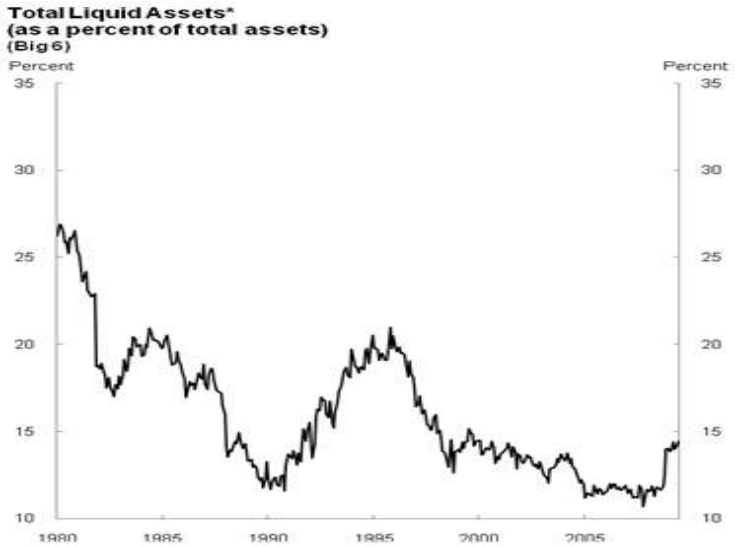
Liquidity management is central to banking. Keeping cash and other liquid assets, such as government treasury bills, on the balance sheet is costly when banks could be using these resources for other purposes. The fraction of total assets held by Canadian banks that are liquid has trended downwards since at least 1980, e.g. see Figure 1. Since 1994 Canadian banks have not faced any reserve requirements (reserve requirements were gradually reduced starting in 1992), therefore unlike American and European banks, there lacks a regulatory reason to hold liquid assets.[1] The main reason to hold liquid assets is to manage their day-to-day business operations and as a buffer in case of negative funding shocks. During the summer and fall of 2007 concern over asset-backed securities in the United States spilled over into Canada with a complete freeze of the asset-backed commercial paper (ABCP) market (Zorn, Wilkins, and Engert (2009)). The Canadian banks, who were the primary issues of ABCP were forced to take them back on their balance sheet, reducing their overall liquidity positions. In addition, spreads in the interbank lending markets were increasing in Canada as they were in the U.S. and Europe (see Figure 2). The Bank of Canada responded in a traditional manner by adding liquidity in the overnight market throughout the summer and fall of 2007. In late 2007 global banks began reporting dismal financial returns, however, and lending tightened further on the interbank market. The Bank of Canada followed other central banks by introducing term liquidity auctions.[2]

Figure 2 depicts the spread between the secured and unsecured interest rates in Canada between 2006-2009. The pattern is very similar to US and EURO markets: immediately after August 2007 the spread substantially widened and culminated after the collapse of Lehman Brothers.

[1]The banks' regulator, the Office of the Superintendent of Financial Institutions (OSFI) has set guidelines for banks to maintain a stock of liquid assets appropriate for their cash flow and funding needs. Furthermore, OSFI requires banks where wholesale is more than 10 per cent of their total funding source to place internal limits on their short-term funding requirements.

[2]On December 12 the Bank of Canada put out a joint press release with the Federal Reserve, Bank of England, Swiss Bank, and European Central Bank saying they were introducing measures to elevate pressures in short-term funding markets. The first term auction was the next day. See Chailloux et al. (2008) for a review of central bank responses to the crisis.

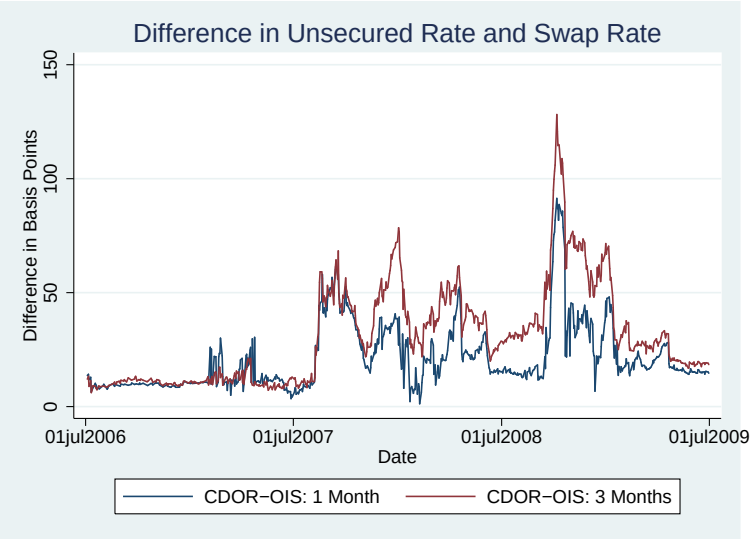
Figure 1: Liquid Assets of the Big 6 Canadian Banks



In our analysis of liquidity demand we document that following the collapse of Lehman Brothers in September 2008, there was a short period of distress, in which Canadian banks offered a significant spread over the reference interest rate in order to get a short-term loan from the Bank of Canada. Unlike in Europe, however, this period of distress lasted only two months, after which the banks returned to their pre-Lehman collapse behavior. Cassola, Hortaçsu and Kastl (2009) analyzed the repo auctions of the European Central Bank and they documented a persistent change in bidding behavior by market participants. Figure 3 shows the aggregate demand curves submitted in these European auctions during 2007. Cassola et al. argued that this increased bidding aggressivity was likely due to increased demand for liquidity by European banks as the outside option of procuring liquidity on the interbank market deteriorated. Banks were thus willing to pay rates even in the primary market (the repo auctions) that were much higher than the reference overnight rate. The situation in Canada was remarkably different. While the default probabilities of individual banks implied by the prices of their respective credit default swap contracts (CDS) followed a similar pattern as their European counterparts, the Canadian banking system showed very limited signs of stress (or increase in liquidity demand) in 2007 and in the first half of 2008. In particular, the Canadian banks were much less willing to pay a premium above the reference overnight rate to obtain liquidity from the Bank of Canada. Figure 4 depicts the aggregate bidding functions (demands) in each auction that the Bank of Canada conducted before September 2008. It shows that virtually all banks felt that even if they would not have their demands in these auctions satisfied, they could secure the liquidity elsewhere and hence were bidding at, or very close to, the reference overnight rate OIS (Overnight Indexed Swap

Figure 2: Interest Rate Spreads in Canada

CDOR is the Canadian Dealer Offered Rate and is equivalent to LIBOR/EURIBOR. It is the average rate for Canadian bankers' acceptances for specific terms-to-maturity, determined daily from a survey on bid-side rates provided by the principal market-makers, including the major Canadian banks. OIS is the Overnight Index Swap rate. It is an over-the-counter derivative primarily used for hedging short-term funding costs or exposures to short-term interest rate movements. OIS rates are calculated in reference to the CORRA, or Canadian Overnight Repo Rate Average. In the U.S. the reference is the daily Fed Funds rate.



rate). Immediately following the failure of Lehman Brothers, the demand for liquidity by both North-American and European banks went through another period of tremendous turmoil. As a response to the increased demand in liquidity the European Central Bank changed their liquidity-provisioning policy from using a discriminatory auction, where the highest bidders win, to a fixed-rate tender, where anybody can borrow as much as they like at the posted rate. Even Canadian banks, whose liquidity demands did not seem to be significantly affected during the dawn of the subprime market crisis in 2007, seemed to have suffered a period of high turbulence in the period immediately following the collapse of Lehman Brothers. Figure 5 depicts the aggregate bid curves in all Canadian auctions for 1-month and 3-month repo loans since December 2007 until December 2009. The figure shows that the Canadian banks were bidding aggressively for these loans only in October and November 2008. Perhaps surprisingly, we find the same pattern in auctions of liquidity with 1-day, 1-month and 3-months maturities.

While the CDS prices exhibit a significant cross-sectional heterogeneity, implying significant differences in perceived default probabilities of individual banks, we do not find a corresponding pattern in the inter-bank transactions. In particular, we do not find that riskier banks, as measured by CDS spreads, would face tougher conditions in the interbank market than their more reliable counterparts.

The rest of the paper proceeds as follows. In section 2 we review the related literature. In section 3 we describe the data and present some summary statistics. In section 4 we go through the results of our

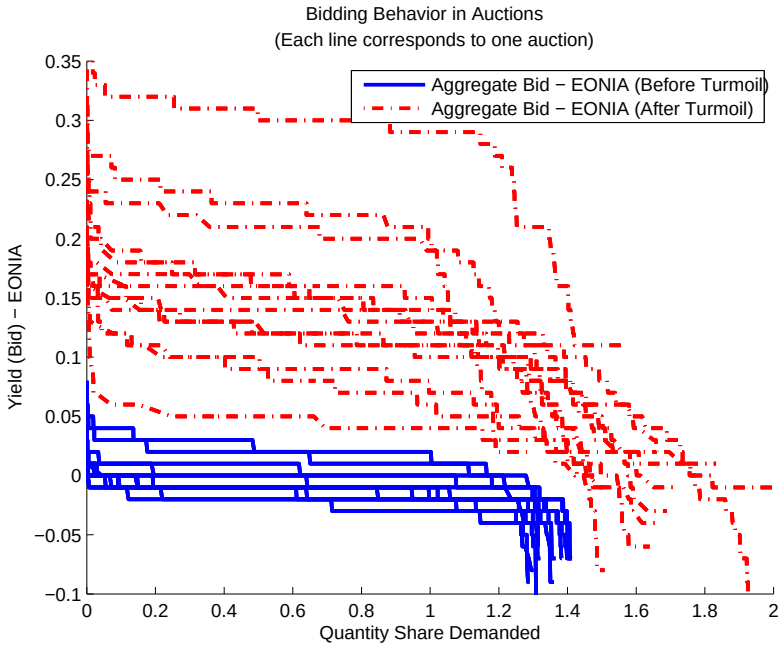


Figure 3: Aggregate demand curves (horizontal sum of individual bids) in European liquidity auctions during 2007 (from Cassola et al., 2009)

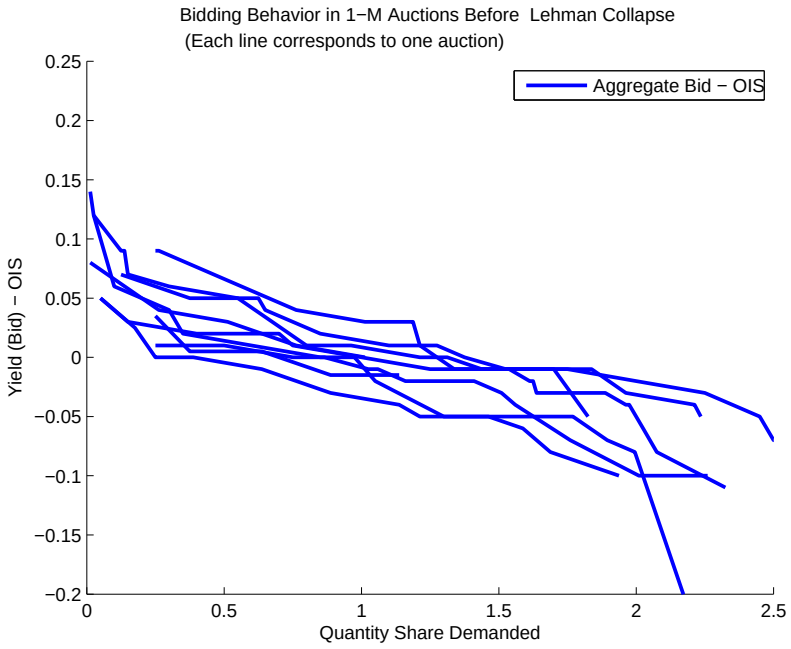


Figure 4: Aggregate demand curves in Canadian liquidity auctions before Lehman Collapse

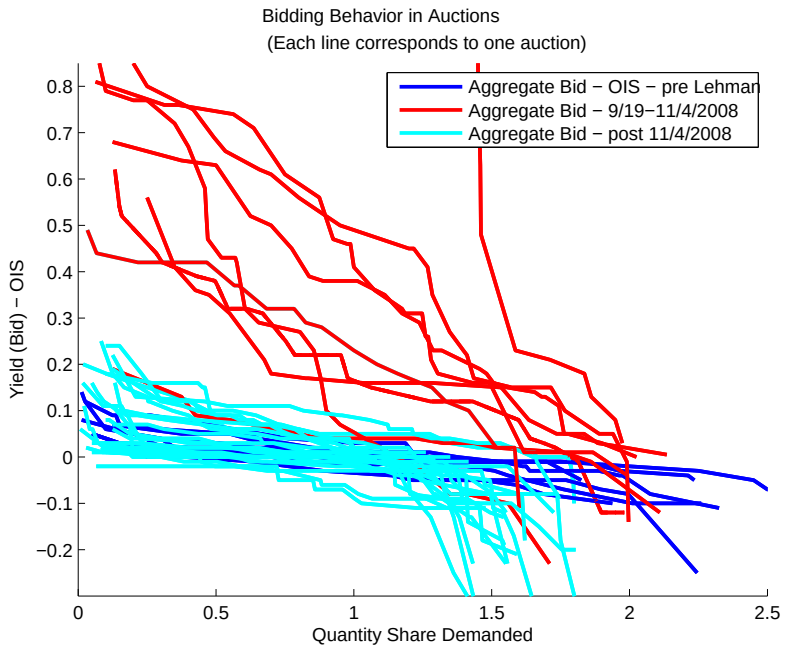


Figure 5: Aggregate demand curves in Canadian liquidity auctions

analysis and section 5 concludes.

2 Literature Review

The financial crisis of 2007-08 naturally generated wide interest among researchers. We review here only the most closely related papers - in terms of methods and results. Afonso, Kovner and Schoar (2010) study the fed funds market (overnight unsecured interbank market). Examining the lending and borrowing patterns between April 2008 and February 2009, they argue that the Lehman Brothers collapse did not cause a cessation in trading in the fed funds market. They provide suggestive evidence, however, that the impact on individual banks varied: banks with worse balance-sheet-based financial indicators had harder time accessing the overnight loans or had to borrow less and at larger spreads.

Stroebel and Taylor (2009) study the effect of the Federal Reserve's mortgage-backed securities purchase program on mortgage rates. They argue that the program did not have an effect on interest rates.

[**TO BE COMPLETED**]

3 Data

In this section, we describe in detail the various data sources that we employ. As hinted upon in the Introduction, we link together detailed data on banks' balance sheets, their bilateral trades with other banks and behavior in various types of liquidity providing facilities.

3.1 Canadian Banking Sector Background

The Canadian banking sector is highly concentrated, with 90 per cent of the industries assets held by the six largest banks.[3] As of March 2010 the Big 6 controlled 2,605 billion Canadian dollars worth of assets. The Canadian banking landscape also includes hundreds of small credit unions and 2 large ones – Alberta Treasury Branch and Caisse Desjardins, about sixty-five foreign subsidiaries, and a small number of trust companies. Due to deregulation in the past twenty years, these financial institutions can now offer a broad selection of financial products to consumers under one bank. The largest of these financial institutions in fact do so, selling consumers mortgages, loans, credit cards, as well as investment products such as term deposits, bonds, and mutual funds. The largest banks also play a special role in Canada's large value payment system. They also participate in the Bank of Canada's treasury bill auctions (see Hortaçsu and Kastl (2008)) and in the Receiver General Auctions (see Chapman, McAdams and Paarsch (2007)) as primary dealers.

3.2 Large Value Transfer System (LTVS)

Unlike the European Central Bank, the Bank of Canada does not impose any reserve requirements through which it could control interest rates and liquidity, but relies on what is called the Large Value Transfer System. This is a mechanism, through which all bilateral (interbank) trades have to be settled by the end of the trading day - and any potential short or long positions must be settled by the appropriate trade with the Bank of Canada at rather unfavorable interest rates. This interest rate band (the difference between the rate on overnight deposits and overnight loans) is set so that banks have the right incentives to find counterparties among themselves to settle the open positions rather than to resort to the central bank. The midpoint of this band is the interest rate that the central bank is targeting.

Like real-time gross settlement systems (RTGS), which are used in almost all countries, including the United States (Fedwire) and Europe (TARGET), finality of payment sent through LVTS is in real-time. Unlike RGTS systems, however, settlement in LVTS occurs on a multilateral net basis at the end of the

[3]These banks are the Bank of Montreal, Bank of Nova Scotia, Banque Nationale, Canadian Imperial Bank of Commerce, Royal Bank Financial Group, and TD Bank Financial Group.

day. This results in substantial cost savings in terms of the amount of collateral a participant needs to put into the system. The trade-off is an increase in default risk.

During the trading day, there are two ways of engaging in a transaction with another bank. A bank in LVTS can either send a payment through a fully collateralized Tranche 1 which involves real-time settlement or through Tranche 2 in which collateral is pooled, risk is shared and settlement is postponed towards the end of the trading day. The two main differences between the two payment systems are the costs and the risk. T1 is a fully collateralized system and is therefore more costly in terms of the opportunity cost of capital. All transactions with the Bank of Canada are done through T1. Payments associated with the settlement activities of clearing houses in the securities and foreign exchange markets are also typically done in T1. On a typical day T1 handles between 10-15 per cent of total payments. The constraint on a participant's payments in T1 depend on their line of credit (which is a function of how much collateral they posted at the beginning of the day) and their payment flows during the day:

$$T1payment_i \leq T1NDC_i + \sum_{j \neq i}^{N} (T1payments_{ji} - T1payments_{ij}),$$

where $T1NDC_i$ is bank i's T1 net debit cap.

In normal times participants prefer to send payments through T2 because the collateral requirements are much smaller than in T1. The typical collateral accepted in LVTS are government of Canada treasury bills; participants can find more productive uses for these highly liquid securities than to have them sit in the payments system. T2 operates by banks extending bilateral credit lines (BCL) to each other, which may be adjusted at any time. Providing credit lines is, however, not costless. The banks have to post collateral with the Bank of Canada which is proportional to the extended credit lines and the size of the credit lines extended towards a potentially failing bank determine a bank's exposure in case of a failure of that particular bank. Therefore T2 is a payment system where the survivor pays (whereas the defaulter pays in T1). Operationally, a BCL granted from i to j is the maximum net debit position that j can incur vis-à-vis i at any time during the day. Participants also face multilateral caps – the maximum multilateral position that bank i can incur vis-à-vis all other participants is given by $T2NDC_i$:

$$T2NDC_i = \sum_{j \neq i}^{N} 0.3BCL_{ji}.$$

In T2 the maximum financial loss of a participant if one of more participant defaults is 0.3 times the maximum BCL that it has granted.

Our data consists of daily credit lines and which channel, T1 or T2, the banks use to transact with

one another. (*together with the actual transactions - which we do not have yet...*) Our data set thus provides us with a unique opportunity to study whether the banks manage their collateral efficiently - for example by reserving the highest collateral for the bilateral transactions on the interbank market in order to secure better rates. Our data covers the time period between 03/01/2004 and 08/31/2009. The Canadian payment system includes 15 banks, one of which is the central bank itself.[4] We have 554,117 observations of bilateral credit lines, 18,369 of which are adjusted during the day. As expected, when the need arises, credit lines are adjusted upwards: conditional on an adjustment, the mean credit line is 841 million Canadian dollars (CAD). (standard deviation 757 million CAD). A striking feature of this data is reciprocity: a bank very often extends to and obtains from another bank the same credit line. While the amount of the credit line varies depending on the pair of banks, reciprocity is quite regular. The mean credit line is 400 million CAD with a standard deviation of 484 million CAD. To illustrate the level of reciprocity, the mean credit line (over the whole time period) extended by bank labeled S in our sample to bank N is 758.7 million CAD, while the mean credit line from N to S is 758.9 million CAD. The standard deviations are 62 million CAD and 67 million CAD, respectively. The credit lines between these two banks are adjusted during the day in about 2% of the cases. This description is representative of the other pairs in our data. Since the beginning of the subprime crises, the incidence of credit line adjustment during the day increased substantially, which suggests that the counterparties may not be willing to adjust the permanent credit line limits and are adjusting them only when the need arises.

3.3 Liquidity

Financial institutions manage their daily liquidity needs through market operations and their interactions with the Bank of Canada. When markets froze during the crisis financial institutions reliance on the central bank grew in importance.[5] Pre-crisis the Bank of Canada's primary tools for providing liquidity to the banking system where primarily to reinforce the target rate. The main facility is LVTS, occasionally supplemented by open market operations such as special purchase and resale agreements (SPRAs) and sale and repurchase agreements (SRAs). These repo transactions are used to reinforce the target rate. In addition the Bank provides liquidity to LVTS participants facing shortfalls in their end-of-day settlement balances at the Bank Rate (Standing Liquidity Facility), and in rare cases financial institutions can request

[4]The direct participants include the Big 6 banks, HSBC, Laurentian Bank, 2 American banks (State Street Bank and Bank of America), a French bank (BNP Paribas), the 2 largest Canadian credit unions (Alberta Treasury Branch and Caisse Desjardins), and a credit union consortium (CUCC). Any deposit-taking institution and member of the Canadian Payments Association (CPA) can be a member of LVTS so long as they maintain an account with the Bank of Canada and have the facilities to pledge collateral for LVTS purposes. Deposit-taking institutions that are not members of LVTS must send (or receive) their payments through one of the direct participants.

[5]See Allen, Carletti, and Gale (2009) for a theoretical model of the interbank market and the optimal role of the central bank.

Emergence Lending Assistance if they are facing serious liquidity problems. The Bank of Canada also manages the federal government's cash balances by holding twice-daily auctions. Financial institutions can access short-term loans in these auctions. During the crisis financial institutions accessed these facilities and the Bank of Canada created new ones to inject more liquidity into the system.

3.3.1 Receiver General Auctions

The Bank of Canada is the Canadian governments fiscal agent and as such manages the Receiver General Account from which the balances required for day-to-day operations are drawn. To manage it's cash balances the Bank of Canada holds twice-daily term auctions. On behalf of the federal government the Bank auctions off short-term loans, whereby it secures short-term interest income on its revenues. These auctions have been analyzed previously in Chapman, McAdams and Paarsch (2007) who find that bidders' behavior is reasonably approximated by a Bayesian Nash Equilibrium. In summary, these auctions are administered twice a day: at 9:30am and at 4:30pm. Bidders are notified before 5pm the day before the morning auction about the cash balances being offered at auction in each concurrently offered tranche, where each tranche differs by maturity. The maturity is between 1 and 30 days, with 93% of offers in our sample being for loans with less than 7 day maturity. Similarly, by 4pm, bidders are notified of balances and tranches offered in the afternoon auction.

The eligible participants are different for the morning and afternoon auctions, although in practice the list of participants is nearly identical. To be eligible for the morning auction a participant must be either a *Crown corporation or an agent of the federal government, a provincial government or an agent of a provincial government, a municipal government or municipal finance authority, a regulated deposit-taking institution, another financial institution, an investment dealer, or a corporation, partnership or other legal entity; and* have a credit rating of at least BBB or be a participant in LVTS or be a primary dealer of Government of Canada securities. The only participants in the afternoon auctions are LVTS direct participants.

All afternoon auctions are unsecured and balances are termed for one business day. The morning auctions can be both secured or unsecured and the terms can be more than one day. In both cases there are limits on participants bids which depend on their credit ratings. Finally, the set of eligible collateral for the morning auctions includes securities issues or guaranteed by the federal government, securities issued or guaranteed by a provincial government, municipality, financial institution or corporation with a credit rating of at least A and with a maturity of at least 10.5 years.

3.3.2 PRA Auctions (Purchase and Resale Agreement)

In order to provide an additional source of liquidity to alleviate potential stresses, the Bank of Canada administered two 1-month loan auctions in December 2007. This was the first time that the Bank of Canada held cash auctions beyond one business day to support liquidity funding. The PRA auctions were multiple yield competitive auctions. Bidders could place up to 3 bids, with the minimum bid of 10 million CAD with increments of 1 million CAD. Participants rated A or higher have a bidding limit of 25% of the auctioned amount and those rated BBB or lower had a bidding limit of 12.5% of the aggregate limit. Initially only primary dealers could participate in the auctions. This includes RBC Dominion Securities, CIBC World Markets. Scotia Capital, BMO Nesbitt Burns, Toronto-Dominion Bank, Banque Nationale Financière, Valeurs Mobilières Laurentienne, Desjardins Valuers Mobilières, HSBC Securities Canada, Casgrain & Co., Deutsche Bank Securities, and Merrill Lynch Canada. The majority of these primary dealers are simply the securities dealing arm of a larger holding company. RBC Dominion Securities, for example, is the securities dealer for Royal Bank Financial Group. The Big 6 banks and the largest credit union, Caisse Desjardins all participated in the term PRA auctions via their securities dealers.[6] Almost all of the primary dealers are members of LVTS (via the holding company), but some members of LVTS are not primary dealers. The initial amounts of the auctions were small, 2 billion CAD. The set of eligible collateral was of high quality assets – it included securities issued or guaranteed by the Government of Canada and provincial of governments as well as bankers' acceptances and bearer deposit notes with remaining maturities of less than 180 days.

Following the collapse of Bear Sterns in March 2008 the Bank reintroduced term PRAs, this time on a biweekly basis. Throughout the spring and summer the Bank auctions off 1-2 billion CAD of cash at 1-month terms. The Bank also expanded the set of eligible collateral in LVTS so that participants could more easily secure funding in the term PRA auctions as well as in other markets. For example, the Bank allowed certain type of asset-backed commercial paper to be pledged in LVTS.

After September 2008, the Bank of Canada added auctions of loans with 3-months maturity and held them on a weekly basis.[7] Each auction was for 2 or 4 billion CAD. That September the Bank also expanded the set of eligible collateral. Participants could now pledge certain commercial paper and short-term municipal paper, corporate, municipal, and foreign issuer bonds with a minimum S&P rating of A-, marketable securities issued by the U.S. treasury, and bank-sponsored unaffiliated asset-backed commercial

[6]The majority of the primary dealers are large players. We do not know the assets of Casgrain because it is a private, but for the other players Laurentienne is the smallest with 22.6 billion CAD in assets in 2010; RBC is the largest Canadian bank with 655 billion CAD in assets in 2010.

[7]For monetary policy reasons the Bank of Canada also introduced 6- and 12-month loan-maturity starting in June 2009.

Table 1: Data Summary for Term PRA Auctions

	Mean	Min	Max	StdDev
Active bidders in an auction	9.3	5	12	1.86
Number of submitted bidpoints	1.87	1	5	0.88
Yield bid (normalized by OIS)	0.04	-0.58	0.92	0.15
Quantity Bids (as a share of supply)	0.14	0.0025	0.25	0.09
OIS rate	1.78	0.24	4.26	1.26
Issued Amount (billion CAD)	4.76	1	12	2.85

paper.[8]

Consistent with the G7 Action Plan in October 14th the Bank substantially increased the size of it's auctions - they would now hold auctions for as much as 12 billion CAD. In addition LVTS members that are not primary dealers could bid in auctions. This includes ATB, Credit Union Central of Canada, Bank of America, BNP Paribas, and State State Bank. Furthermore, there was a substantial collateral policy announcement on October 17, 2008. The Bank announced that they would temporarily allow (eligible) LVTS participants to pledge their non-mortgage loan portfolio as collateral in the payments system.[9] A financial institutions' non-mortgage loan portfolio (NMLP) is highly illiquid (for example it includes credit card and person loans) and the Bank took a 40% haircut. By pledging their NMLP a financial institution could free up more marketable securities to support borrowing or be used in the term PRA.[10]

Table 1 offers some summary statistics of our sample of bids in these auctions.

The types of securities posted as collateral for the auction are shown in Figure 6

3.4 Term Loan Facility

On November 12th, 2008 the Bank of Canada announced it would provide exceptional liquidity to financial institutions under a Term Loan Facility (TLF). The TLF was a single price auction and the primary goal was to get around the stigma associated with the Emergency Lending Assistance program (see Armantier, Ghysels, Sarkar, and Shrader (2010)) for the effects of stigma in the Fed's discount window and its effects on bidding in TAF by American banks during the crisis). There was very little demand, however, for TLF.

[8] For a full list see $http://www.bankofcanada.ca/en/notices\_fmd/2008/not230908.html$.

[9] Foreign-bank participants could not pledge their NMLP and credit unions could only pledge the credit card portion of their portfolio.

[10] Chailloux et al. (2008) discuss cross-country differences in collateral policies pre-crisis and how this affected central bank responses during the crisis. Canada, like the U.S. had a much narrow set of eligible collateral for its open market operations and standing lending facilities than the ECB. During the crisis changes to collateral requirements was one way the Bank of Canada could free of liquidity. The fact that the central bank was taking on more credit risk – bad collateral was clearly driving out good collateral (a form of Gresham's Law) – was less of a concern that getting liquidity to the market.

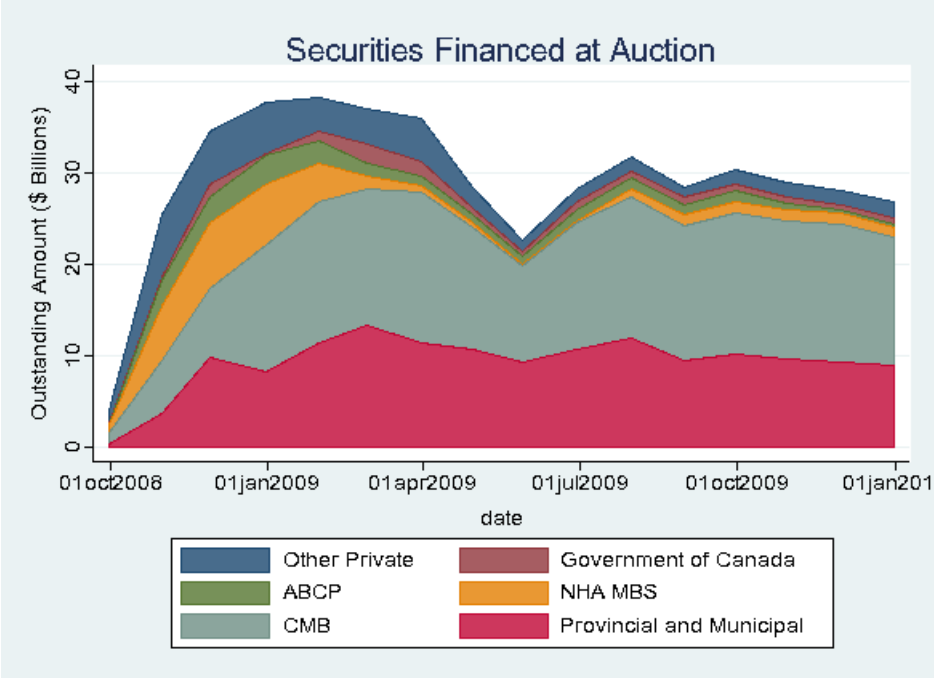


Figure 6: Collateral Outstanding

3.5 Mortgage Buyback Programs

In Canada the federal government explicitly insures approximately 50% of mortgages outstanding, either through a crown corporation – the Canada Mortgage and Housing Corporation (CMHC), or by one of two private insurer, Genworth Financial or AIGs subsidiary, Canada Guaranty. CMHC-insured mortgages carry a 100% government guarantee whereas the private-insured mortgages carry a 90% guarantee. This provides incentives for lenders to provide credit and promotes home-ownership. Borrowers pay a premium, typically between 100 and 275 basis points, depending on the loan-to-value ratio, and the bank underwriter is guaranteed to get the money back if the borrower were to default.

In addition the federal government established the Canada Mortgage Bond (CMB) program in 2001 to improve funding, at lower cost, to lenders. The Canada Housing Trust sells non-amortizing CMBs to investors and uses the proceeds to buy pooled National Housing Act Mortgage Back Securities (NHA-MBS). The NHA-MBS are created when CMHC approved-sellers pools insured mortgages for the purpose of securitization. All participants have equal access to funds at the same price under the CMB.

Up until the financial crisis securitization was not an important feature of the Canadian mortgage market. About 17% of mortgages, for example, were securitized in 2007. This is far less than in the United States where more than half of all mortgages were securitized. Allen, Clark, and Houde (2010) suggest that the lack of securitization in Canada stems from the fact that mortgages are short-term (typically 5

years), and therefore Canadian banks do not have as much incentive as U.S. banks to sell off the interest rate risk associated with selling a mortgage. During the crisis, however, the level of mortgage securitization in Canada increased substantially – to 30% in 2009. The increased securitization came through different government programs aimed at providing banks liquidity.

In the summer of 2008 the federal government increased the size of the CMB program, buying a record 11.5 billion CAD in June alone. At the end of July 2008, the CMHC announced an expansion of its regular CMB program to allow banks to off-load 10-year mortgages in addition to the 3 and 5 year mortgages it typically purchased.[11]

Following the collapse of the Lehman Brothers and in order to ensure that the mortgage market did not dry up, the Canadian government started a new program in which it offered to buy back insured residential mortgages. On October 16, 2008 the Government of Canada announced that it would buy up to $25 billion of insured mortgages off the books of Canadian banks. The maximum was raised to $75 billion on November 12, 2008 and to $125 billion on January 28, 2009.[12] The government's goal was to add liquidity to the banks balance sheets so that they could continue lending. The only mortgages that were eligible were those already insured. The government argued that since they were explicitly insuring the mortgages anyway, they were not taking on any excess risk by buying them directly.[13] The effect would be to add liquidity to the banks balance sheet in the short-term and in the medium- and long-term the government would likely make a profit.

The CMHC held reverse auctions on the governments behalf, held about once or twice a month. A schedule of planned auctions was published before each quarter. For each auction the minimum bid was set at a rate higher than the government's cost of borrowing, either a fixed rate for a pool of fixed-term mortgages (usually 5 years) or a fixed premium above CDOR (Canadian Dealer Offered Rate, which is the Canadian equivalent to LIBOR) in the case of a pool of floating-term mortgages (also typically 5 years). The minimum bid rate was set at 9:40am on the day of the auction and the bids had to be received by 10:00am. Funds were allocated beginning with the highest bid until the amount of available funds were depleted, with settlement 5 days following the reverse auction.

Table 2 offers some summary statistics of the IMPP auction. Like other markets in Canada the number of participants in the IMPP is small, on average only 4 banks participated in an auction – and on average they off-loaded 60% of the mortgages that the government said they would buy. The average buy-back

[11]The vast majority of residential mortgages in Canada are 5-year, however, and have to thus be refinanced or fully paid at the end of every 5-year period.

[12]The IMPP was established because CMHC's borrowing capacity through the CMB is limited, i.e. it would be difficult for the CMHC to borrow the 75 or 125 billion dollars. The IMPP allowed the government, which does not face a borrowing constraint, to buy the mortgages directly.

[13]see Allen, Clark, and Houde (2010) for a detailed discussion of the Canadian mortgage market.

Table 2: Data Summary for IMPP Auctions

	Mean	Min	Max	stDev
Active bidders in an auction	4	9	1	2.25
Quantity Sold	0.854	0.038	2	0.64
Spread over reserve	0.130	0	0.778	0.168
Buy-back Amount (billion CAD)	5.3	4	8	1.68
Coverage ratio	60%	12%	100%	32%

[a] Depending on the auction the government either set the reservation bid rate at a fixed rate or a floating rate which is a function of the 1 month CDOR rate. The minimum rate is set at or above the government's borrowing rate.

amount was 5.3 billion, and the government purchased approximately 65 billion CAD worth of mortgages over our sample period. Banks on average sold 854 million worth of mortgages for 13 basis points above the reservation price, i.e. above the governments cost of borrowing.

The effect of the Insured Mortgage Purchase Program on the market share of the private insurers' mortgages-insured outstanding is quite apparent in Figure 7. The market share of Genworth Financial dramatically decreased during the time period following the Lehman Brothers collapse. Canada Gauranty's market share was basically eliminated. We use the bidding behavior in these auctions, together with data from the liquidity auctions to analyze liquidity versus counterparty risk.

4 Results

Having described our data sources, we now move on to construct various risk measures and attempt to compare them against each other. Our goal is to construct these measures using information that is public, partially private and private and evaluate how well these measures perform during the crisis. We begin by describing risk measures using publicly available data - the CDS prices and various balance sheet ratios. Such data could thus potentially be used by any counterparty. We then utilize data from the LVTS - the Canadian payment settlement mechanism - in which 14 banks participate and thus these 14 banks likely have access to more information about the other counterparties in the LVTS than outsiders. Finally, we look at information that is not observed by any counterparty, but is observable by the central bank: behavior of banks in various liquidity-providing mechanisms, such as auctions of liquidity or auctions to off-load mortgages etc.

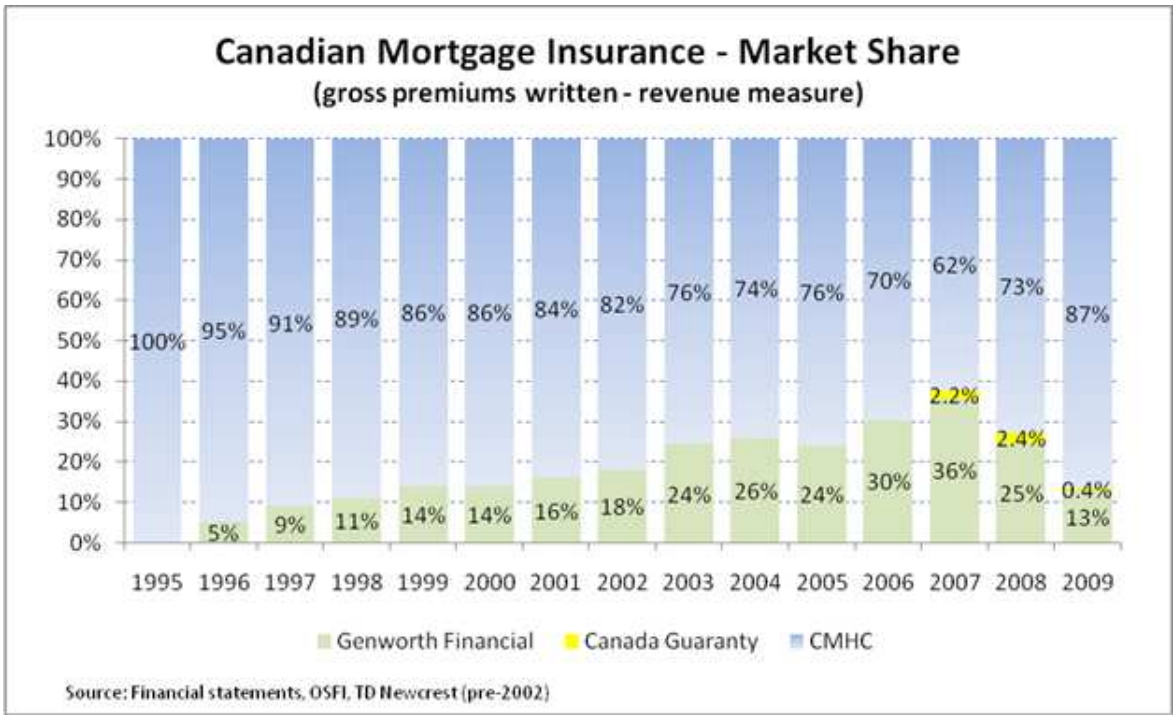


Figure 7: Market Shares of Mortgage Insurers (New Mortgages)

4.1 Risk Implied by CDS prices

Figure 8 shows the time series of the prices[14] of a 5-year credit default swap contract for 8 banks in our sample. A CDS contract is essentially an insurance contract: the buyer (who may or may not actually hold a bond issued by the bank whose CDS contract he/she purchases) is protected against default of this bank over the period of 5 years. In the event of default, the seller of the insurance contract has to pay either the face value of the bond in exchange for it or the difference between the face value and the recovery value of the bond.[15] As elsewhere, the market perception of default risk of Canadian banks captured in the prices of the CDS contracts started increasing in the second half of 2007 and peaked in the last quarter of 2008 following the collapse of Lehman Brothers in September 2008. Using the standard formula (see e.g., Hull (2007)):

$$\Pr\left(Default-5y\right)_T = 100 * \left(1-\left(1/\left(1+\left(cds_T/10000\right)/\left(1-recovery\right)\right)^T\right)\right)$$

we can recover the risk-neutral default probabilities implies by the CDS prices. For the largest institutions, banks A,E and K, the implied default probabilities (assuming 40% recovery rates) went from...

[14] We combined data from Bloomberg and Markit.

[15] Since 2009 the CDS contracts have been standardized to require the seller of the insurance to pay the difference between the face value of the bond and its market price as determined in an auction run after the default occurs.

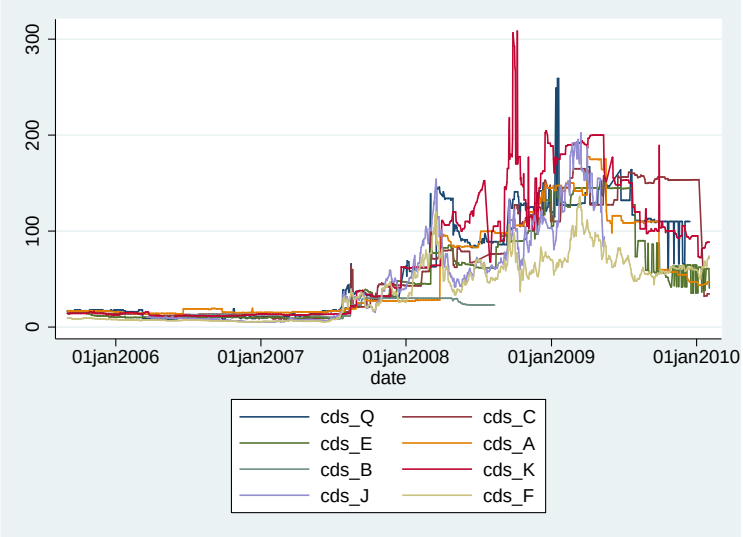


Figure 8: Prices of 5-y Credit Default Swap Contracts

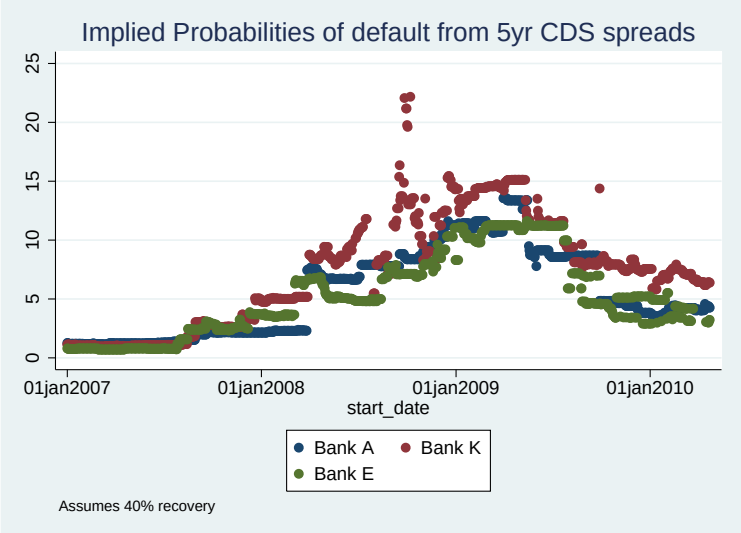


Figure 9: Probability of default (over 5-years) implied by the CDS prices

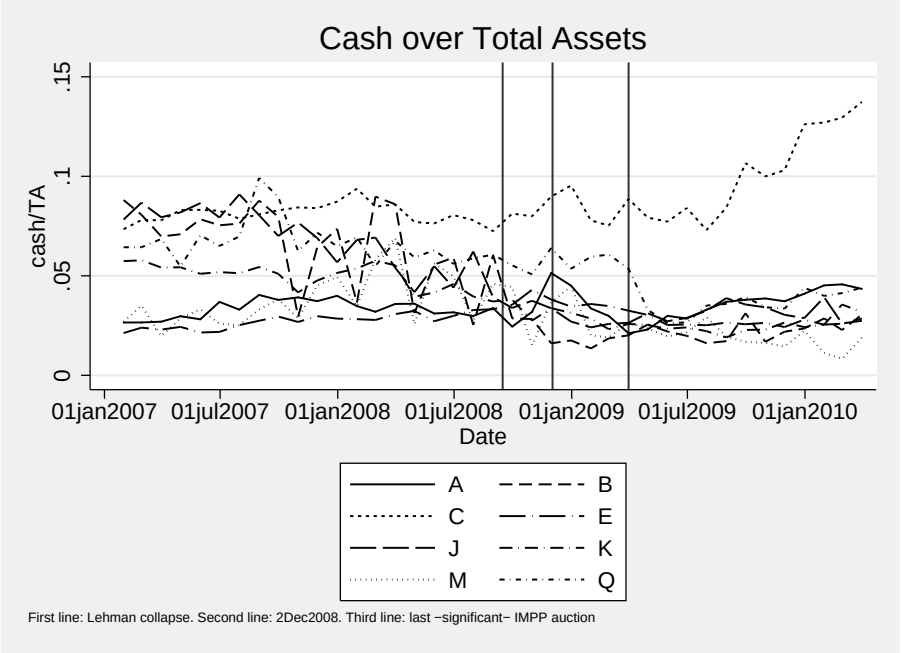


Figure 10: Cash/Total Assets

4.2 Balance sheet indicators

Canadian banks have to report the detailed structure of their balance sheets to the Bank of Canada and to the regulator (the Office of the Superintendant of Financial Institutions) on a monthly basis. Somewhat coarser information about balance sheets, is published on the regulators website and thus becomes subsequently public. Therefore, the Bank of Canada and the regulator have some informational advantage over the other banks. In Figure 10 we plot the ratio of cash to total assets for all banks in our data and Figure 11 depicts the evolution of the share of liquid to total assets. Figure 12 shows the evolution of the share of residential mortgages among total assets. These figures show that immediately following the collapse of the Lehman Brothers banks started working hard to substitute away from illiquid assets. The share of cash in the portfolio increased substantially between September 15, 2008 and December 2008 which corresponds to the time period in which banks were bidding in the liquidity auctions significantly above the reference interest rate. At the same time, all banks made extensive use of the mortgage repurchasing program and reduced their exposure to residential mortgages by off-loading more than the amount of newly underwritten ones. Unlike the behavior in the liquidity auctions, this pattern persisted until the end of the first quarter of 2009 after which the use of the mortgage repurchasing program decreased and the accepted bids thereafter were at or very close to the minimum acceptable bid rate.

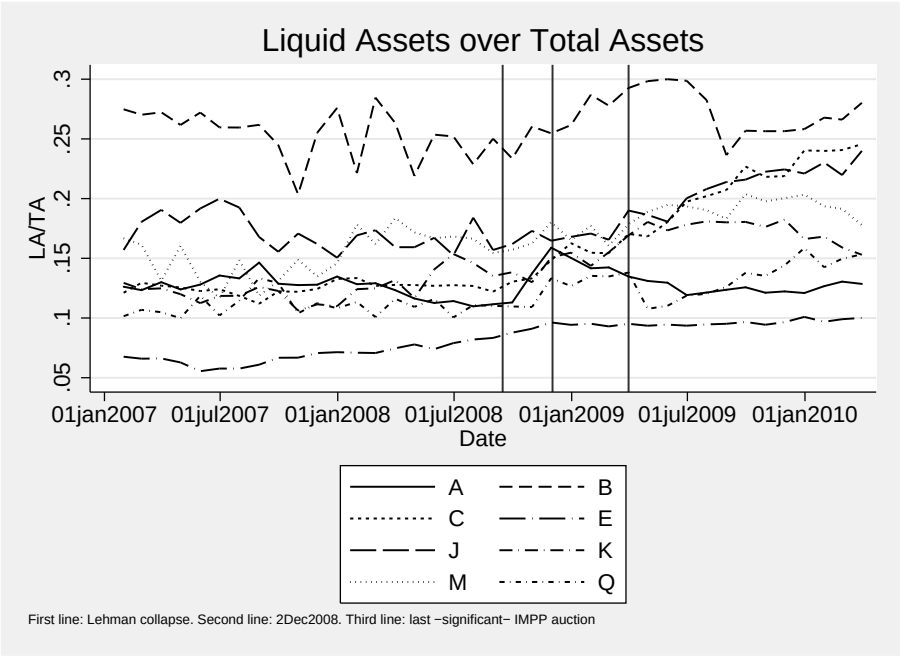


Figure 11: Liquid Assets/Total Assets

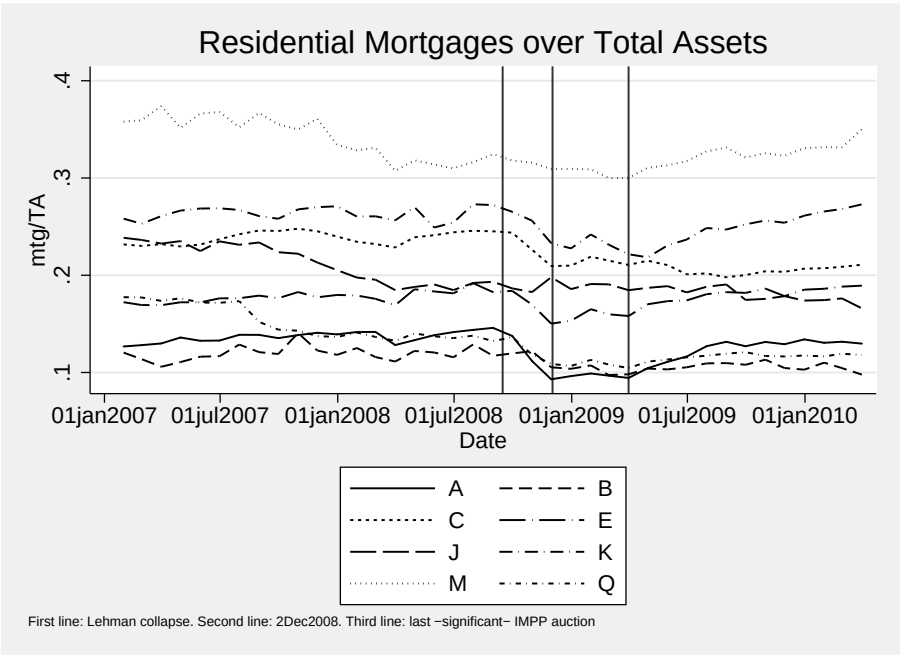


Figure 12: Residential Mortgages/Total Assets

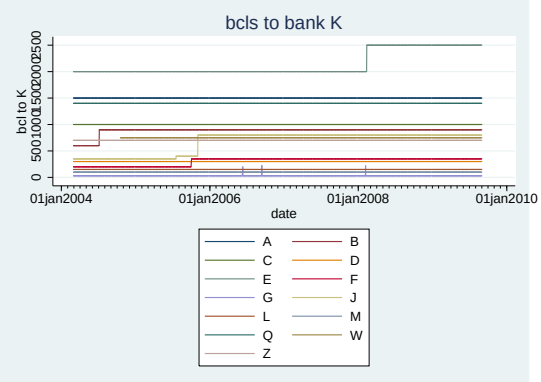


Figure 13: Credit Lines to K

4.3 Bilateral credit lines in the Large Value Transfer System

During the financial crisis, the Bank of Canada severely expanded the collateral deemed as acceptable in the payment system. In particular, most participants were allowed to pledge their whole non-mortgage loan portfolio as collateral (to which BoC applied a 40% haircut). This in turn meant that virtually every participant in the LVTS had an abundance of unused collateral in the system. Since as we described in section 3.2, the LVTS has two channels: a fully collateralized channel, T1, and a partially collateralized one, T2. It would thus seem natural that if the opportunity cost of collateral vanish and default probabilities of counterparties increase banks might be less reluctant to deal with their counterparties through T2 (and thus potentially bear some default risk). In figure 13 we plot the time series of credit lines extended to bank K, which according to the CDS prices experiences the most dramatic increase in the probability of default. Clearly, the other counterparties in the LVTS did not fear that K might be close to declaring bankruptcy since they neither refused to trade with K, nor decreased the extended credit lines.

Finally, there does not seem to be any sign of banks being worried about their counterparties defaulting as the overall share of transactions process through the fully collateralized channel does not appreciably increase either on the aggregate level or on the bilateral level.

4.4 Measuring stress using willingness-to-pay for liquidity

To recover banks' true willingnes-to-pay for short-term funds from the observed bids, we assume that they employ bidding strategies that are consistent with a Bayesian Nash Equilibrium. This strategy is quite standard in the auction literature and in the case of discriminatory auctions has been employed previously in the context of the European short-term loan auction by Cassola, Hortaçsu and Kastl (2009). They show that accounting for the strategic component of bids is empirically important, since many banks increase

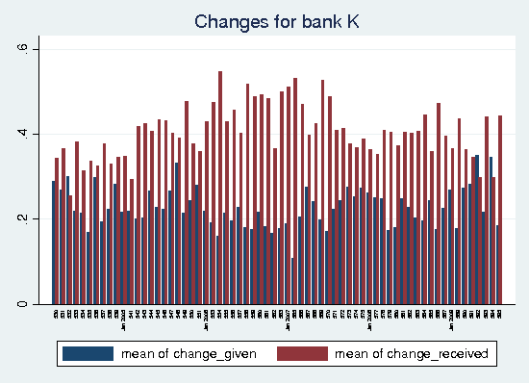


Figure 14: Intraday changes for K

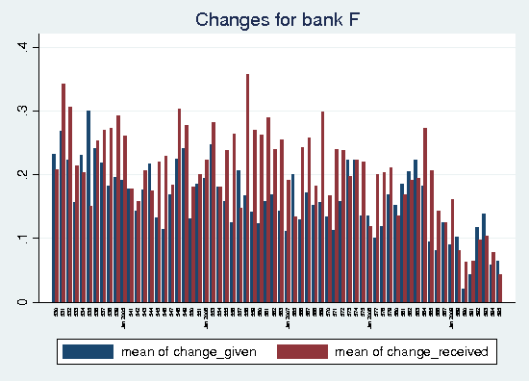


Figure 15: Somewhat fewer changes for BCLs extended to (less risky) F

their bids during the crisis not necessarily because of their increased willingness-to-pay (for example due to a higher need for liquidity), but rather as a best reponse to more aggressive behavior by some of their rivals. Using the same method as Cassola et. al, we recover the true marginal willingness-to-pay from the observed bid from the euqilibrium relationship:

$$v\left(q_k, \theta_i\right) = b_k + \frac{\Pr\left(b_{k+1} \geq P^c\right)}{\Pr\left(b_k > P^c > b_{k+1}\right)}\left(b_k - b_{k+1}\right) \tag{1}$$

where P^c is the market clearing price, which is random from the perspective of each bidder, q_k is the quantity demanded at step k and b_k is the associated bid. This relationship basically says that in equilibrium of a discriminatory auction, bidders will shade their bids so as to trade-off the effect of saving due to shading against the decreased probability of winning.

We use our data for auctions of loans with maturity of 1 day or few days administered on behalf of the Receiver General and of 1- or 3-month maturity conducted by the Bank of Canada. The variation in the willingness-to-pay for a fixed bank over the different maturities may provide a useful insight into that bank's assesment of ease with which it could secure liquidity if such need should arise.

Figure 16 depicts the aggregate willingness-to-pay curve corresponding to the bids for the 1-month loans. This picture suggests that the Canadian banks did not seem to have been hard pressed for liquidity except for the turbulence period in October 2008. During that period, some banks were willing to pay up to 140 basis points premium over the reference interest rate to obtain a 1-month loan. This is perhaps surprising since in the same time, banks could borrow overnight from the central bank at the premium of 50 basis points, which might suggest that the temporal distinction between obtain a loan for 1-month versus rolling over overnight loans might have been an important trade-off in that turbulent time period.

Turning attention to auctions of overnight funds, perhaps surprisingly, we find the same general story. In Figure 17 we plot aggregate bids in 20 randomly chosen auctions from first 8 months of 2008. It is evident that banks were not willing to pay more than the reference interest rate, and in most cases were offering yields significantly below this rate - up to 25 basis points lower, with some auctions even clearing at such a low price. Figure 18 depicts different 20 randomly chosen auctions from the period of turbulence following the collapse of Lehman Brothers until December 2008. As in the term auctions, banks started offering premium over the reference interest rate in order to obtain liquidity. Only few auctions cleared below the reference interest rate - and only minimally so. Many auctions, on the other hand, cleared at prices about 5 basis points higher than the reference interest rate. After December 2008, bidding again returned to its pre-Lehman state: virtually no bid exceeded the reference interest rate thereafter.

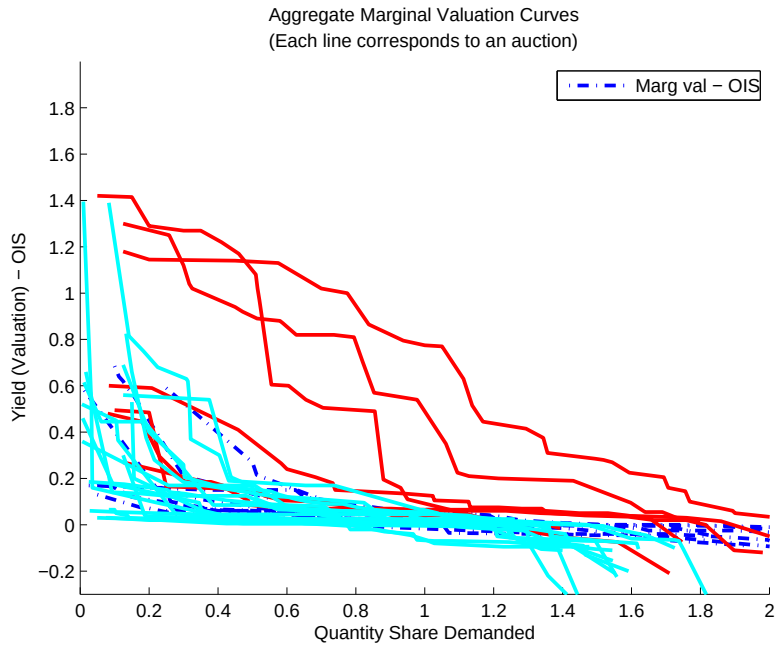


Figure 16: Willingness-to-pay for 1-m liquidity

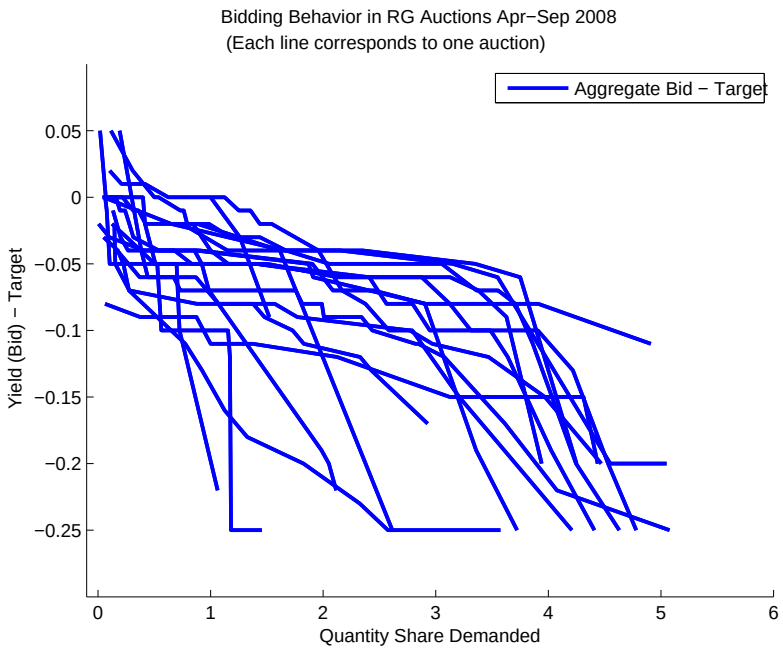


Figure 17: Bidding for overnight liquidity before Lehman Collapse

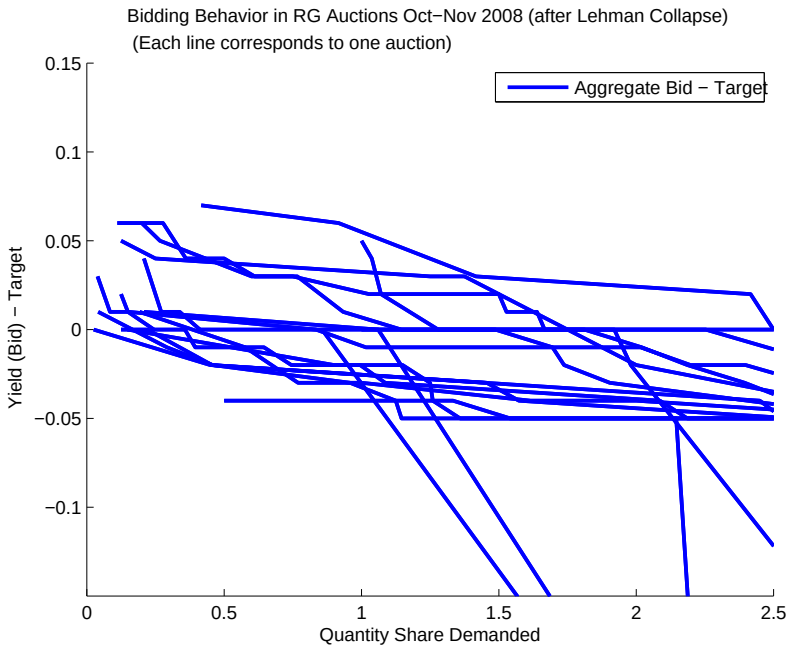


Figure 18: Bidding for overnight liquidity after Lehman Collapse

4.5 Liquidity risk or counterparty risk?

4.5.1 Liquidity and risk premium in IMPP auctions

Figure 19 offers a picture of the development in the IMPP auction market. In the turbulance period following the Lehman collapse during which the Bank of Canada started this program, Canadian banks were offering a high price in order to off-load some of the residential morgages from their books. The supply (maximum amount to be purchased by the Canadian Mortgage and Housing Corporation) was almost always exhausted before March 2009. Moreover, banks were willing to accept a much lower amount than the face value and, more importantly, were competing for the supply thus driving the discount much higher than the reserve (the minimum acceptable discount). The reserve discount in November 2008 was 3.433%, in January 2009 it was 2.266%, in February 2.59%, in March 2.46% and in April 2.431%. While the reserve discount did not change too much, banks' interest in off-loading mortgages from their portfolio at that discount disappeared relatively quickly.

Let us now look closer at banks' behavior in these mortgage off-loading auctions together with our data on banks' demand for short-term liquidity in the PRA auctions analyzed earlier. Bank A is the most frequent bidder with bids substantially below the reference interest rate in liquidity auctions, which suggests that bank A felt virtually no short-term liquidity oressure. Nevertheless, the same bank is one of the largest participants in the mortgage buyback auctions. It was willing to off-load insured mortgages at a significant

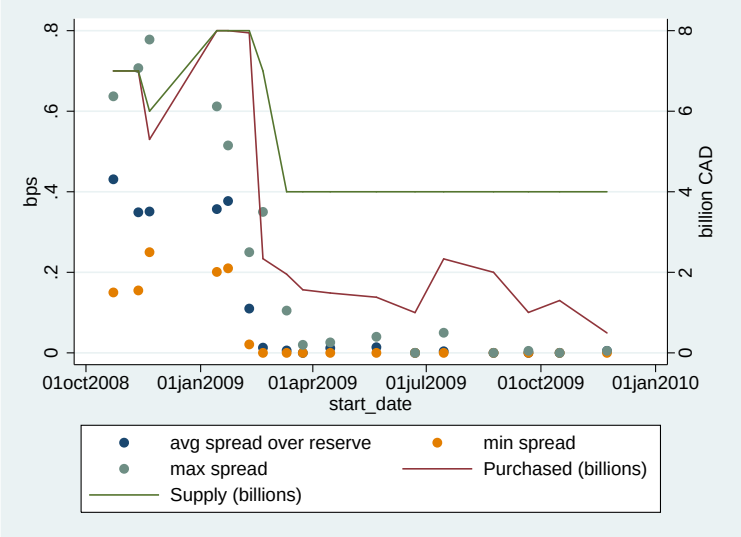


Figure 19: Results of auctions for mortgage repurchases

discount. Why is that? One potential explanation is the perceived counterparty risk with respect to the private mortgage insurer. About 30% of insured mortgages are insured for 10% of the facevalue by a private insurer, so there there could be default risk, if this private company were to go bankrupt. Since bank A was willing to accept a 42 basis points discount to exchange these insured mortgages for liquidity without actually demanding liquidity through other channels at perhaps more favorable rates, it likely attaches a significant probability to the private insurer going bust. Using the same logic underlying the CDS pricing formula, the 42 basis points discount on a 5-year loan corresponds to a (risk-neutral) default probability of approximately 3.4% over the loan horizon.

4.6 Putting Everything Together

In the previous sections we offered smaller bits and pieces of the puzzle. We showed that based on the CDS prices, there is considerable increase in the default probability at least for some Canadian banks. Even though there is this high degree of heterogeneity in implied default probability, banks' behavior vis-á-vis other banks was virtually unaffected. Even though all banks pledged excessive collateral into the payment system, they did not require the riskier banks to send more payments through the fully collateralized channel or reduced the credit lines extended to them. In terms of the distribution of the willingness-to-pay for liquidity across the different banks, there also does not seem to be a significant correlation with the CDS-implied default probability - banks with high CDS prices do not seem to have higher value for liquidity obtained from the central bank corroborating the evidence that other banks' behavior towards these riskier ones did not change and hence it was probably not impossible to secure liquidity through other channels

than the auctions administered by the Bank of Canada.

We also showed that the usual measures of a bank's financial health, such as the ratio of liquid assets on its balance sheets, were improving throughout the crisis. One channel through which this change was taking place was the insured mortgages purchase program. Banks used this tool extensively to off-load mortgages from their portfolio in exchange for liquidity - and they were willing to accept significant discounts to achieve it. On the other hand, the situation stabilized very quickly and banks were not reluctant to issue new mortgage loans. This suggests that banks possibly perceived the risk coming from a potential bankcruptcy of private insurer, whose market share significantly decreased during the crisis.

Of course, the ultimate question that still remains to be answered is what was the cause of the quick recovery from the shock of the collapse of Lehman Brothers. Was it an action of the Bank of Canada or was it simply the more conservative structure of Canadian banks' balance sheets already on the onset of the crisis? Answering this question convincingly would clearly have important implications for policy-makers.

5 Conclusion

As the rest of the world, the Canadian banking sector came under substantial stress during the recent financial crisis. In this paper we document that, suprisingly, this stress lasted only for few months immediately following the demise of Lehman Brothers. By the end of 2008, the behavior of Canadian banks does not exhibit any signs of anxiety and is virtually indistinguishable from their behavior prior to the crisis, which is quite in contrast to European or U.S. banks. We provide suggestive evidence that this was perhaps due to a more conservative nature of portfolios that these banks held. Furthermore, we show that it is rather hard to interpret the rising prices of credit default swap contracts during the crisis, since the cross-sectional variation in the implied default probabilities is not reflected in other aspects of those banks' transactions.

[**TO BE COMPLETED**]

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