Crisis Management: Analyzing Default Risk and Liquidity Demand during Financial Stress *

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Abstract

This paper shows that strategies in, and reliance on the payments system as well as special liquidity-supplying tools provided by the central bank are important indicators of distress of individual banks. We conclude that central banks can benefit from using high-frequency data on liquidity demand to obtain a better picture of the financial health of individual participants of the financial system. For the particular case of Canada, using unique features of the payments system and information from the liquidity facilities we find that the willingness-to-pay for liquidity during the financial crisis stayed at low levels throughout the Canadian financial system and that there was no increase in counterparty risk. This suggests that the central bank's overall policy response might have been less pronounced if they had used the methods employed in this paper to analyze the crisis than the actual response.

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This paper uses transactions-level data from the Canadian unsecured interbank market and from the term liquidity auctions to evaluate the extent and dynamics of counterparty risk and to estimate market participants' willingness-to-pay for liquidity during the financial crisis. Surprisingly, the willingness-to-pay for liquidity expressed as a premium over a reference rate was very small throughout almost the entire crisis. We compare this to transaction-level data on unsecured overnight lending and find, similar to Afonso, Kovner and Schoar (2010) for the U.S., that the overnight market remained quite active throughout the crisis, indicating that participants did not believe there were significant liquidity or counterparty risks. Finally, we use a unique feature of the Canadian payment system in terms of interbank credit lines to firmly conclude that there was no increase in counterparty risk during the crisis.

In periods of financial distress bank supervisors and central banks are at the front lines. These institutions, like all market participants, attempt to determine which institutions are under distress as well as understand the systemic implications of the event. During these periods market prices such as those on credit default swap contracts (CDS) or interbank spreads (e.g. LIBOR-OIS) are used as indicators of the extent of a crisis. This is because financial markets are able to gather large amounts of information efficiently and reveal it through prices. Overall this appears to be the case. Take for example CDS prices. Following a surge in the prices of CDS contracts on General Motors' bonds, GM needed government intervention, while some American and European banks with skyrocketing CDS prices indeed ended up facing severe difficulties (e.g. Merrill Lynch, RBS, or Dexia). At the same time, however, the insurance cost (prices of CDS contracts) for many banks' bonds increased substantially during recent times, and often stayed at high levels, without any evidence of financial difficulties. This was the case in Canada. Nevertheless, as CDS prices increased so did interbank spreads, also indicating an increase in risk. Furthermore, $LIBOR$ was likely understated, that is it appears that quoted rates, such as $LIBOR$, may have been fixed during the crisis. The U.S. Department of Justice and Securities Exchange Commission is currently investigating whether some banks manipulated $LIBOR$ between 2007 and 2008.[1]

Knowing the true levels of bank default risk and their demand for liquidity is important because it affects the policy response. On December 12, 2007, for example, 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 cash auction was the following day.[2] In Canada there was an increase in auction activity in the spring of 2008 following the collapse of Bear Stearn's. The federal government also introduced a mortgage buy-back program in October of 2008, around the same time that the Bank of Canada introduced new collateral rules in the

[1] Financial Times Wednesday 7, 2011

[2] See Chailloux et al. (2008) and Lavoie et al. (2011) for a review of central bank responses to the crisis.

large value payment system to free-up more marketable securities. Given the movements in the CDS prices and in the interbank market rates, these moves all appear to be well warranted.

Figure 1, for example, depicts the spread between unsecured interest rates and swap rates in Canada between 2006-2009. The spread between the Canadian Dealer Offered Rate (CDOR) and overnight index swap (OIS) rate can be thought of as a measure of tension in the Canadian interbank money market. The pattern was very similar in the U.S. and EURO markets: immediately after August 2007 the spreads in money markets substantially widened and culminated after the collapse of Lehman Brothers. Spreads, however, remained above their pre-crisis levels throughout 2009.[3]

We argue in this paper, however, that for Canada public measures appear to have over-estimated the risk, at least relative to the price Canadian banks were willing to pay for liquidity and the amount of counterparty risk in the overnight unsecured interbank market. It appears, therefore, that the policy response was overly aggressive – or at least sustained for too long. Our main argument is that there is valuable information in high-frequency data on liquidity that has largely been ignored. This information, in addition to publicly available prices, can be extremely valuable to policy-makers. The lesson from this analysis, therefore, which is true beyond Canada, is that there can be instances when market prices hide important details and policy-makers should use all available information to measure their response.

We begin by analyzing the demand for liquidity on an individual bank level by using data from the Bank of Canada's term purchase and resale agreement auctions (PRA). These auctions provided cheap short-term liquidity to banks during the crisis in exchange for high quality collateral. Our analysis of liquidity demand focuses on heterogeneity in risk and bids in the Bank of Canada's liquidity facilities. 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 substantial spread over the reference interest rate in order to get a short-term loan from the Bank of Canada. This period of distress, however, lasted less than two months, after which the banks returned to their pre-Lehman collapse behavior. This differs markedly from the situation in Europe – Cassola, Hortaçsu and Kastl (2011) analyze the repo auctions of the European Central Bank and document a persistent change in bidding behavior by market participants. Figure 2 shows the aggregate demand curves submitted in these European auctions during 2007. Cassola et al. (2011) argue that this increased bidding aggressiveness was likely due to a persistent increase in demand for liquidity by European banks as the outside option of procuring liquidity on the interbank market deteriorated. Banks

[3]There is already a broad literature studying the impact of the financial crisis on term lending in the United States. This is likely due to the problems being most obvious in this market. The Federal Reserve introduced three main facilities during the financial crisis: (i) Term Auction Facility, (ii) Term Securities Lending Facility, (iii) Primary Dealer Credit Facility. The majority of studies focus on the effectiveness of these facilities in bringing down spreads in the interbank market for term loans. The large spreads were caused by two factors: counterparty risk and liquidity demand. Taylor and Williams (2009) focus on counterparty risk and find that TAF had no effect on the interbank market. Wu (2008) separates out both risks and claims that TAF was effective in satisfying banks liquidity demand, which did reduce the stresses of the interbank market.

were thus willing to pay rates even in the primary market (the repo auctions) that were much higher than the reference overnight rate.[4]

The situation in Canada was remarkably different. While the default probabilities of individual banks implied by the prices of their respective CDS contracts 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 3 depicts the aggregate bidding functions in each auction that the Bank of Canada conducted before September 2008. It suggests that virtually all banks judged 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).

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. 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. As illustrated in Figure 4 Canadian banks bid aggressively for liquidity provided by the Bank of Canada only in October and November 2008. We find the same pattern in auctions of liquidity with 1-day, 1-month and 3-months maturities. This suggests that following Lehman's collapse banks' willingness-to-pay for both a very short (an overnight) loan and for longer-term loans increased, albeit temporarily.

Using transactions level data we find that overnight market remained quite active throughout the crisis – total loans transacted stayed virtually unchanged while prices actually fell. This indicates that participants did not believe there were significant liquidity or counterparty risks. Similarly, Afonso, Kovner and Schoar (2010) find that the overnight Feds Fund market remained active following the collapse of Lehman Brothers, although they do find evidence of increased counterparty risk. We argue that the impact of various liquidity-providing actions undertaken by the cental bank and federal government during 2008 might have led to a surplus of liquidity in the market, resulting in overnight unsecured loans transacting even below the target rate. In contrast, we find that during the asset-backed commercial paper (ABCP) crisis in the summer of 2007, when these extraordinary liquidity facilities did not exist, interbank rates did increase. Similar to Acharya and Merrouche (2010) this suggests liquidity was more scarce at this time. In neither episode, however, do we find evidence of an increase in counterparty risk.

[4]Evidence in Eisenschmidt, Hirsch, and Linzert (2009) suggests this continued throughout 2008 until rule changes in October led to a single-price auction where anybody could borrow as much as they like at the posted rate. The rule change was due to the increased demand for liquidity by European banks.

We are further able to explore the question of counterparty risk using data on intraday credit lines granted between market participants. This is the major advantage of using Canadian data relative to U.S. or European data. Since the payment system is one where banks provide each other intraday credit lines (rather than participants receiving intraday credit from the Federal Reserve, for example in Fedwire), and therefore face manageable default risk, we can analyze changes in these credit lines to measure change in counterparty risk. We find that there are no significant changes in the credit lines during the crisis, even after the Bank of Canada introduced changes to the payment system that encouraged financial institutions to lower credit limits to riskier banks. This provides further evidence that there was no increase in counterparty risk during the financial crisis for Canadian financial institutions.

The rest of the paper proceeds as follows. In section 1 we describe the data and present some summary statistics. In section 2 we go through the results of our analysis and section 3 concludes.

1 Data

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

1.1 Canadian Banking Sector Background

The Canadian banking sector is highly concentrated, with 90 per cent of the industry's assets held by the six largest banks, worth a total of $2,605 billion as of March 2010.[5] The Canadian banking landscape also includes a large regional co-operative network – the Desjardins Movement in Quebec, a provincially owned deposit-taking institution – Alberta's ATB Financial, hundreds of small credit unions, about sixty-five foreign bank subsidiaries, and a small number of trust companies.

Larger Canadian financial institutions have an informational advantage over smaller institutions stemming from the tiering of the payments system and securities dealings.[6] Alfonso, Kovner and Schoar (2010) suggest that the likely reason they do not find liquidity hoarding in Fedwire while Acharya and Merrouche (2010) find liquidity hoarding in the Sterling money market is tiering. Tiering in a payments network refers to an organizational structure whereby some financial institutions participate directly ("direct" clearers) while other financial institutions participate indirectly ("indirect" clearers). Chapman, Chiu, and

[5]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.

[6]This is also the case in the United Kingdom where the payments system is also characterized by significant tiering.

Molico (2010) present a model illustrating how tiering can improve efficiency and cost savings by reducing informational frictions in the interbank market. Savings are achieved because direct participants provide intraday credit to indirect participants. The associated cost, however, is that if an indirect participant defaults the direct participant is on the hook for the payments. Research from the recent crisis suggests there might be another cost to tiering. Alfonso, Kovner and Schoar (2010) examine (U.S.) Fedwire - a system with almost no tiering and do not find evidence of liquidity hoarding. Acharya and Merrouche (2010) study the Sterling money market where there is substantial tiering and find evidence of liquidity hoarding. The different findings between these two studies suggest another cost of tiering might be that in times of crisis a tiered system could induce liquidity hoarding. Direct participants might hoard liquidity because of an increase in credit risk of their indirect participants and not for precautionary reasons as in Allen, Carletti and Gale (2009) or Diamond and Rajan (2009), or increase in credit risk of other direct participants as in Flannery (1996) or Furfine (2001).

1.2 Large Value Transfer System (LVTS)

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 implements monetary policy through the Large Value Transfer System (LVTS). During our period of study LVTS included 14 direct participants and the central bank.[7] LVTS is a payment and settlement system operated by the Canadian Payments Association through which all 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 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 central bank target rate.

Like real-time gross settlement systems, 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 real-time gross settlement systems, however, settlement in LVTS occurs on a multilateral net basis at the end of the 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. It is this feature that makes the

[7]The direct participants include the Big 6 banks, Laurentian Bank, foreign banks with branches in Canada (State Street Bank, Bank of America, BNP Paribas, HSBC), the largest co-operative movement in Canada (Caisse Desjardins) and a provincially owned deposit-taking institution (Alberta Treasury Branches) as well as a credit union consortium (Central 1 Credit Union). 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.

Canadian system advantageous when studying counterparty risk. Financial institutions have counterparty default exposure in the payment system and they can manage it.

During the trading day, there are two ways of engaging in a transaction in LVTS with another bank. A bank can either send a payment through a fully collateralized Tranche 1 (T1) which involves real-time settlement or through Tranche 2 (T2) in which collateral is pooled, risk is shared and settlement takes place at the end of the trading day. The two main differences between the two tranches are the costs and the risk. T1 is fully collateralized and is therefore more costly in terms of the opportunity cost of capital.

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 securities; 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, however, is 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).

Our data consist of daily credit lines and T1 and T2 interbank transactions. 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. As expected, when the need arises, credit lines are adjusted upwards: conditional on an adjustment, the mean credit line is \$841 million (standard deviation \$757 million).[8] 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 with a standard deviation of \$484 million. 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, while the mean credit line from N to S is \$758.9 million. The standard deviations are \$62 million and \$67 million, 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.

[8] All dollar figures are Canadian currency.

1.3 Counterparty Risk Implied by CDS Prices

Credit default swap contracts rose to prominence during the financial crisis with the U.S. Treasury's bail-out of AIG. These types of contracts had been traded since the early 1990s, however, and publicly listed prices of CDS contract on a bank's debt, for example, could be used to measure counterparty risk.[9]

Figure 5 shows the time series of the prices[10] 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 duration of the contract. 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.[11] 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)):

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

we can recover the risk-neutral default probabilities implied by the CDS prices. For the largest institutions, banks A,E and K, the implied default probabilities (assuming 40 per cent recovery rates) went from close to zero to over 15 per cent. Given the increase in default risk implied by the CDS contracts on the banks in our sample we might expect an increase in liquidity hoarding during the crisis. We explore liquidity in the next section.

1.4 Liquidity

Financial institutions manage their daily liquidity needs through market operations and their interactions with the Bank of Canada. The Bank of Canada's primary objective in providing liquidity intraday and overnight to the banking system is to reinforce the target rate (The target rate as well as the one-month and three-month overnight index swap rates are plotted in Figure 7). The main facility is LVTS, occasionally supplemented by open market operations such as special purchase and resale agreements and sale and repurchase agreements. 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

[9] Even before the collapse of AIG some research had started to focus on the counterparty risk of the insurer in the CDS market. See for example Thompson (2010) and Arora, Gandhi, and Longstaff (2010).

[10] We combined data from Bloomberg and Markit.

[11] Since 2009 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.

Rate, and in rare cases financial institutions can request 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. When markets froze during the crisis financial institutions reliance on the central bank for liquidity grew in importance. During the crisis financial institutions accessed the aforementioned facilities and the Bank of Canada created new ones to inject more liquidity into the system.

1.4.1 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 its cash balances, the Bank of Canada holds twice-daily auctions through which it auctions off short-term loans, whereby it secures short-term interest income on its revenues. All auctions are held 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 21 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. 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. These auctions have been analyzed in Chapman, McAdams and Paarsch (2007) who find that bidders' behavior is reasonably approximated by a Bayesian Nash Equilibrium. In this paper we focus solely on the unsecured morning auctions. Our data set included bids (size,rate) from the morning Receiver General auctions between 01/02/2007 and 04/20/2009.

1.4.2 Term Purchase and Resale Agreement Auctions (PRA)

As the financial crisis unfolded it became it appeared that traditional liquidity injections were ineffective in getting liquidity from direct participants to market participants. In order to provide an additional source of liquidity to alleviate potential stresses, the Bank of Canada conducted two 1-month repo auctions in December 2007.[12] This was the first time that the Bank of Canada held cash auctions beyond one business day to support liquidity funding.[13] The PRA auctions were multiple yield competitive auctions, or in the language of auction theory, discriminatory auctions. The amounts of the initial auctions were small, $2 billion. Bidders could place up to 3 bids, with the minimum bid of $10 million with increments of $1 million.

[12]The broad principle that underlined the liquidity facility was to maintain liquidity in the financial system while minimizing distortions (Selody and Wilkins (2010)).

[13]Longer-term repos had been widely used by other central banks pre-crisis, most notably the Reserve Bank of Australia, but also the ECB and Bank of England. Canada, like the U.S., however, did not use long-term repos until the crisis.

Participants rated A or higher had a bidding limit of 25 per cent of the auctioned amount and those rated BBB or lower had a bidding limit of 12.5 per cent 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 subsidiary of a larger parent company. RBC Dominion Securities, for example, is the securities subsidiary of 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.[14] Almost all of the primary dealers are members of LVTS (via the parent company), but some members of LVTS are not primary dealers. 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.

After the December 2007 term auctions problems in funding markets quickly faded and the Bank of Canada stopped providing term liquidity. Following the collapse of Bear Stearns in March 2008, however, the Bank reintroduced term PRAs, this time on a biweekly basis. Throughout the spring and summer the Bank auctioned off $1 to $2 billion 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, freeing up higher quality collateral which could then be posted in the term PRA auctions or in the repo market.

Following the collapse of Lehman in September 2008, the Bank of Canada added repo auctions with 3-months maturity and held them on a weekly basis.[15] Each auction was for $2 or $4 billion, i.e. "commensurate with market conditions." 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 paper.[16] By accepting a wider range of assets as collateral the Bank of Canada in effect reduced the illiquidity premium of those assets.

Consistent with the G7 Action Plan in October 14th the Bank modified its liquidity facilities further so as to provide exceptional liquidity to the financial system. First, the Bank substantially increased the size

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

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

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

of the term auctions to as much as $12 billion. At its peak the amount of liquidity the Bank of Canada auctioned was 2% of the value of total bank assets. In the U.S. the peak was about 7% and in the Euro area the peak was 5%, again of total banking system assets.

Second, LVTS members that were not primary dealers became eligible to participate in the repo auctions. This includes ATB, Credit Union Central of Canada, Bank of America, BNP Paribas, and State State Bank. Thirdly, the Bank announced on October 17, 2008 that (eligible) LVTS participants would be temporarily allowed to pledge their non-mortgage loan portfolio as collateral for LVTS and Standing Liquidity Facility purposes.[17] A financial institutions' non-mortgage loan portfolio (NMLP) is highly illiquid (for example it includes credit card and personal loans) and the Bank took a 40 per cent haircut. This measure intended to free-up more marketable securities to support borrowing or be used in the term PRA.[18]

Table I offers some summary statistics of our sample of the bids in the term PRA auctions. The average number of bidders is 9 and the number of submitted bids averages less than 2. The average amount issued in PRAs was $4.76 billion and the yield bid (expressed as a spread over the overnight index swap (OIS)) is quite low, 0.04, with a minimum of -0.58 basis points and a maximum of 92 basis points. We use these bids to estimate banks' willingness-to-pay (WTP) for liquidity during the crisis. The reason is that since the WTP for liquidity obtained from the Bank of Canada should be equal to the opportunity cost of obtaining liquidity in the interbank market, studying the dynamics of the WTP allows us to look into the issue of counter-party risk as well. Banks that are perceived by their counterparties as riskier would be in the interbank market required to pay a premium for any loan that is not backed up by a risk-free collateral and thus would be willing to pay more. We now move on to our results.

[Table I]

2 Results

During the financial crisis central banks and financial institution regulators appeared very concerned with illiquidity and then insolvency of important financial institutions. Since the typical CDS contracts cover 5-years, their prices likely reflect mostly the likelihood of insolvency, even though there may be events

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

[18] 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. Central banks would point out, however, that they took significant haircuts were applied to this new collateral.

triggering payout on CDS contracts that are related to illiquidity. Over periods of several months, the distinction between illiquidity and solvency becomes more-or-less semantic. Therefore, a WTP for liquidity, which persistently exceeds that of other market participants, could also be viewed as a bad signal about solvency. In this section we analyze the liquidity positions taken by Canada's main financial institutions and test how closely it relates to the financial market's perceptions of the riskiness of these institutions.

2.1 Measuring stress using banks' bids for central bank-provided liquidity

Like many central banks during the crisis an important question for the Bank of Canada was how much demand existed for term liquidity. We use data for auctions of liquidity with maturity of 1-3 days administered by the Bank of Canada on behalf of the Receiver General and of 1- or 3-month term PRA operations conducted by the Bank of Canada. To recover banks' true willingness-to-pay 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 et. al (2011). They show that accounting for the strategic component of bids is empirically important, since many banks increase 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 response to more aggressive behavior by some of their rivals. Using the same method as Cassola et. al (2011), we recover the true marginal willingness-to-pay from the observed bid from the equilibrium 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.

Figure 8 depicts the aggregate willingness-to-pay curve corresponding to the bids for the 1-month term PRA. 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 a 140 basis points premium over the reference interest rate to obtain a 1-month loan. This is perhaps surprising since at 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 obtaining a loan for 1-month versus rolling over overnight loans might have been an important trade-off in that turbulent time period.

Turning our attention to the Receiver General auctions, perhaps surprisingly, given the very short-maturity structure of these loans, we find the same general story. In Figure 9 we plot aggregate bids in 20 randomly chosen auctions for overnight loans from the 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 10 depicts a 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 a premium over the reference interest rate in order to obtain liquidity. Only a 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.

We begin our regression analysis by studying the relationship between the spread (of the quantity-weighted bid) over the index swap rate (OIS) that an individual bank is offering to pay to obtain a repo-loan from the Bank of Canada in one of the liquidity auctions and key determinants of risk.[19] Table II presents summary statistics of the risk variables in the regressions.

[Table II]

Table III summarizes the results. It is immediately visible that controlling for bank heterogeneity using bank fixed effects is important; otherwise several variables would have a counterintuitive sign. For example, the larger the share of conventional mortgages, i.e. low loan-to-value mortgages, to total assets, the lower the spread. The results depict a convincing picture that the bids are strongly related to the share of retail deposits, the share of mortgages, and to Merton's (1974) measure of distance to default. The distance to default measures the market value of a financial institutions assets relative to the book value of its liabilities. Merton's insight was that we could use the Black and Scholes (1973) framework to solve for the asset value and volatility of any firm using the value and volatility of their equity. Given asset values and volatility, as well as a risk-free rate, the distance to default is calculated as follows:

$$DD = \frac{\log V_A/L + (R - \frac{1}{2}\sigma_A^2)(T-t)}{\sigma_A\sqrt{T-t}}.$$

It follows that the smaller the distance to default the larger the probability the bank will default on its debt. A negative and significant coefficient on distance to default, therefore is consistent with financial

[19] Given the competitive outcome of the term PRA auctions it turns out that there is very little difference between using bids and willingness-to-pay. This is very different than the ECB auctions analyzed in Cassola, Hortaçsu and Kastl (2011) where bidders perceived much more uncertainty about the market clearing price despite the large number of participants.

institutions that are further away from default bidding less for liquidity in the term PRA auctions. Unlike the correlation between distance to default and bidding we do not find a similar correlation between CDS prices and bids. This is true irrespective of whether or not we control for distance to default. This suggests that banks own valuation for liquidity via their bids is not correlated with CDS prices.

We do not find a significant relationship between banks' bids and their share of liquid assets to total assets or the amount of liquidity they obtained through the TAF. The Term Auction Facility (TAF) was the United States Federal Reserve's extraordinary liquidity facility implemented in December 2007 to extend collateralized term loans to deposit-taking institutions. Canadian banks with operations in the U.S. could bid at the auctions for 1 and 3 month loans. Unlike the Bank of Canada's Term PRA facility the TAF was a single-price auction.[20] TAF was another way Canadian banks could access liquidity, but more importantly a way for Canadian banks to access U.S. dollar liquidity. The 5 major banks accessed TAF dollars, largely in the period immediately following the collapse of Lehman Brothers, but the amount accessed did not affect their bids in the Term PRA.[21]

[Table III]

2.2 Balance sheet indicators

Canadian banks have to report the detailed structure of their balance sheets to the Bank of Canada, regulator (the Office of the Superintendent of Financial Institutions), and the deposit insurer (Canada Deposit Insurance Corporation) on a monthly basis. Somewhat coarser information about balance sheets is published on the regulator's website and thus becomes subsequently public. In Figure 11 we plot the ratio of cash to total assets for all banks in our data and Figure 12 depicts the evolution of the share of liquid to total assets. Figure 13 shows the evolution of the share of residential mortgages among total assets. These figures show that in the summer of 2007 as Canadian banks brought back off-balance sheet items to the balance sheet their share of liquid assets to total assets fell. These figures also show however, that immediately following the collapse of the Lehman Brothers banks started working hard to substitute away from illiquid assets. The share of cash in their asset portfolio increased substantially between September 15, 2008 and December 2008 which corresponds to the time period when banks were bidding aggressively in the liquidity auctions.

[20] 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 further increase flexibility in providing 1-month term liquidity since participants could use NMLP as eligible collateral. One effect of TLF would be to remove 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.

[21] In addition to the variables presented in Table III we also looked at bank issuance of equity and domestic and foreign debt using the SDC database and found insignificant effects.

At the same time banks were aggressively bidding for cash in the term PRA program banks also took advantage of a government mortgage buy-back program known as the Insured Mortgage Purchase Program (IMPP). Details of the IMPP are provided in the Appendix. The IMPP allowed participating financial institutions to reduce their exposure to residential mortgages. For a short period of time between the start of the IMPP program in October 2008 and December 2008 financial institutions did this which explains the drop in residential mortgages on the balance sheets. By January 2009, however, new mortgage lending had picked up and for most financial institutions the ratio of residential mortgages to total assets was back to (or near) where it was pre-Lehman collapse.

2.3 Dynamics of overnight lending

Using the Furfine algorithm (Furfine (1999)) we were able to construct a series of (unsecured) overnight lending on the interbank market between January 2007 and July 2009.[22] While neither the total transacted volume nor the average size of an individual loan changed substantially during the period of our data, the interest rates varied substantially. Figures 14 and 15 plot our results. In particular, the data suggest that there was excess liquidity in the market and banks were willing to lend cash overnight for less than the target rate throughout the crisis, with the exception of the fall of 2007 during the ABCP crisis. At the same time, the variance of the rates increased substantially during the crisis. We view these two facts together as suggestive evidence that in the face of increased uncertainty banks took conservative liquidity positions and thus were willing to lend cash at rates below the target to reliable counterparties, which was not observed before the crisis.

For a deeper understanding of overnight lending patterns, we now broadly replicate the basic regression exercise presented in Afonso, Kovner and Schoar (2010) while also taking into account the events of the summer of 2007 as in Acharya and Merrouche (2010). Afonso, Kovner and Schoar (2010) focus on the impact of the Lehman collapse on liquidity hoarding and counterparty risk in the U.S. overnight interbank market. Their primary specification is therefore the following:

$$F_{b,t} = \beta(Date) + \theta \log\left(\frac{amount_{b,t}}{assets_{b,t-1}}\right) + \alpha_b + \epsilon_{b,t}, \tag{2}$$

where $F_{b,t}$ is spread to target or log of loan size for bank (borrower/lender) b at time t, $Date$ is a vector

[22] The idea behind the algorithm, as we apply it, is to look at flows in the payment system and find a payment π from bank A to bank B in the late afternoon at date t and a return payment in the morning of date $t+1$ of size $\pi(1+i)$ and classify these payments as loans. The price of the loan is i. The main issue with the Furfine algorithm is that it has the potential to identify some transactions as loans when they are indeed payments. This is particularly true in the case of using the algorithm early in the day or for small transactions. Unlike Fedwire, which processes Euro-dollar transactions, tri-party repo legs and bank to non-fedwire institution transactions, which may or may not be considered loans, LVTS does not process these types of transactions. Therefore using the Furfine algorithm in LVTS is less likely to lead to a misclassification of transactions. In addition we only examine transactions late in the day making misclassification even less likely.

of indicator variables, *amount* is the amount borrowed/lent overnight in the spread regression and α_b is a borrower/lender fixed effect. The dates of interest are $DFri12$, $DMon15$, and $DTue16$, corresponding to the Friday before the Lehman collapse, the Monday of the Lehman collapse, and the Tuesday after. The key result is that aggregate trading volumes in the Feds Funds market did not change during the crisis but that the composition of the participants and the price and volumes at which they traded did change.

Acharya and Merrouche (2010) instead focus on the ABCP crisis in the summer of 2007 and its impact on the demand for liquidity in the U.K. overnight interbank market. In the above notation they are interested in measuring the impact of $DAug9$, i.e., the news of BNP Paribas closing two funds exposed to the U.S. subprime crisis on Thursday August 2007, on overnight lending in the U.K. interbank market.[23] The key result is that there was precautionary liquidity hoarding in the summer of 2007 and this increased interbank rates, regardless of counterparty risk.

In Table IV we report results combining the date indicator variables from each period and measure the impact of both set of dates on interbank lending in the Canadian overnight market. Focusing first on the post-Lehman period, we find strong evidence that Canadian banks were not hoarding liquidity in the overnight interbank market. Neither prices or loan amounts appear to be affected by the events surrounding Monday September 15th. This is true on average (regressions which do not have bank fixed effects) and at the bank level (regressions with bank fixed effects). Only on the 16th do we see a significant drop in spreads, although there was no change in amount borrowed or lent. Afonso, Kovner and Schoar (2010) report a substantial change in borrower composition related to counterparty risk in the Feds Funds market. Larger, worst-performing banks loss access to the overnight market, while smaller, better performing banks increased their access to the market. Unlike Angelini, Nobini and Picillo (2009), however, who find that the most liquid lenders charge the highest rates (on the Italian interbank deposit market), which suggests banks were hoarding liquidity, Afonso, Kovner and Schoar (2010) do not find any such evidence. We do not find a change in the average price or loan size or a change in the composition of borrowers and/or lenders during the Lehman crisis. This suggests that Canadian banks did not hoard liquidity or that was not an observable change in counterparty risk in the overnight interbank market.

It may not be surprising that the composition of overnight interbank participants remained the same post-Lehman given that the Canadian market is a tiered structure, with only 14 direct participants. This is in contrast to the Feds Fund market where there are potentially thousands of participants, and the composition can and did change (Afonso, Kovner and Schoar (2010)). It is the change in borrower type in the Feds Fund market which identifies the increase in counterparty risk with no change in overall liquidity.

[23] Given the reserve requirement framework in the U.K. the level of liquidity demanded (supplied) by any particular bank is not strictly exogenously given by the idiosyncratic payments flows throughout a day. Therefore Acharya and Merrouche (2010) require an instrumental variable approach.

Turning the focus to the summer of 2007, as in Acharya and Merrouche (2010), we find a slightly different story. The effect of BNP Parisbas' acknowledgement of the crisis on August 9th led to an increase in overall spreads as well as borrower- and lender-specific spreads.[24] The amount traded, however, did not change on August 9th and 10th. At the end of day on August 13th there was an announcement of disruption in the Canadian non-bank asset-backed commercial paper market, and this shows up in the coefficient on $DAug13\_14$. Again spreads increased. Throughout the remaining part of summer and fall of 2007 as banks brought back ABCP onto their balance sheet, spreads on the interbank market went higher than the rest of the sample, as did the amounts traded. Interestingly, the coefficients on the amount borrowed (lent) with and without fixed effects are nearly identical. This indicates that the result of the crisis was an upward shift in demand spread across the same borrowers pre-crisis and met by the same lenders pre-crisis, but at a higher rate.[25] On December 12th, 2007 the Bank of Canada implemented its first term PRA auction. At this point spreads in the overnight market fell back to their normal levels. As mentioned above, things changed again following the collapse of Lehman Brothers.

[Table IV]

2.4 Repo market

Gorton and Metrick (forthcoming) argue that the financial crisis was centered around the repo market. As counterparty risk increased concerns about the value and liquidity of collateral suffered a run due to higher required haircuts. Similarly, Brunnermeier (2009) argues that repo lenders required more collateral, which further drained the system of liquidity. In Figure 18 we depict the end of month outstanding balances of repo transactions of the 12 largest Canadian banks. Similar to our analysis of the overnight interbank market, there seems to be little evidence of any persistent impact of the crisis on the Canadian repo market. Part of the repo transactions shifted from trade between private banks to trade with the Bank of Canada via the purchase and resale agreement auctions, but the overall amount seems to be fairly constant over the period of our study. Of course, this figure needs to be interpreted cautiously since the structure of the outstanding collateral might have changed.

[24] We pool the effects of August 9th and 10th, although this is simply for brevity since the coefficients for both days are of the same sign and significance. We do the same for August 13th and 14th.

[25] In results not reported here we interact the date dummy variables with the fraction of non-performing loans to total assets. Given they find a compositional change in lenders Afonso, Kovner and Schoar (2010) use this approach to test for hoarding. Since we do not have a change in composition of lenders this test is redundant. Nevertheless the coefficients are all insignificant, suggesting a lack of hoarding by the weaker banks.

2.5 Liquidity risk or counterparty risk?

Sofar we have analyzed the demand for liquidity by Canada's main financial institutions. Balance sheet data suggests that there was some liquidity hoarding, although results from the term PRA and Receiver General Auctions suggest that this was largely isolated to an immediate period following the collapse of Lehman Brothers. The dynamics of overnight lending do not suggest liquidity hoarding. Another question relates to intraday interbank counterparty risk during the financial crisis. The dynamics of overnight lending suggest very little evidence of changes in counterparty risk during the crisis. We analyze counterparty risk in more detail in this section.

2.5.1 Counterparty Risk Implied by the Bilateral Credit Lines in LVTS

During the financial crisis, the Bank of Canada substantially expanded the collateral deemed acceptable in the payment system. In particular, most participants were allowed to pledge their whole non-mortgage loan portfolio as collateral. This in turn meant that virtually every participant in the LVTS had an abundance of unused collateral in the system. Since as described in section 1.2, the LVTS has two tranches: a fully collateralized tranche, T1, and a partially collateralized one, T2 – it would thus seem natural that if the opportunity cost of collateral vanishes and default probabilities of counterparties increases, banks would be less reluctant to deal with their counterparties through T2 (and thus potentially bear some default risk). In figure 16 we plot the time series of credit lines extended to bank K, which according to its CDS price experienced the most dramatic increase in the probability of default.[26] Clearly, K's counterparties in the LVTS did not fear that K might experience solvency problems since they neither refused to trade with K using T2, 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 processed through the fully collateralized tranche of LVTS does not appreciably increase either on the aggregate level or on the bilateral level. Figure 17 presents the fraction of transactions that pass through the fully collateralized tranche relative to the partially collateralized tranche. There was an increase in this ratio in the summer of 2007, but a fall to normal levels in the fall of 2007 and throughout 2008. This happened despite of the abundance of collateral in T1 due to the Bank of Canada's actions to allow financial institutions' non-mortgage loan books to be used in the payment system (of course, subject to a haircut).

[26] For confidentiality reasons we cannot show dollar amounts and therefore only present a graph of the relative BCLs. The point is simply that BCLs rarely change.

2.6 Putting Everything Together

In the previous sections we offered smaller bits and pieces of a puzzle. We showed that CDS prices suggested a considerable increase in the default probability at least for some Canadian banks. Despite this high degree of heterogeneity in implied default probability, banks' behavior vis-à-vis each other 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. Moreover, the distribution of the willingness-to-pay for liquidity across the different banks suggests that there is no 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" banks 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. The persistently high prices of CDS contracts may suggest that virtually all Canadian banks may face solvency issues over the life of the contract. Nevertheless, we did not find any bank having persistently high WTP for liquidity, which should be a necessary condition for insolvency. Of course, we cannot rule out that the solvency problems signalled in the CDS prices might still lie in the future.

Interestingly, Figure 8 of Taylor and Williams (2008), which shows the CDS prices of Bank of America, JP Morgan and Wells Fargo being nearly identical throughout the crisis, while Citigroup CDS prices are higher, suggesting the market thought that at least three of these banks were similarly risky. Therefore, it would be interesting to look at the cross-sectional variation in rates paid in the Feds Fund market as well as bidding behavior in TAF to see whether or not these institutions believed themselves to be as risky (or riskier) than the market believed using data similar to that used in Afonso et al (2010).

We also showed that the usual measures of a bank's financial health, such as the ratio of liquid assets on its balance sheets, improved throughout the crisis. One channel through which this change took place was the insured mortgages purchase program. Banks used this tool extensively to sell mortgages from their portfolio in exchange for liquidity. On the other hand, the situation stabilized very quickly and banks were not reluctant to issue new mortgage loans.

3 Conclusion

As in most developed countries, the Canadian banking sector came under substantial stress during the recent financial crisis. In this paper we document that, surprisingly, this stress lasted only for a few months

immediately following the demise of Lehman Brothers. By the end of 2008, the behavior of Canadian banks did not exhibit any signs of anxiety and was virtually indistinguishable from their behavior prior to the crisis, which is quite in contrast to European banks. We provide suggestive evidence that this was perhaps due to a more conservative nature of portfolios that these banks held. Our results also suggest that although the Bank of Canada's response to public signals of the financial crisis may have been warranted, in light of the financial institutions' behavior in the payment system and their willingness-to-pay for liquidity it may been too strong.

We argue that looking at banks' behavior in liquidity auctions organized by the central bank might provide the Bank of Canada with a more accurate picture of the situation of the individual banks. The spread over the index swap rate each bank is offering to pay for a repo-loan is suggestive about how much it is pressed for liquidity which it might not be able to secure elsewhere. Using an equilibrium model of bidding, one can recover the willingness-to-pay from the bids, which is indicative of the opportunity cost of obtaining funding from other sources (interbank markets). We show that in our application these spreads are indeed related to various measures of bank's solvency and riskiness from the balance sheets. The bids thus may act as an aggregated snapshot of a bank's situation.

Figure 1: Interest Rate Spreads in Canada

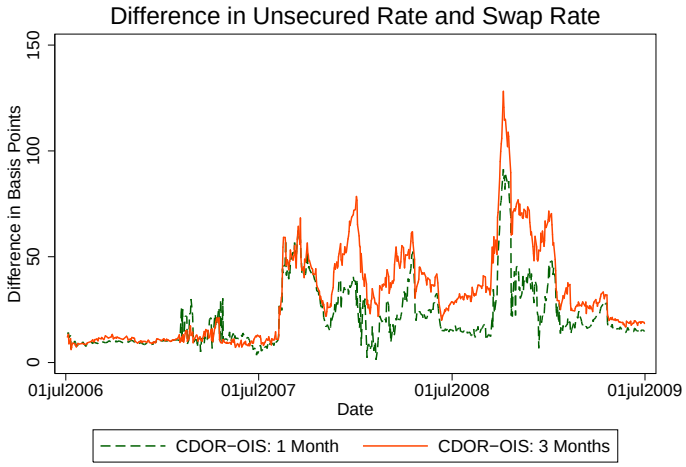


Figure 1 shows the daily CDOR and OIS rates. CDOR is the Canadian Dealer Offered Rate and is equivalent to LIBOR/EURIBOR. It is the average rate for Canadian bankers' acceptances for specific terms-to-maturity, determined daily from a survey on bid-side rates provided by the principal market-makers, 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.

Figure 2: Aggregate demand curves in European liquidity auctions during 2007

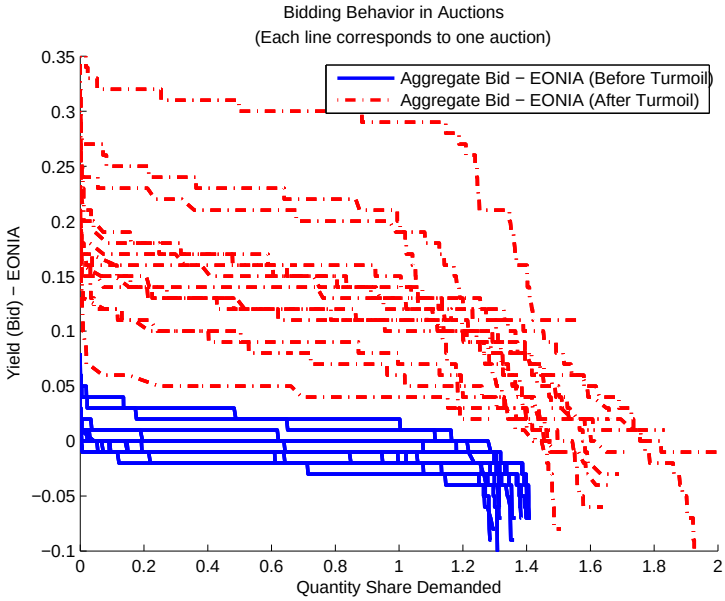
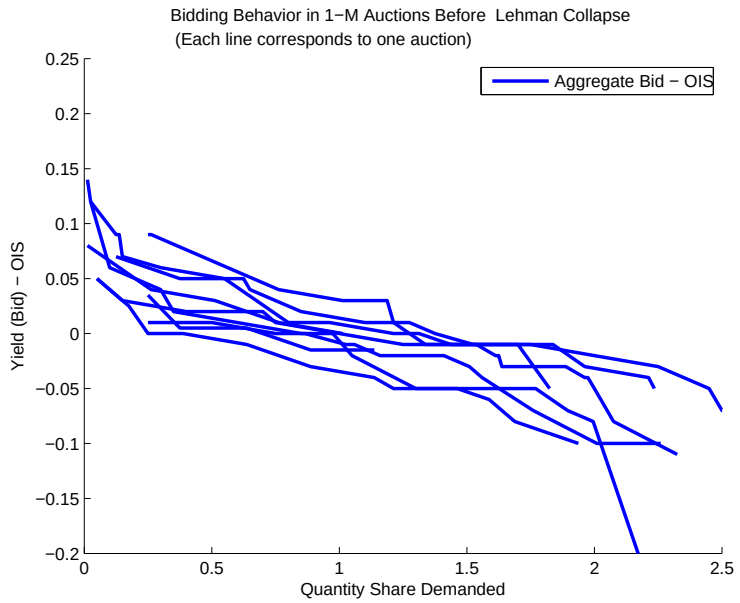


Figure 2 is taken from Cassola, Hortaçsu, and Kastl (2011). It shows the aggregate demand curves (horizontal sum of individual bids) of the liquidity auctions help by the ECB in 2007.

Figure 3: Aggregate demand curves in Canadian liquidity auctions before Lehman Collapse



Since Figure 7 shows that OIS rates capture expectations of the financial markets with respect to the target rate well, we use them to express all bids as spreads over the expected target rate.

Figure 4: Aggregate demand curves in Canadian liquidity auctions

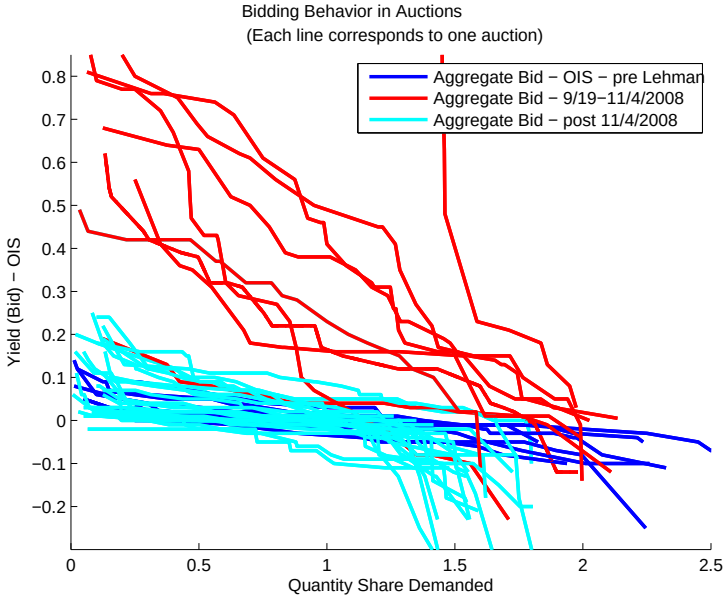


Figure 5: Prices of 5-y Credit Default Swap Contracts

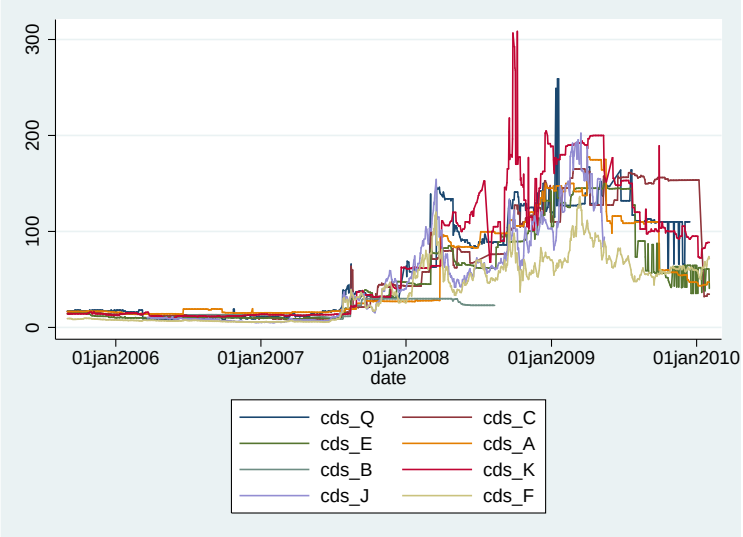


Figure 6: Probability of default (over 5-years) implied by the CDS prices

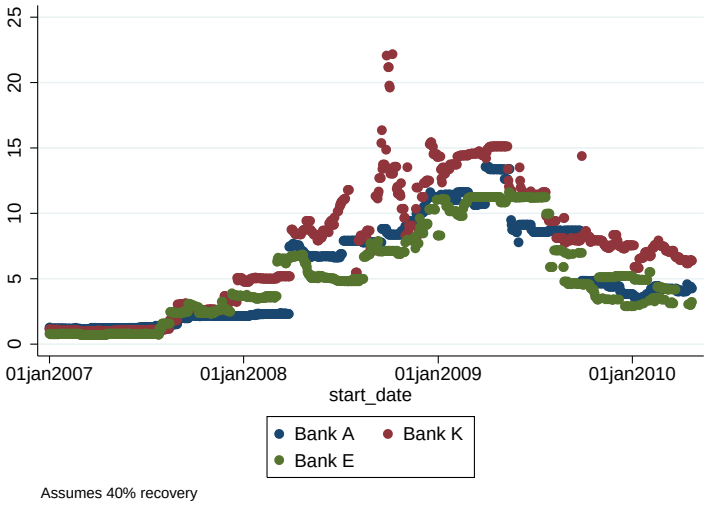


Figure 7: Overnight Index Swap Rates and the Target Rate

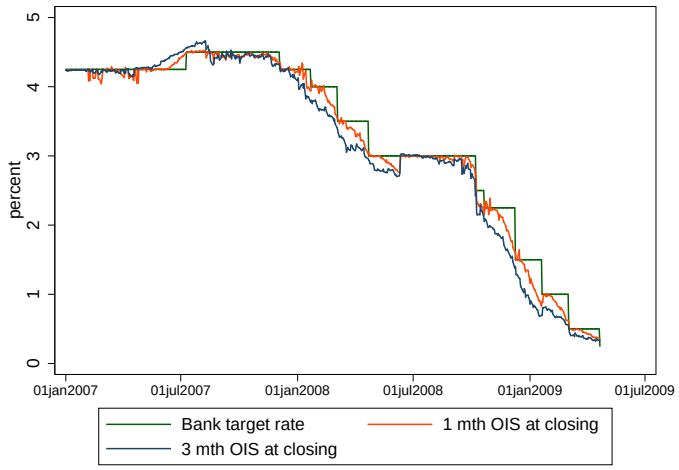


Figure 7 shows the daily values of 1-month and 3-month OIS rates and the Target Rate of the Bank of Canada. Even though in Canada OIS rates are calculated in reference to the CORRA, or Canadian Overnight Repo Rate Average, they capture expectations of the financial markets with respect to the target rate well.

Figure 8: Willingness-to-pay for 1-m liquidity

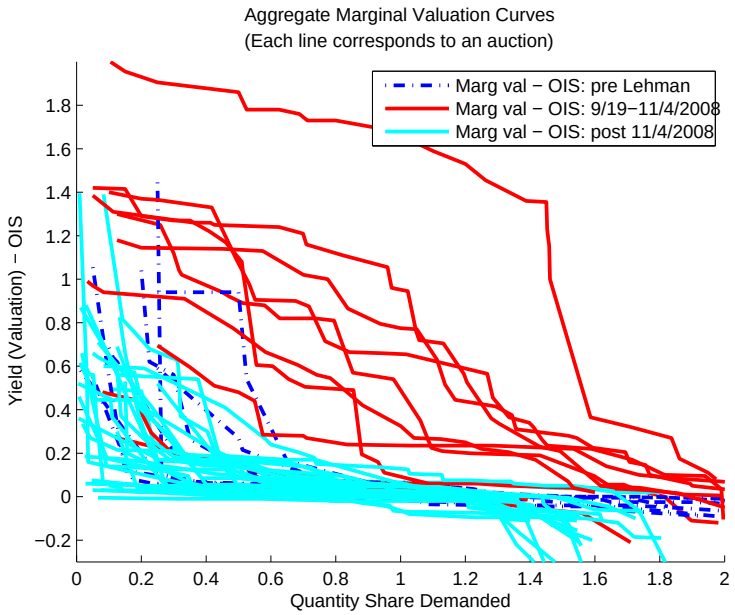


Figure 9: Bidding for overnight liquidity before Lehman Collapse

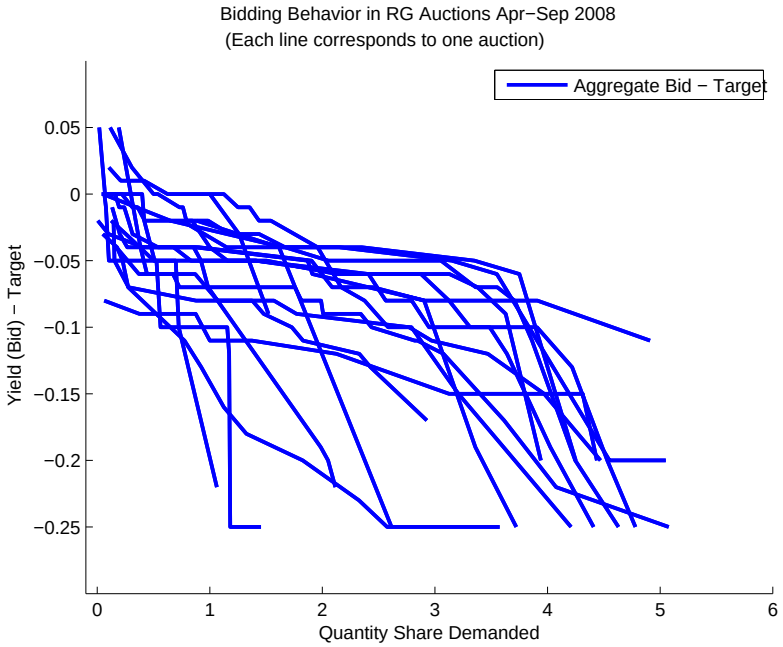


Figure 10: Bidding for overnight liquidity after Lehman Collapse

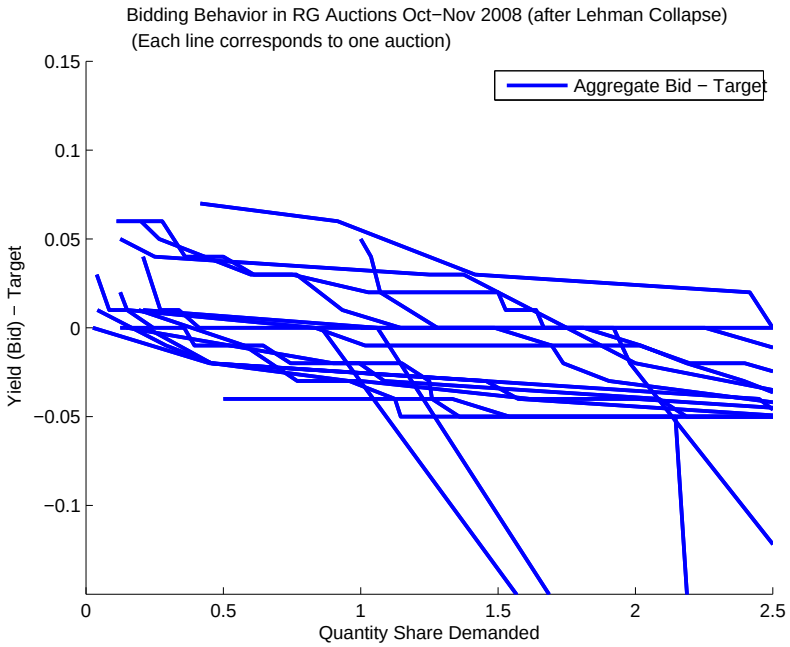
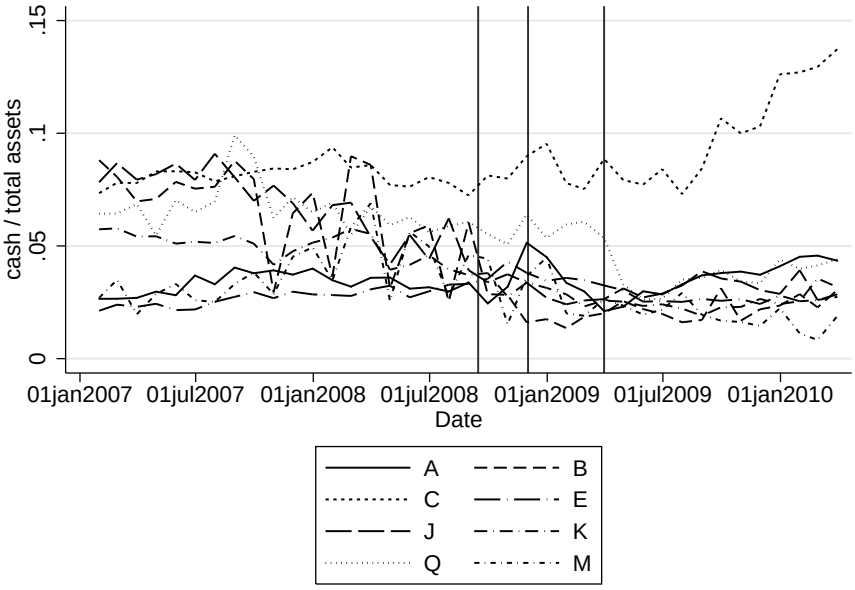
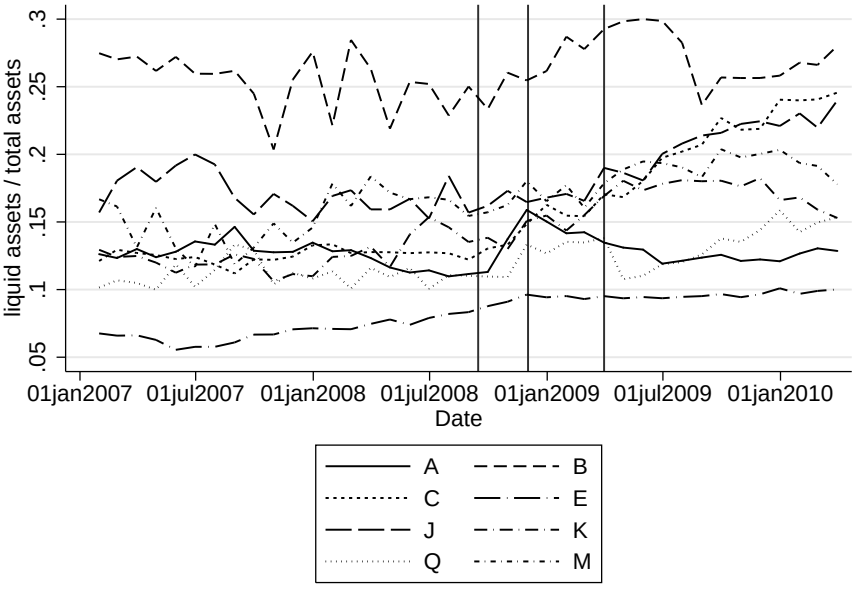


Figure 11: Cash/Total Assets



First line: Lehman collapse. Second line: 2Dec2008. Third line: last −significant− IMPP auction

Figure 12: Liquid Assets/Total Assets



First line: Lehman collapse. Second line: 2Dec2008. Third line: last −significant− IMPP auction

Figure 13: Residential Mortgages/Total Assets

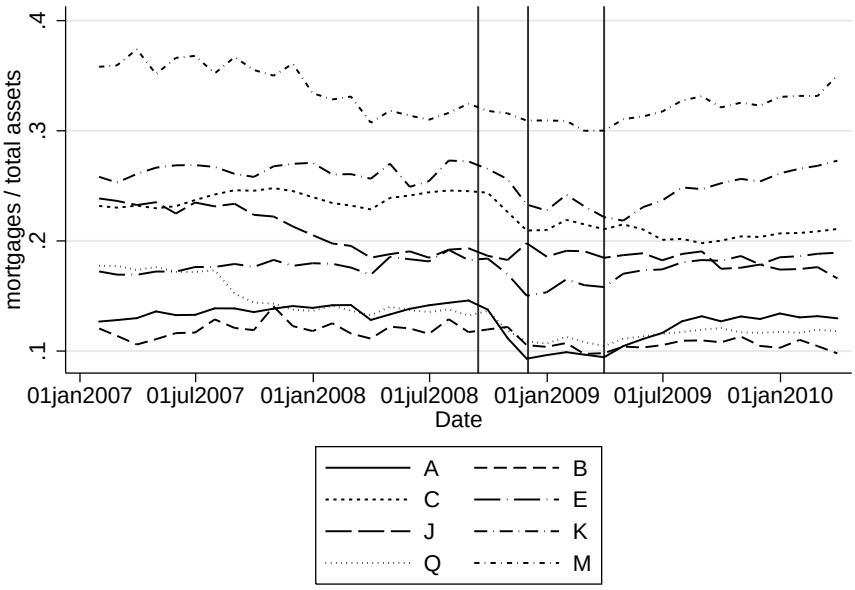


Figure 14: Total Overnight Loan Amount

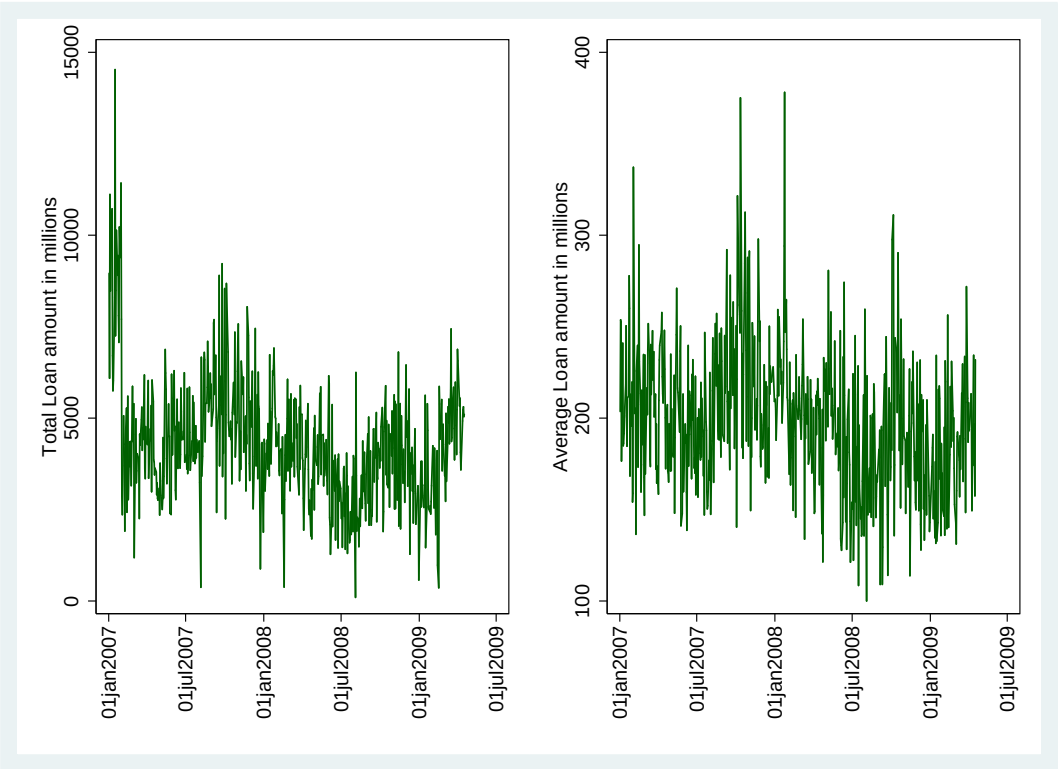


Figure 14 shows the aggregate amount borrowed in the Canadian unsecured interbank market (in millions of Canadian dollars) between January 2007 and April 20, 2009.

Figure 15: Average and Std Dev of Overnight Unsecured Rate

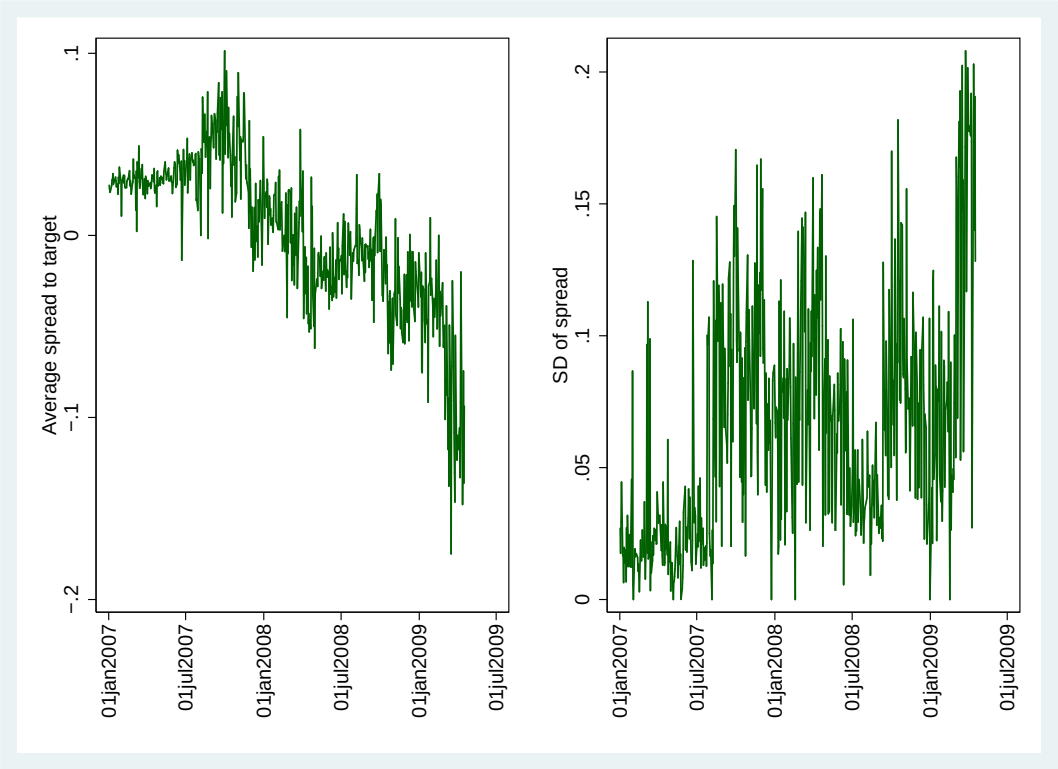


Figure 15 shows two things: (1) the average spread between the rate paid for a loan and the Bank of Canada target rate in the Canadian unsecured interbank market between January 2007 and April 20, 2009 and (2) the standard deviation in the same spread.

Figure 16: Credit Lines to Financial Institution K in the Payment System

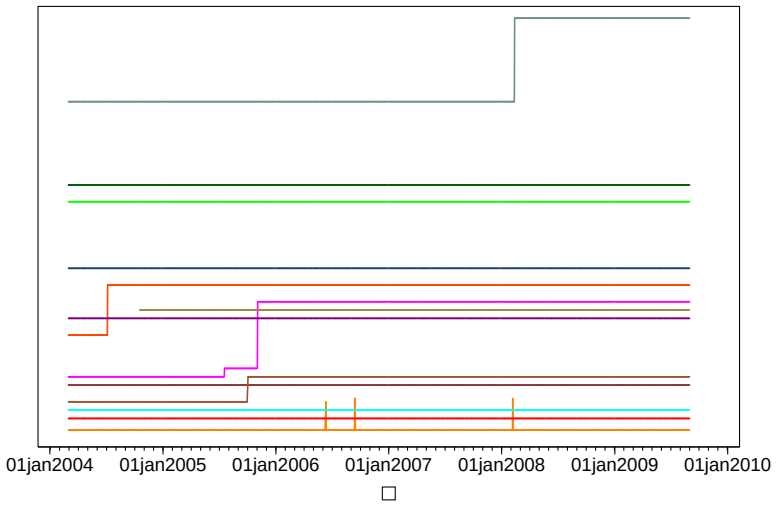


Figure 16 shows the bilateral credit lines in LVTS from all participants to financial institution K from April 2004 to April 2009.

Figure 17: Ratio of Tranche 1 to Tranche 2 Transactions – Value

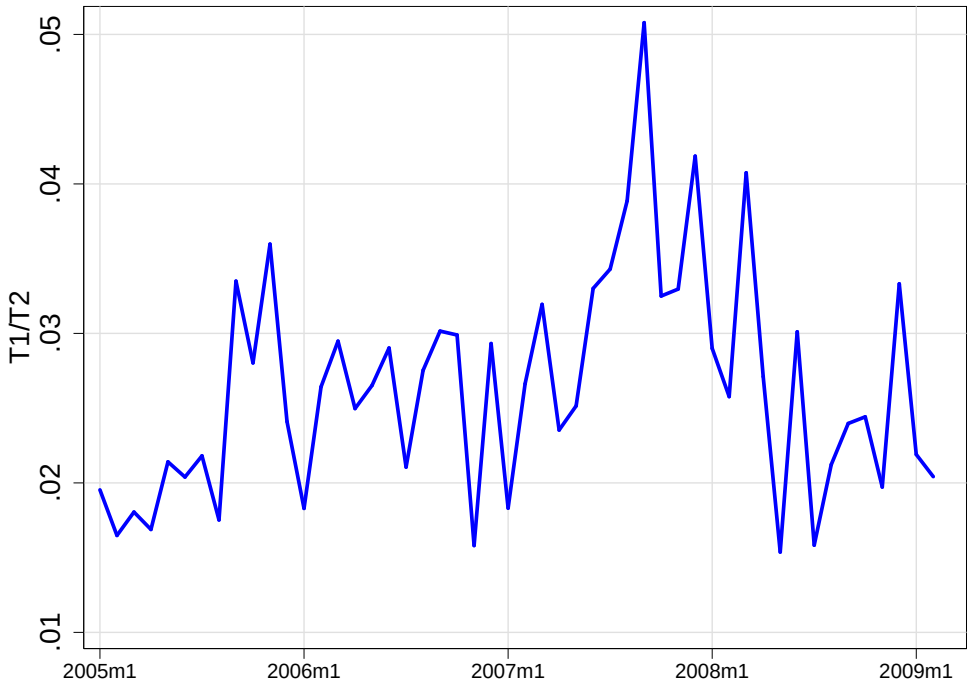


Figure 17 shows the fraction of transactions in dollar value sent via T1 versus T2 between January 2005 to April 2009.

Figure 18: End of Month Outstanding Balance of Repo Transactions of 12 largest Canadian Banks

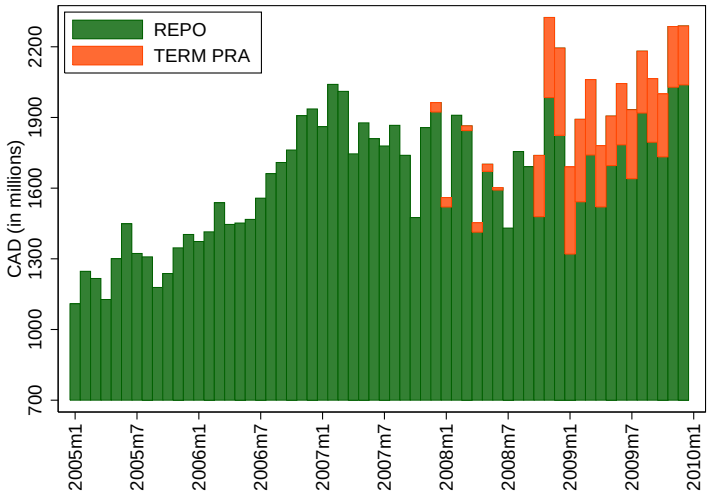


Figure 19: Putting it All Together

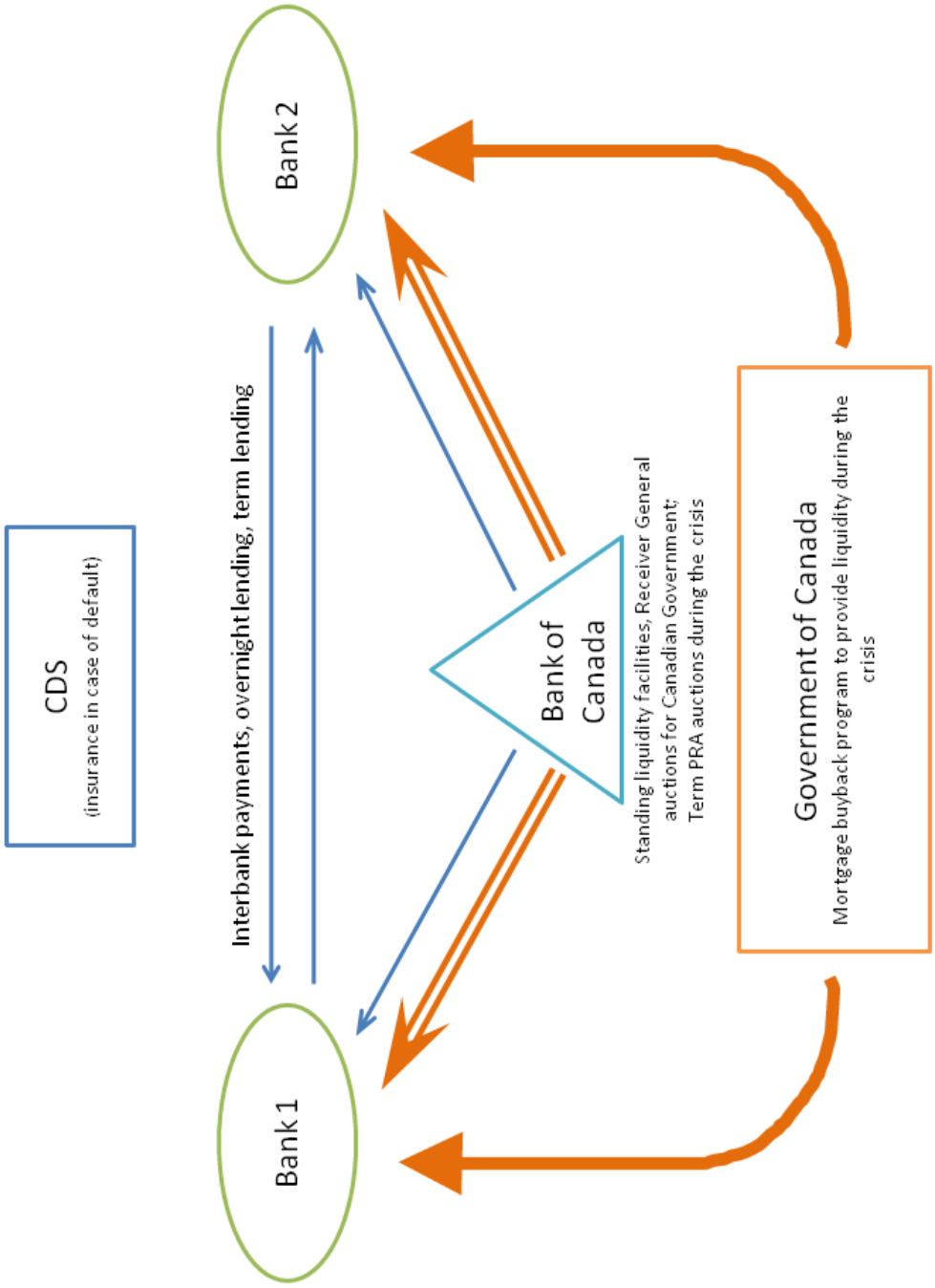


Table I: Data Summary for Term PRA Auctions

	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

Table II: Data Summary for Bank Characteristics used in the Regression Analysis

Variable	Mean	Standard deviation	Min	Max
Table III variables				
Quantity-Weighted Bid-OIS Spread	0.148	0.276	-0.07	1.46
Liquid assets/TA	0.160	0.058	0.071	0.293
Retail deposits/TA	0.251	0.039	0.184	0.368
Wholesale deposits/TA	0.380	0.048	0.304	0.478
Conventional mortgages/TA	0.086	0.044	0.033	0.166
Insured residential mortgages/TA	0.084	0.037	0.037	0.171
Allowances for losses/TA	0.004	0.001	0.003	0.006
Loans outstanding/TA	0.522	0.055	0.432	0.627
Loans obtained via TAF (in millions)	7.85	6.90	0	16.59
Distance to default	2.575	1.685	1.6685	6.800
5 year CDS spread	118.30	53.52	13.26	308.5
Table IV variables				
Spread to Target	-0.011	0.063	-0.497	0.453
Overnight Loan Amount/TA	0.013	0.035	-	-

[a] For confidentiality we do not allowed to report the minimum and maximum values of the Overnight Loan Amount/TA.

Table III: Explaining Bid-OIS Spread

The sample is from the first Term PRA auction on December 12, 2007 to April 21, 2009 – when the facility was used for monetary policy in addition to liquidity reasons and a minimum bid rate equal to the target rate of 25 basis points was set. The dependent variable is log(0.1+bid minus OIS) where 0.1 is added since the lowest spread bid is -0.07. TAF is the U.S. Term Auction Facility run by the New York Federal Reserve. TA is total assets. All balance sheet data are monthly. Distance-to-default is calculated using Merton (1974)'s model. The prices of the 5 year CDS contracts are based on the CDS of senior debt. Constant term not reported. Standard errors clustered at bank level.*,**,*** denotes significance at 10, 5, 1% level, respectively.

	log(0.1+Bid-OIS)					
	(1)	(2)	(3)	(4)	(5)	(6)
Dummy=1 if Auction 9/24/2008-11/10/2008	1.457	1.430	1.404	1.450	1.416	1.377
	(0.075)***	(0.111)***	(0.067)***	(0.06)***	(0.094)***	(0.144)***
log(Liquid Assets/TA)	0.068	-.969	0.105	-.364	0.107	-.994
	(0.183)	(0.509)*	(0.245)	(0.325)	(0.194)	(0.441)**
log(Retail Deposits/TA)	0.101	-8.182	0.232	-4.608	0.041	-8.598
	(0.303)	(2.622)***	(0.254)	(2.988)	(0.302)	(2.627)***
log(Conventional Mortages/TA)	-.029	2.214	-.107	1.391	-.056	2.190
	(0.179)	(0.527)***	(0.067)	(0.491)***	(0.186)	(0.663)***
log(Insured Residential Mortgages/TA)	-.140	1.752	-.231	0.455	-.155	1.873
	(0.132)	(1.033)*	(0.082)***	(0.548)	(0.187)	(1.075)*
log(Allowances for Losses/TA)	-.750	0.635	-.602	0.419	-.921	0.498
	(0.494)	(0.646)	(0.545)	(0.585)	(0.575)	(0.77)
log(Loans Outstanding/TA)	1.735	-1.409	2.015	-.734	2.125	-.955
	(0.643)***	(0.953)	(0.801)**	(1.372)	(1.103)*	(1.584)
log(1+Loan obtained at TAF)	0.034	0.013	0.018	0.053	0.034	0.0003
	(0.057)	(0.058)	(0.042)	(0.07)	(0.057)	(0.058)
log(Distance-to-Default)	-.038	-.888			-.250	-.966
	(0.114)	(0.24)***			(0.125)**	(0.274)***
log(5-year CDS Contract)			-.028	0.172	-.106	0.094
			(0.083)	(0.199)	(0.097)	(0.168)
Bank Fixed Effects	NO	YES	NO	YES	NO	YES
Observations	162	162	158	158	144	144
R^2	0.675	0.764	0.675	0.731	0.679	0.766

Table IV: Overnight Rate Regressions

The sample is from Jan 2, 2007 to April 20, 2009. The dependent variable *spread* is the difference between the transaction rate and the Bank of Canada target rate. $DAug\_9\_10$, $DAug13\_14$, $DAug15 - Dec11$, $DDec12 - Dec11$ are indicators variables equal to 1, respectively, for August 9 and 10, 2007, August 13-15, 2007, August 15-December 11, 2007, and December 12-December 31, 2007. $Dweek\_pre1$ is an indicator variable equal to 1 for the week prior to August 9, 2007. $DFri12$, $DMon15$, $DTue16$ are indicator variables equal to 1, respectively, for September 12, 2008, September 15, 2008, and September 16, 2008. $DpostAIG$ is an indicator variable equal to 1 starting September 18, 2008. TA is total assets. Robust standard errors in parentheses. *,**,*** denotes significance at 10, 5, 1% level, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	borrower				lender			
VARIABLES	spread		log(loan)		spread		log(loan)	
$DAug9\_10$	0.0677**	0.0689**	0.0452	-0.0711	0.0527***	0.0548***	-0.0740	-0.145
	(0.0301)	(0.0305)	(0.226)	(0.211)	(0.0114)	(0.0111)	(0.291)	(0.279)
$DAug13\_14$	0.0393***	0.0361***	0.508**	0.504**	0.0338***	0.0338***	0.237	0.337
	(0.00695)	(0.00759)	(0.230)	(0.203)	(0.00664)	(0.00585)	(0.206)	(0.218)
$DAug15 - Dec11$	0.0370***	0.0365***	0.218**	0.189*	0.0307***	0.0311***	0.164	0.177*
	(0.00799)	(0.00832)	(0.0927)	(0.0915)	(0.00902)	(0.00875)	(0.0962)	(0.0877)
$DDec12 - Dec31$	0.00241	0.00177	0.161	0.144	-0.00310	-0.00320	0.133	0.187
	(0.00468)	(0.00476)	(0.128)	(0.116)	(0.0133)	(0.0135)	(0.137)	(0.121)
Dweek_pre1	-0.0194***	-0.0157***	-0.511**	-0.620***	-0.00635	-0.0129	-0.398**	-0.402*
	(0.00306)	(0.00341)	(0.175)	(0.163)	(0.0109)	(0.00937)	(0.175)	(0.200)
DFri12	-0.0323*	-0.0296*	-0.609	-0.450	-0.0228	-0.0203	0.452	0.248
	(0.0156)	(0.0157)	(0.392)	(0.297)	(0.0218)	(0.0191)	(0.256)	(0.272)
DMon15	-0.00908	-0.0125	0.656**	0.598***	-0.00713	-0.0114	0.396	0.445*
	(0.00731)	(0.00998)	(0.262)	(0.127)	(0.00770)	(0.00659)	(0.288)	(0.238)
DTue16	-0.0325***	-0.0327***	-0.278	-0.123	-0.0583**	-0.0593**	-0.354	-0.121
	(0.00606)	(0.00651)	(0.324)	(0.282)	(0.0196)	(0.0198)	(0.222)	(0.235)
DpostAIG	-0.0454***	-0.0439***	-0.0459	-0.0774	-0.0421***	-0.0445***	0.00839	0.0276
	(0.00555)	(0.00517)	(0.0704)	(0.0647)	(0.00992)	(0.00940)	(0.119)	(0.118)
log(Overnight Loan Amount/TA)	-0.000226	0.00333			0.00847**	0.00377		
	(0.00266)	(0.00330)			(0.00386)	(0.00323)		
Constant	0.0136	0.0435	19.30***	19.20***	0.0606**	0.0116	19.27***	19.11***
	(0.0172)	(0.0258)	(0.167)	(0.0161)	(0.0200)	(0.0248)	(0.297)	(0.0275)
Bank fixed effects	NO	YES	NO	YES	NO	YES	NO	YES
Observations	4673	4673	4673	4673	3923	3923	3923	3923
R^2	0.158	0.197	0.011	0.351	0.119	0.185	0.004	0.506

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

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A Appendix

A.1 Insured Mortgage Purchase Program

Following the collapse of the Lehman Brothers the Canadian government started a program in which it offered to buy back insured residential mortgages, called the Insured Mortgage Purchase Program (IMPP). 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.[27] 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. 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.

The CMHC held reverse auctions on the government's 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.

Figure 20 offers a picture of the development in the IMPP auctions. In the turbulence period following the Lehman collapse during which the government started this program, Canadian banks were offering a high price in order to sell some of the residential mortgages. The supply (maximum amount to be purchased by the Canada Mortgage and Housing Corporation) was almost always exhausted until 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 discounts thus declines over time from 3.433% in November 2008 to 2.266% in January 2009 to 2.59% in February, 2.46% in March and 2.431% in April. While the reserve

[27] See Allen, Clark, and Houde (2011) for a detailed discussion of the Canadian mortgage market. Up until the financial crisis securitization was limited in the Canadian mortgage market. For example, about 17% of mortgages were securitized in 2007. This is far less than in the United States where more than half of all mortgages were securitized. The lack of securitization in Canada likely 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.

discount did not change too much, banks' interest in selling mortgages from their portfolio at that discount disappeared relatively quickly.

Figure 20: Results of auctions for mortgage repurchases