Efficiency and Bargaining Power in the Interbank Loan Market*

Jason Allen† James Chapman‡ Federico Echenique § Matthew Shum ¶

February 18, 2012

Abstract

We use data on interbank loans and a core equilibrium concept to examine the efficiency of the interbank market in Canada and the bargaining power of its participants. We show that while the market is fairly efficient, systemic inefficiency persists throughout our sample. The exact level of inefficiency matches distinct phases of both the Bank of Canada operating procedures as well as phases of the 2007-2008 financial crisis, where more intervention implies more inefficiency. We also find that bargaining power tilted sharply towards borrowers as the the financial crisis progressed. This supports a "weak" version of the Too-Big-To-Fail hypothesis, whereby market participants continued to lend to risky borrowers at favorable rates without the explicit involvement of governmental authorities.

*The views expressed here are those of the authors and should not be attributed to the Bank of Canada. We thank the Canadian Payments Association who collects the data. We thank Lana Embree, Rod Garratt, Thor Koeppl and James Thompson as well as seminar participants at the University of Western Ontario, the Bank of Canada workshop on financial institutions and markets, and the FRBNY for comments. Any errors are our own.

†Financial Stability Department, Bank of Canada; jallen@bankofcanada.ca

‡Financial Stability Department, Bank of Canada; jchapman@bankofcanda.ca

§Division of the Humanities and Social Sciences, California Institute of Technology; fede@caltech.edu

¶Division of the Humanities and Social Sciences, California Institute of Technology; mshum@caltech.edu

1 Introduction

Multilateral trading markets are endemic in modern economies with well-known examples such as the bargaining over tariffs and similar trade barriers among the WTO countries, monetary and fiscal policy-making among the European Union countries, setting copayment rates between hospital and insurance company networks, and even trades of players among professional sports teams, etc. Our paper presents a novel approach to empirically assess the *efficiency* of these markets, and the *bargaining power* of the different agents in the market. We use data from the Canadian market for overnight loans.

A serious impediment to the analysis of efficiency and bargaining power in real-world trading environments is the complexity of the markets themselves. The players are engaged in a complicated imperfect competition game in which some of their actions are restricted by trading conventions, but where the players may communicate and send signals in arbitrary ways. Even if we could write down a formal model that would capture the interactions among players, it would be difficult to characterize the equilibrium of such a game—a prerequisite to any analysis of bargaining and efficiency. Assuming that the obstacle of computing equilibria could be overcome, the outcome of such a game greatly depends on the assumed extensive-form. For example, outcomes can vary according to the sequencing of the offers (who is allowed to make an offer to whom and when), as well as the nature of information asymmetries among the players. For these reasons, a complete "structural" analysis of such imperfectly competitive bargaining environments seems out of the question. Finally, we focus in part on the market for loans during the financial crisis of 2008: it is hard to write down a model for the functioning of this market that would remain valid during this turmoil.

In this paper we take a different approach. Instead of modeling the explicit multilateral trading game amongst market participants, we impose an equilibrium assumption on the final outcome of the market. Our approach is methodologically closer to general equilibrium theory than to game theory: We use the classical equilibrium concept of the *core*. The core simply imposes a type of ex-post no-arbitrage condition on observed outcomes; it requires that the outcome be immune to defection by any subset of the participating players. Many alternative equilibrium concepts would imply outcomes in the core, but the advantage for our purposes is that the core is "model free," in the sense that it does not require any assumptions on the extensive-form of the game being played. The core might seen too weak a theory, but as we shall see, it allows us to draw some sharp conclusions.

We introduce a measure of bargaining power, using the idea of the core. For outcomes which are in the core, we define a simple measure of how much the observed outcomes favor particular market participants. We use this measure as an indicator of bargaining power and analyze its relationship to characteristics of the market and its participants. Thus, in our paper *efficiency* means the degree to which the absence of arbitrage conditions imposed by the core are satisfied, and *bargaining power* results from the position of the outcomes in the core. If the outcome is relatively more favorable to some agents, we shall say that these agents have exerted greater bargaining power.

We study the Large Value Transfer System (LVTS) in Canada, which is the system the Bank of Canada uses to implement monetary policy. Throughout the day LVTS participants send each other payments and at the end of the day must settle their positions to zero. If there are any remaining short or long positions after negotiating amongst themselves these must be settled with the Bank of Canada at unfavorable rates. Participants are therefore encouraged to trade with each other overnight. This market is ideal for various reasons: first, the market operates on a daily basis among seasoned players, so that inexperience or naïvete of the players should not lead to any inefficiencies. Second, there is a large amount of detailed data available on the amount and prices of transactions in this market. Finally, the LVTS is a "corridor" system, meaning that interest rates in the market are, for the most part, bounded above and below, respectively, by the current rates for borrowing from and depositing at the Bank of Canada. This makes it easy to specify the outside options for each market participant, which is a crucial component in defining the core of the game; at the same time, the corridor leads to a simple and intuitive measure of bargaining power between the borrowers and lenders in the market. In contrast, in overnight markets without such an explicit corridor, both the outside options and bargaining power are not as convenient to define.[1]

Several researchers have explicitly modeled the decision of market participants in environments similar to LVTS. For example, Ho and Saunders (1985), Afonso and Lagos (2011), Duffie and

[1]Many central banks use a corridor system – e.g. the ECB. However, the Federal Reserve does not. In response to the financial crisis, however, the Federal Reserve started paying interest on reserves, and therefore the U.S. interbank market today looks like a corridor system.

Gârleanu (2005), and Duffie, Gârleanu, and Pedersen (2007) examine the efficiency of the allocation of funds in the Federal funds market or over-the-counter markets, more generally.[2] The systems, markets and agents under study in this paper have previously been examined in Chapman, McAdams, and Paarsch (2007), Hendry and Kamhi (2009), Bech, Chapman, and Garratt (2010), and Allen, Hortaçsu, and Kastl (2011).

A market outcome is the result of the overnight loans between the banks at the end of the day: the outcome consists of the payoffs to the different banks. We (1) check if each outcome is in the core (this can be done by simply checking a system of inequalities), and (2) measure the degree to which outcomes are aligned with the interests of net borrowers or lenders in the system. We proceed to outline our results.

In the pre-crisis period, 2004-2007, the system largely complies with the core: it is efficient and there are few deviations from the absence of arbitrage. The bargaining power measure generally hovers around 0.5, meaning that borrowers and lenders are equally favored. When a borrower represents a riskier prospect than average, the bargaining power favors the lender, meaning that a lender can command higher interest rates if it lends to a riskier bank (or to a given bank in riskier circumstances).

With the onset of the crisis in 2008 we see some interesting changes. There is generally an increase in the number of violations of the core, so that the market becomes less efficient (in absolute terms, though, the inefficiencies are never very large). The bargaining power shifts to favor the borrowers; indeed, increased levels of risk are associated with changes in bargaining power *to favor borrowers*. That is, during the crisis period, when a net borrowing bank sees an increase in standard measures of counterparty risk (including the Merton (1974) "distance to default" measure, credit default swap (CDS) prices, and exposure to wholesale funding), it receives better terms in the interbank loans market. All these results contrast sharply with our findings for the "normal" period, 2004-2007.

The needs for funds during the crisis should, as one might expect, have favored the lenders. Instead, we see borrowers obtaining better terms, and (surprisingly) a positive correlation between borrowers' bargaining power and measures suggesting increasing default risk in the market.[3]

[2] An interested reader can find a book length treatment of the economics of OTC markets in Duffie (2012).

[3] Acharya, Gromb, and Yorulmazer (2010) construct a model in which "strong" banks exercise market power over "weak" banks which do not have other non-central bank outside options. Our findings seem to go counter to their results. Qualitatively, at least, our results are in line with Goodfriend and King (1988)

During the financial crisis the Bank of Canada increased its injections of cash to the LVTS. We do not find a relation between the injections and bargaining power, but they are positively correlated with violations of the core. The additional cash seems to have cause some situations where arbitrage opportunities were left unexploited. In turn, we find that more core violations are associated with higher bargaining power for the borrowers.

We believe that our findings may reflect an attempt by the system to shore up troubled banks: A "too big to fail" theory. In the words of then Bank of Canada Governor David Dodge, "We have a collective interest in the whole thing not going into a shambles." Our evidence is consistent with lenders being more lenient with borrowers, and in particular with the borrowers who were subject to higher levels of risk (be it at the level of the individual bank, or the system). It is also possible that the additional core violations during the crisis reflect banks being less concerned with exploiting arbitrage opportunities and more with keeping the system whole.

There is a particular reason why Canadian banks might be more concerned about the failure of other banks. The entry into the Canadian system is regulated. The result is an oligopolistic market where banks can exploit monopoly rent. The failure of one bank might have opened the door for the entry of new players into the market, something that the existing banks would not be favorable to. It is therefore plausible that the banks who were relatively better off could have offered better terms to the most troubled banks during the crisis. This interpretation is in the long tradition of the theory of regulation presented in Becker (1983) and Becker (1985).

Another reason is that mark-to-market accounting and bank interconnectedness means that some banks were concerned with their positions vis-á-vis the riskier banks (e.g. Bond and Leitner (2010)). The short-term cost of lending to a risky interconnected bank at a discount might be far less than the cost of having to mark down assets linked to a failed institution.

Overall, our findings are consistent with a "weak" version of the too-big-to-fail (TBTF) hypothesis, whereby banks within the Canadian overnight market continued to lend to risky counterparties despite the increasing risk in the market. However, such actions were not directly supported or guaranteed by regulators, as would be the case under the government-sponsored TBTF hypothesis; indeed, unlike in the U.S., no bail-outs or other forms of support were ever mentioned or undertaken in the Canadian financial sector. Rather, the observed effects appear to be a spontaneous reaction among the players in the market.

Of course, the TBTF hypothesis has been widely discussed and circulated in both the academic (O'Hara and Shaw (1990), Rochet and Tirole (1996), Flannery (2010)) and nonacademic financial press (Sorkin (2009), Krugman (2010)). As far as we are aware, this paper presents some of the first quantitative evidence of such a hypothesis.

The remainder of the article is organized as follows. Section 2 presents the data. Section 3 discusses the methodology, both conceptually and how we implement it using the Canadian overnight interbank lending market. Section 4 presents the results and section 6 concludes.

2 The Canadian Large Value Transfer System (LVTS)

The primary data for our analysis comes from daily bank transactions observed in Canada's Large Value Transfer System (LVTS). LVTS is Canada's payment and settlement system and it is operated by the Canadian Payment Association. Similar to CHAPS in the U.K. LVTS is a tiered system, unlike Fedwire in the U.S. That is, there are a small number of direct participants and a larger number of indirect participants.[4] There are currently 15 direct participants in LVTS. These are the Big 6 Canadian banks (Banque Nationale, Bank of Montreal, Bank of Nova Scotia, Canadian Imperial Bank of Commerce, Royal Bank of Canada, Toronto-Dominion Bank), HSBC, ING Canada, Laurentian Bank, State Street Bank, Bank of America, BNP Paribas, Alberta Treasury Branches, Caisse Desjardins, and a credit union consortium (Central 1 Credit Union). State Street joined LVTS in October 2004 and ING joined in October 2010.

Throughout the day payments are sent back-and-forth between direct participants. Like real-time gross settlement systems (RTGS), finality of payment sent through LVTS is in real-time; however, settlement in LVTS occurs at the end of the day. Relative to a RTGS system, an LVTS system has higher costs given default, but also substantial cost savings since banks do not need to post as much collateral. This is because most transactions in Canada are sent via a *survivors pay*, or partially collateralized, tranche. The cost of a partially collateralized system is an increase in counterparty risk. Participants manage counterparty risk by setting bilateral credit limits at the beginning of

[4]Indirect participants are outside LVTS and are the clients of the direct participants.

each day and also manage these limits throughout the day. Allen, Hortaçsu, and Kastl (2011) find, however, that even during the financial crisis direct participants did not lower their credit limits. They take this as evidence that there was no increase in counterparty risk in the payments system during the crisis.

2.1 Data Description

We are interested in studying the price and quantity of interbank overnight loans. Our period of analysis is April 1, 2004 to April 17, 2009. Unfortunately, as flows in LVTS are not classified as either a payment or a loan, we have to pick out those transactions which we think are loans from the potentially thousands of transactions. For this we use the Furfine algorithm (Furfine (1999)). This approach has been recently used by Acharya and Merrouche (2009), Afonso, Kovner, and Schoar (2011), and Allen, Hortaçsu, and Kastl (2011) to study liquidity hoarding and counterparty risk during the financial crisis. The idea is to focus on transactions sent, for example, from bank A to B towards the end of the day (for robustness we study two different windows: 4-6:30pm, and 5-6:30pm; but we only report results for the latter) and returned from B to A the following day before noon for the same amount plus a mark-up equal to a rate near the Bank of Canada's target rate. We are relatively loose with the definition of 'near', allowing financial institutions to charge rates plus or minus 50 basis points from target. This approach allows us to identify both the quantity borrowed/lent and at what price.[5]

Figure 1 plots both the total loan amounts and average loan size for transactions in LVTS after 5pm between April 2004 and April 2009. On the average day approximately 1.63 billion is transacted, about 184 million per financial institution. By construction the smallest loan is 50 million; the largest loan is 1.7 billion. Aside from the large spike in transactions in January 2007, the key noticeable pattern is the increase in loan amounts in the summer and fall of 2007. The sum of daily transactions in this period were consistently above $3 billion. This coincides with the Asset-Backed Commercial

[5]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 when using the algorithm early in the day, or for small transactions. The situation with LVTS is less problematic than with 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. Therefore using the Furfine algorithm on LVTS transactions is less likely to lead to misclassification error. In addition, we only examine larger transactions late in the day, making misclassification even less likely.

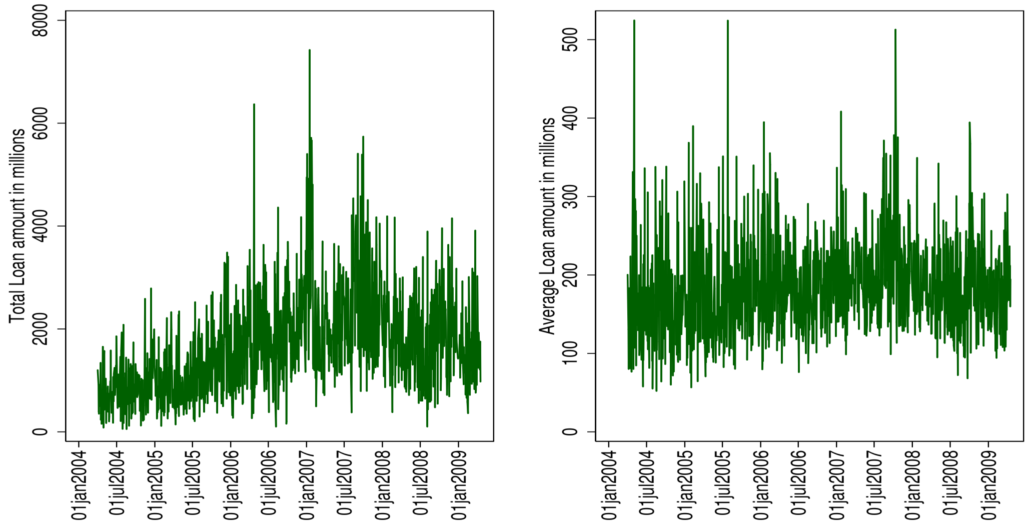


Figure 1: Loan Quantities in LVTS

Paper (ABCP) crisis in Canada.[6] At the time the market for non-bank issued ABCP froze and banks had to take back bank-issued ABCP on their balance sheet. By July 2007, the ABCP market was one-third of the total money market and when maturities came due and were not renewed this created substantial stress on other sources of liquidity demand. Irrespective of the freezing of the ABCP market, however, direct participants in LVTS continued lending to each other. The question is at what price did this lending occur.

Figure 2 plots the average spread to the target rate and its standard deviation for transactions sent after 5pm between April 2004 and April 21, 2009. Prior to the summer of 2007, i.e. normal times, the average spread to target is approximately 1 basis point. During the summer of 2007, however, financial institutions did increase the price of an overnight uncollateralized loan. Between August 9th, 2007 and October 11th, 2007 the average spread to target was about 4.7 basis points.[7] Somewhat surprisingly the spread to target post-October 2007 is 0, and -0.6 basis points in the six weeks following the collapse of Lehman Brothers. (Allen, Hortaçsu, and Kastl (2011) find that LVTS

[6] ABCP is a package of debt obligations typically enhanced with a liquidity provision from a bank. In Canada the bank providing the liquidity only has to pay out under catastrophic circumstances and was not even triggered during the financial crisis. In addition, the regulator did not require banks to hold capital against the provision. Under these rules the market approximately doubled between 2000 and 2007 to $120 billion.

[7] The start of the ABCP crisis is recognized to be August 9th. The Bank of Canada held its first liquidity auction on October 12th, 2007.

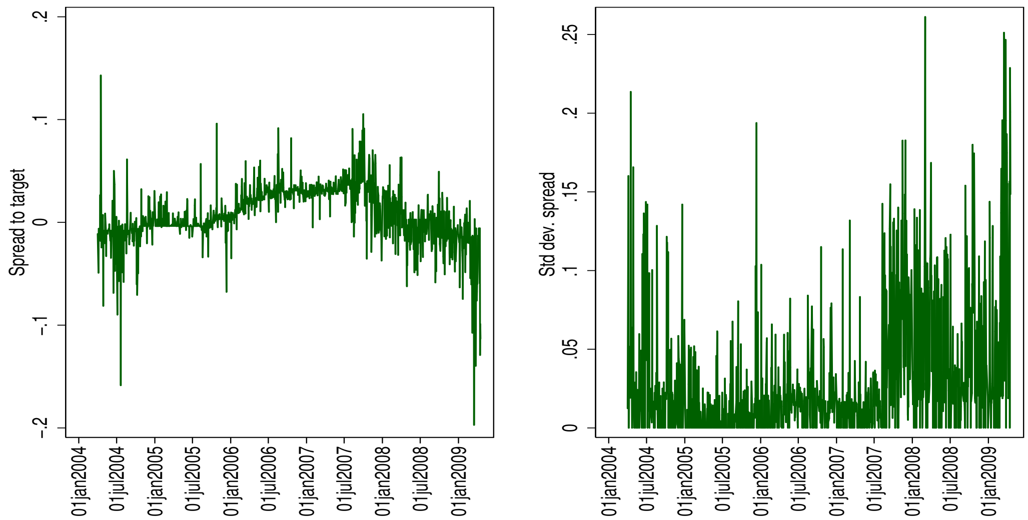


Figure 2: Loan Prices in LVTS

participants demand for term liquidity was substantial only in this period.)

2.2 Monetary policy and Liquidity policy

Monetary policy has been implemented in Canada since 1999 through LVTS (Reid (2007)). At the end of the day any short or long positions in LVTS must be settled, either with the Bank of Canada at a penalty rate, or through interbank trades. The interest rate corridor (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 their positions. The midpoint of the corridor is the interest rate that the Bank of Canada targets in its execution of monetary policy.

The symmetry of the interest rate corridor is meant to encourage trading at the target rate.Within a corridor system a central bank can increase the supply of liquidity without excessively lowering the target rate since it is bounded below by the deposit rate. Therefore a central bank operating a corridor can provide liquidity to LVTS participants (liquidity policy) without lowering nominal rates “too much” (monetary policy).

When the Bank of Canada first implemented LVTS, it targeted zero excess liquidity in the system. That is, participants had to flatten out their long and short positions completely and leave cash settlement balances at zero. However, subsequently the Bank of Canada intervened by supplying liquidity to the market.

With implementation there was substantial volatility in the overnight rate, therefore in 1999 the Bank started allowing positive "settlement balances" – what this meant was that at the end of the trading day, market participants were allowed to have short positions, up to a pre-specified upper limit. Effectively, then, these settlement balances were a means for the Bank of Canada to inject liquidity into this market. In November 1999, this limit was around $200 million, which was divided among the 15 LVTS participants at that time. In 2001 the Bank of Canada lowered the amount of settlement balances to $50 million, and the system remained stable until the end of 2005. Starting in March 2006, faced with strong downward pressure on the overnight rate, the Bank of Canada implemented a low liquidity policy by reducing the required balance back to zero, thereby not allowing participants to have a short position at the end of the day. This regime continued until the summer of 2007 when, on the eve of the financial crisis, the Bank of Canada joined other central banks in injecting liquidity into the banking system. Settlement balances were increased to $500 million. Figure 3 presents the settlement balances in LVTS at the end of each day between April 2004 and April 2009, which is our sample period.

Since we expect these shifts in liquidity policy would natually affect efficiency in the LVTS, our subsequent empirical analysis focuses on how efficiency and bargaining power changed across the three periods just discussed: First, April 1, 2004 to February 28, 2006, a period of stability in the Canadian interbank market. Second, March 1, 2006 to February 14, 2007, a period of no liquidity injections by the central bank. Third, the financial crisis: August 9, 2007 to April 20, 2009.

3 Methodology

We present a cooperative bargaining model of the market for overnight loans, and use it to study efficiency and bargaining power. We prefer this cooperative approach to a noncooperative (game-theoretic) model of bargaining which, as is well-known, very sensitive to the specific extensive-form which is assumed: it depends on the order in which offers are made, on the assumptions of player communication, and the information that they posses. Given that we study the volatile period

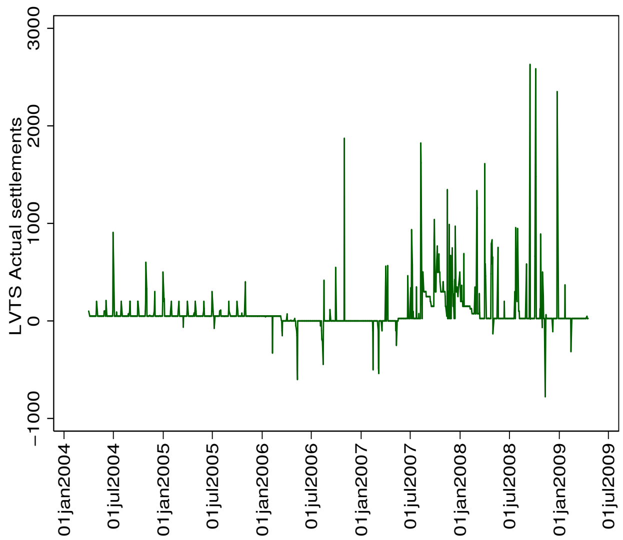


Figure 3: Settlement Balances in LVTS

surrounding the financial crisis of 2008, the assumption that a stable extensive form bargaining model is valid throughout this period would be quite strained. The crisis period is very unlikely to fit any version of known extensive-form bargaining models.

Instead of a game-theoretic model of bargaining, we apply the concept of the *core* to an interbank loan market. Essentially, the core is a basic "no-arbitrage" requirement; it may at first not seem restrictive enough, but we show that it can used to investigate the bargaining power of the financial institutions in the system. We can estimate a simple measure of the bargaining power of the institutions who had a need for funds, versus those that held a positive position in the market for interbank loans.

The cooperative approach assumes that agents can make binding commitments. In contrast, a non-cooperative model would need to construct explicit commitments through repeated-game effects. Repeated games are empirically complicated because they tend to predict too little. Our approach gives a set-valued prediction (the core of the market), so we shall not predict a unique allocation of trades; but, as we shall see, the prediction is still quite sharp and useful. At the same time, for allocations which are within the core, we can naturally construct a measure of bargaining power, by looking at whether the observed allocation favors lenders or borrowers in the market more.

The market has n agents, each with a net position (at the end of the day) of $\omega_i \in \mathbf{R}$. The Bank of Canada sets a *target rate* r. It offers each bank (collateralized) credit at the *bank rate* $b = r + 25$, and pays the *deposit rate* $d = r - 25 > 0$ on positive balances. These rates are fixed "take it or leave it" offers, and hence we use these as the benchmark from which to calculate bargaining power. In a sense, the Bank of Canada has the maximum bargaining power in this market, and we use its rates to calibrate the bargaining power of other agents.

We assume that $\sum_i \omega_i = 0$, so that positive and negative balances in the aggregate cancel out. It is easy to accommodate $\sum_i \omega_i$ of any magnitude in the analysis below, but since we calculate balances from transactions data, $\sum_i \omega_i = 0$ is always satisfied automatically in our data.

In this setup, agents have incentives to trade with each other at rates somewhere in the band. Define a characteristic function game by setting the stand alone value for a coalition $S \subseteq N = \{1, ..., n\}$ as:

$$\nu(S) = \begin{cases} b \sum_{i \in S} \omega_i & \text{if } \sum_{i \in S} \omega_i \leq 0 \\ d \sum_{i \in S} \omega_i & \text{if } \sum_{i \in S} \omega_i > 0 \end{cases} . \tag{1}$$

These inequalities present the idea that the best a coalition S can do is to use multilateral negotiations to pool their net positions, and then deposit (or borrow) the pooled sum $\sum_{i \in S} \omega_i$ at the Bank at the rate d (or b).

The payoff to a bank is simply a number, x_i, which is the net position of that bank, ω_i, multiplied by the bank's negotiated rates (y_i). The *core* of ν is the set of rates $(y_1, ..., y_n)$ such that: (i) $\sum_{i \in N} y_i \omega_i = 0$ (this is just an accounting identity that among all the banks net payments and outlays must cancel out); and, (ii) for all coalitions S, $\sum_{i \in S} y_i \omega_i \geq \nu(S)$. That is, any coalition must obtain a payoff exceeding its standalone value.

Intuitively, the core of this game is the set of rates which are "immune" to multilateral negotiations on the part of any coalition S (which would result in the coalition payoff $\nu(S)$ defined in equation 1). Clearly in LVTS full multilateral bargaining among all subsets of the participants may not be feasible, due perhaps to time constraints, informational issues, etc. The empirical question is how many observed outcomes are outside the core and whether there is any pattern to these violations.

Necessary Conditions: We first derive necessary conditions for a set of interest rates $\{y_1, ..., y\}$ to be in the core.

1. Individual rationality requires that $y_i\omega_i \geq \nu(\{i\})$. That is: $y_i \geq d$ if $\omega_i > 0$ and $y_i \leq b$ if $\omega_i < 0$.

2. Similarly, $\sum_{j\in N\backslash\{i\}} y_j\omega_j \geq \nu(N\backslash\{i\})$ implies the following: if $\omega_i > 0$ then $\sum_{j\in N\backslash\{i\}} \omega_j = \sum_{j\in N} \omega_j - \omega_i = 0 - \omega_i < 0$. Therefore $\nu(N\backslash\{i\}) = -b\omega_i$. Hence,

$$0 - y_i\omega_i = \sum_{j\in N\backslash\{i\}} y_j\omega_j \geq \nu(N\backslash\{i\}) = -b\omega_i,$$

which implies that $y_i \leq b$. Therefore

$$b \geq y_i \geq d. \tag{2}$$

A similar argument implies that $b \geq y_i \geq d$ when $\omega_i < 0$.

Now it is easy to check that the vectors of rates $(d, ..., d)$ and $(b, ..., b)$ are both in the core.[8] The first is the best allocation for the debtors and the second is the best allocation for the creditors. All the allocations $\lambda(b, \ldots, b) + (1 - \lambda)(d, \ldots, d)$ for $\lambda \in (0, 1)$ are in the core as well. *In fact, when the allocation lies on this line, or close to it, the we can interpret λ as a measure of bargaining power for the creditors.* When $\lambda \sim 1$ we obtain the core allocations that are best for the creditors; note that in this case the creditors are obtaining a deal which is similar to the "take it or leave it" offer of the Bank of Canada. It makes sense to interpret such an allocation as reflective of a high bargaining power on the side of creditors. Similarly, when $\lambda \sim 0$ we obtain the core allocations that are best for the borrowers. In this case, they are getting a similar deal to the one obtained by the Bank of Canada in its role as borrower.

Below, we will show that, for the trades observed in the LVTS, this λ measure is an adequate measure of bargaining power.

[8] Thus, the core is always non-empty. A necessary and sufficient condition for the non-emptiness of the core is that the game be balanced. A basic exposition of the theory is in Osborne and Rubinstein (1994).

3. For a general coalition S, we require that

$$\sum_{i \in S} y_i \omega_i \geq d \sum_{i \in S} \omega_i, \quad \text{for } \sum_{i \in S} \omega_i > 0$$
$$\sum_{i \in S} y_i \omega_i \geq b \sum_{i \in S} \omega_i, \quad \text{for } \sum_{i \in S} \omega_i < 0. \tag{3}$$

   In the second inequality above, because $b > 0$ (as is typically the case), the right-hand side of the inequality is negative. These two inequalities embody the intuition that a coalition which is collectively a net lender (resp. borrower) must obtain a higher payoff than lending to (resp. borrowing from) the Bank of Canada.

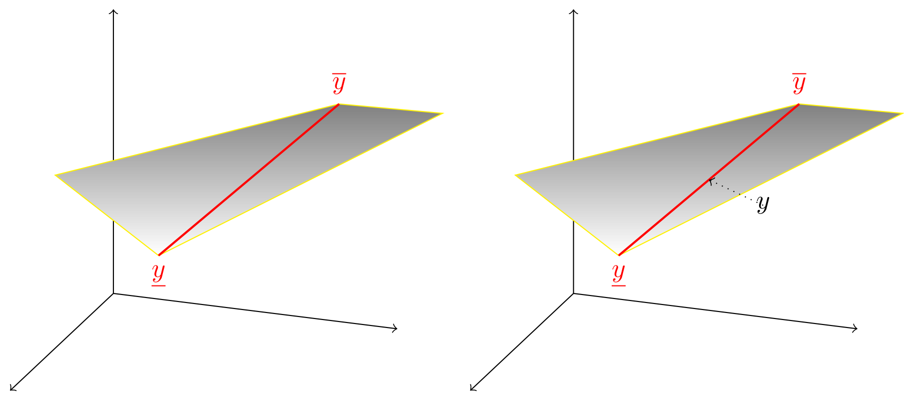
4. Finally, when $\sum_{i \in S} \omega_i = 0$ we need to impose that $\sum_{i \in S} y_i \omega_i \geq 0$. This just means that a coalition in which the members' balances cancel out should not be making a negative payoff.

Next, we provide several examples of the core of markets. In the first, the core is simply the line segment $\lambda(b, \ldots, b) + (1 - \lambda)(d, \ldots d,)$; in the second example the core is "wider." The third example is an actual trading day in the LVTS.

Example 1: Suppose that $|\omega_i| = 1$ for all i. Then if $\omega_i = 1$ and $\omega_j = -1$ we require $y_i - y_j \geq 0$, as $\nu(\{i, j\}) = 0$. Similarly, reasoning from $N \backslash \{i, j\}$ we get $y_i - y_j \leq 0$, so $y_i - y_j = 0$. Then the core is exactly the allocations $\lambda * (b, \ldots, b) + (1 - \lambda) * (d, \ldots d,)$ for $\lambda \in (0, 1)$.

Example 2: Suppose that there are three agents, and that the agents' net positions are $(\omega_1, \omega_2, \omega_3) = (-1, -1, 2)$. The core is the set of points (y_1, y_2, y_3) that satisfy the core constraints. First, no individual agent must be able to block a core allocation, hence all the points in the core are in $[d, r]^3$. Second, we obtain that $2y_3 - y_1 \geq d$ and $2y_3 - y_2 \geq d$ for coalitions $\{1, 3\}$ and $\{2, 3\}$, respectively. Finally, the coalition of the whole requires that $-y_1 - y_2 + 2y_3 = 0$. The latter condition, together with $(y_1, y_2, y_3) \in [d, r]^3$, imply the conditions for coalitions $\{1, 3\}$ and $\{2, 3\}$. Thus the inequalities $2y_3 - y_1 \geq d$ and $2y_3 - y_2 \geq d$ are redundant.

We illustrate the core in Figure 4. Allocations are points in $\Re^3$, as there are three agents in the example. The shaded region is the set of points that satisfy the core constraints. Geometrically, it consists of the points on the plane $-y_1 - y_2 + 2y_3 = 0$ that have all their coordinates larger than d



(a) The core in Example 2: $\underline{y} = (d, d, d)$ and $\overline{y} = (b, b, b)$.

(b) An allocation y projected onto the $\underline{y}$—$\overline{y}$ line.

Figure 4: An illustration of Example 2.

and smaller than b. The half-line $\lambda(b, b, b) + (1 - \lambda)(d, d, d)$ is indicated in red in the figure and is a proper subset of the core. There are then core allocations, such as $(b, d, (b + d)/2)$, which are not symmetric.

Figure 4(b) also illustrates how we calculate bargaining power. A point y is projected onto the line $\lambda(b, b, b) + (1 - \lambda)(d, d, d)$. The value of λ corresponding to the projection is a measure of the bargaining power of the creditors in the bargaining process that resulted in the allocation y.

Example 3: Finally, we consider one illustrative example of an actual allocation from the LVTS. On this particular day, there were four banks (labeled A,B,E,K) involved, and a total of three trades: Because we have normalized the target rate to zero, the values of (b, d) are $(0.25, -0.25)$.

Based on these trades, we can construct the bank-specific balances and prices (ω_i, y_i). For concreteness, consider bank E, which is both a lender (to B) and a borrower (from K). The value of ω for E is just its net position, which is $-0.29 = 1 - 1.29$. Correspondingly, its price y is the trade-weighted interest rate:

$$\omega_E = \frac{(1.0) * (-0.0077) + (-1.29) * (-0.0581)}{1 - 1.29} = -0.2319.$$

Similarly, Table 2 contains the positions and prices for all four banks.

Table 1: Sample trades

Borrower	Lender	Amount	Interest Rate(rel. to target rate)
B	E	1.00	-0.0077
E	K	1.29	-0.0581
K	A	1.00	0.0022

Table 2: Banks positions and prices

Bank	ω	y
A	1.00	0.0022
B	-1.00	-0.0077
E	-0.29	-0.2319
K	0.29	-0.2660

For these four banks, there are $2^4 - 1 = 15$ coalitions to check. The different possible coalitions are listed in Table 3 along with whether they satisfy the core inequalities defined in section 3 above.

First, note that, by construction, $\sum_{i=A,B,E,K} \omega_i = 0$ and $\sum_{i=A,B,E,K} y_i \omega_i = 0$. Second, we can see by examining the trades in Table 1 for the reasons that the three coalitions fail to satisfy the inequalities. In the data, bank K is a net lender of 0.29, at a price of -0.2660, which is lower than the rate of $d = -0.25$ it could have obtained by depositing the net amount of 0.29 at the Bank of Canada. Also, the coalition of $\{E, K\}$ has a net zero balance, but a payoff of $\sum_{i=E,K} \omega_i y_i = 0.29 * (0.2319 - 0.2660) < 0$, which is negative. They could have done better if K lent the amount of 0.29 to E at any rate, in which case their payoff would have been zero.

On the other hand, consider the coalition $\{A, B, E\}$, with a net position of $\sum_{i=A,B,E} \omega_i = -0.29$. The payoff for this coalition at the observed allocation is $\sum_{i=A,B,E} \omega_i y_i = 0.0771$ which exceeds $b * (-0.29) = -0.0725$. That is, on net, this coalition, despite having a negative net balance, obtains a positive net payoff, which is of course preferable to borrowing 0.29 from the Bank of Canada at the rate $b = 0.25$. This also implies that the banks who are borrowing from the coalition $\{A, B, E\}$ – here it is just bank K – must be paying too much for borrowing; this is indeed the case, as the singleton coalition $\{K\}$ violates the inequalities.

Table 3: Inequalities

Coalition	Satisfies inequalities?
$\{A, B, E, K\}$	Yes
$\{B, E, K\}$	Yes
$\{A\}$	Yes
$\{A, E, K\}$	Yes
$\{B\}$	Yes
$\{A, B, E\}$	Yes
$\{K\}$	No
$\{A, B, K\}$	Yes
$\{E\}$	Yes
$\{B, E\}$	Yes
$\{A, K\}$	Yes
$\{E, K\}$	No
$\{A, B\}$	Yes
$\{A, E\}$	Yes
$\{B, K\}$	Yes

3.1 In operation

Assuming that the Furfine algorithm correctly gives us the quantities and prices traded every day, we have (ω_{it}, y_{it}) for banks $i = 1, ..., n$ and days $t = 1, ..., T$. This corresponds to the outstanding balance at bank i at the end of day t and the interest rate that bank i either paid (if $\omega_{it} < 0$) or earned (if $\omega_{it} > 0$) by borrowing or lending in LVTS. Necessary conditions for the day t settlement interest rates $\{y_{it}\}_{i=1}^{n}$ to be in the core of the game are the inequalities (2) and (3) sketched above.

3.1.1 Are Trades in the Core?

Figure 5 plots the degree to which each day's allocation do not satisfy the core requirement as well as a one week moving average. It is a plot of the percent coalitions on each day that are violating our equilibrium concept. On most days the vast majority of overnight loans do not violate our core equilibrium restrictions and are therefore deemed efficient. However, on approximately 54 per cent of days there is at least one core restriction that is violated: at least one coalition could do better by trading among themselves. There are only 9.4 per cent of days where more than 10 per cent of trades violate the core inequality restrictions. The percent of inefficient coalitions, however, increases in the fall of 2007 and throughout most of 2008.

We have looked at whether a coalition could improve by trading on its own, and reported the

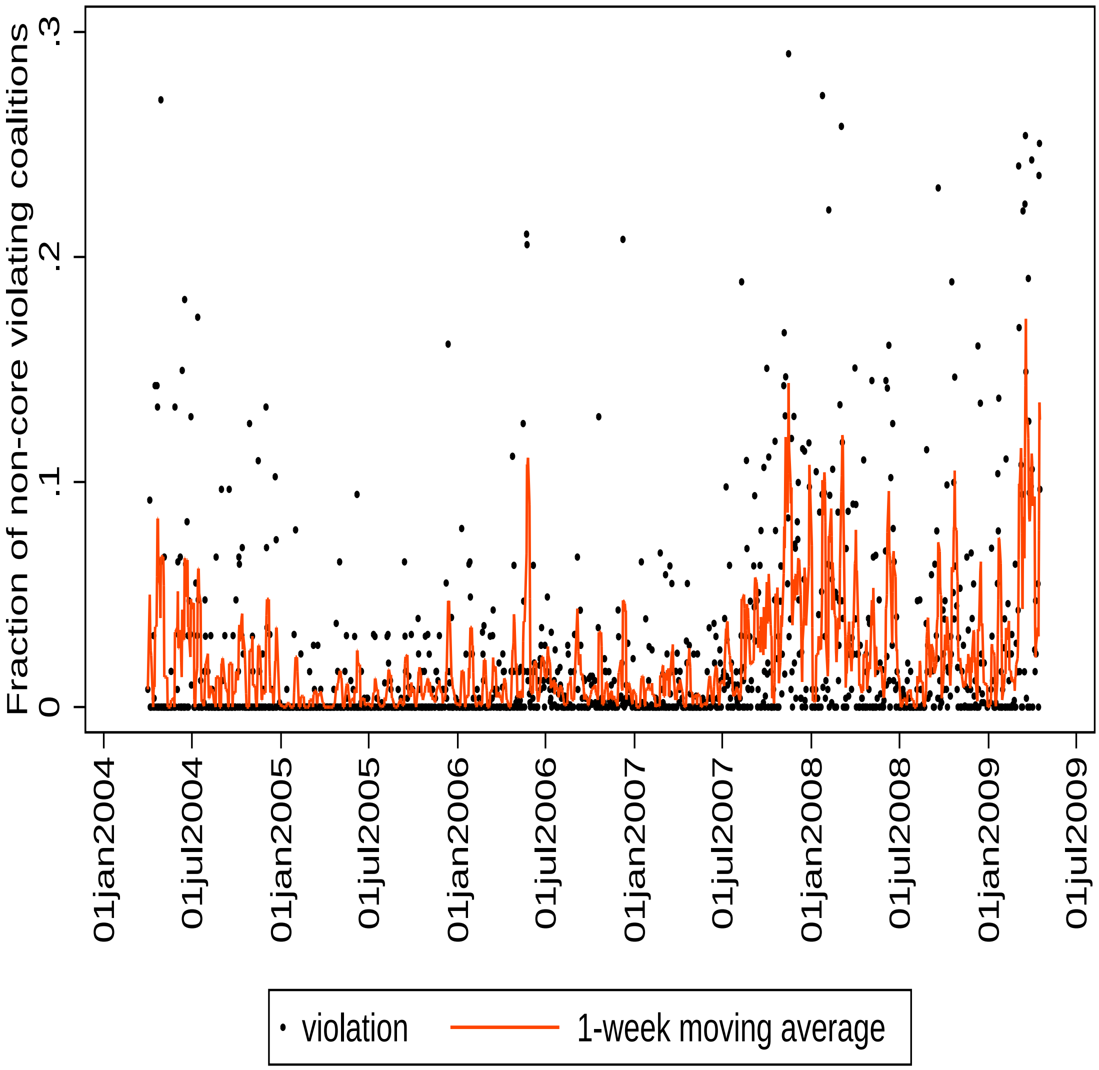


Figure 5: Percentage of Coalitions that are Efficient

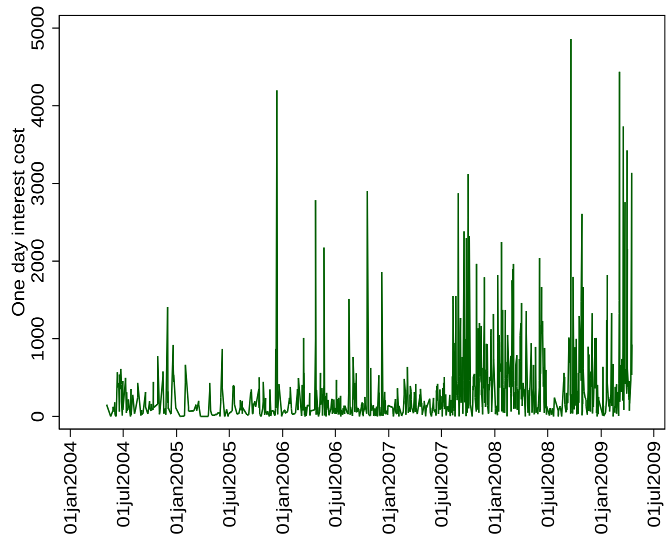


Figure 6: Costs of Overnight Loan Outside the Core

percentage of such coalitions (section 3.1.1). One may want to know by how much they could gain: if the gain is small it might not be worthwhile for lenders and borrowers to negotiate a better allocation. We can think of the gain as the distance of the allocation to the core, or as the *cost* of the bargaining outcome relative to full efficiency.

Next, we assess how large these inefficiencies are. We consider two approaches. The simplest approach is to measure the distance from the weighted average interest rate from a violating coalition and the deposit (or Bank) rate and multiply it by loan amount. We calculate this difference as follows. We take the relevant inequality in equations (3) and divide through by $\sum_{i \in S} \omega_i$. This gives a quantity weighted average interest rate:

$$r^* = \frac{\sum_{i \in S} y_i \omega_i}{\sum_{i \in S} \omega_i}. \tag{4}$$

Multiplying the difference between r^* and the relevant edge of the corridor (d or b) by the loan amount gives an annual interest cost. Since we are interested in overnight loans we divide this

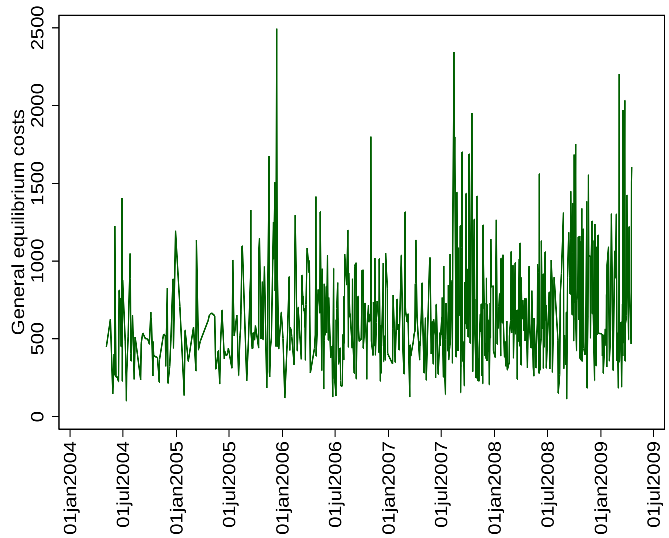


Figure 7: Costs of Overnight Loan Outside the Core – Optimal Solution

amount by 360 to give a daily cost. The overnight costs are presented in Figure 6.[9] The average cost of a violating allocation is \$375, while the largest cost was \$4859. Given that the average bargaining power is approximately 0.5 and there are 8 participants on average where there is a violation, this cost is split evenly across participants, where each participant on average loses \$47 for trading outside the *core*. This measure, however, does not provide us with the right distribution of who bears the costs of violating the core constraints because not everyone is trading outside the core on each day.

A more comprehensive approach to calculating cost is to measure the distance between the allocation x at any give date and the closest core allocation. To determine this distance we need to solve the problem of minimizing $||x - z||$, where z satisfies all the core constraints described in section 3.

The overnight costs are presented in Figure 7. The average cost of correcting a violating allocation is \$636 and the maximum is \$2495. These costs are slightly higher than the ones calculated before as

[9]Formally we can calculate the overnight cost of being outside the core as follows:

$$cost = sign(x)sign(i)\frac{|x|(|i| - 25)}{360},$$

where x is the loan amount of a violating coalition and i is the interest rate of a violating coalition.

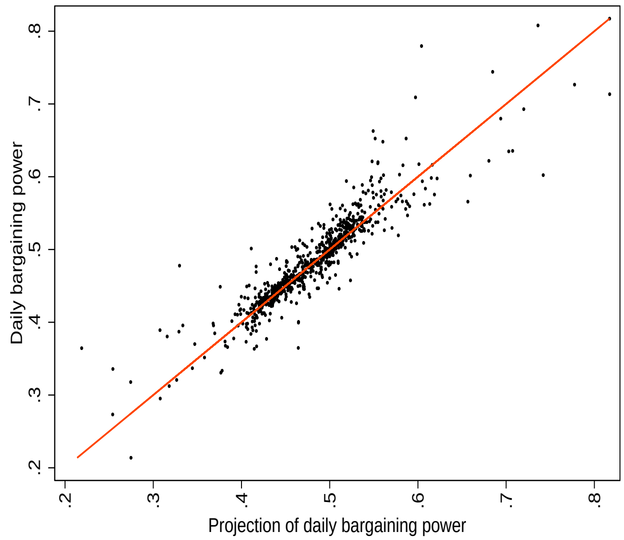


Figure 8: Goodness of Fit

"money-on-the-table" since only the violating coalition members pay though the reallocation, rather than all players. These costs are larger than found in Chapman, McAdams, and Paarsch (2007) who study the bidding behavior of these same participants in daily 4:30pm auctions for overnight cash. The authors find that while there are persistent violations of best-response functions in these auctions, the average cost of these violations is very small, only a couple of dollars.

3.1.2 Bargaining Power

We construct a measure of bargaining power for lenders relative to borrowers for each day, and then evaluate how it evolves over time. Specifically, we project each daily allocation onto the line $\lambda(b, \ldots, b) + (1 - \lambda)(d, \ldots d,)$. This gives us an estimate of λ for each day.

As Figure 8 illustrates, λ is an adequate measure of bargaining power for the LVTS trades. In that figure, we plot (on the y-axis) the actual interest rates received by the LVTS participants, versus (on the x-axis) the linear projection of this rate on the line segment betwen $(b, b, \ldots, b)$ and $(d, d, \ldots, d)$. That is, for the interest rate y_{it} received by bank i on date t, the projected rate is $\hat{y}_{it} = \hat{\lambda}_t * b + (1 - \hat{\lambda}_t) * d$ where $\hat{\lambda}_t$ denotes the bargaining power measure estimated for day t. (Note that the projected rate $\hat{y}_{it}$ is the same for all banks i trading on day t, because λ_t does not vary across banks.) Figure 8 shows that, for the vast majority of trades, the projected rate is quite close to the actual rate. This provides reassurance that λ_t serves as an adequate measure of bargaining power for this market.

Figure 9 plots the bargaining power of the lenders. When λ equals 1 the lender has all the bargaining power and when it is 0 the borrower has all the bargaining power. The bargaining power of lenders and borrowers is roughly equal between April 2004 and January 2006. Then it moves in favor of lenders until January 2008. Lenders bargaining power is the greatest in August to October of 2007 following the closure of two funds on August 9, 2007 by BNP Parisbas and the ECB and other central banks, including the Bank of Canada, stating they would inject overnight liquidity.[10] Starting in January 2008 the bargaining power of borrowers is greater than that of the lenders. We analyze the determinants of bargaining power in section 4.

4 Results

Given the prices and quantities from LVTS our approach allows us to solve for the percentage of transactions that are violations of *core* (denoted by av), as well as the bargaining power (λ) of lenders relative to borrowers on every given day. This section explores how av and $(1-\lambda)$, i.e., the borrowers bargaining power, are correlated with bank and LVTS characteristics. We also analyze how costs are related to violations and bargaining power.

4.1 Explanatory Variables

Table 4 presents summary statistics of our variables of interest and explanatory variables. Our analysis includes bank risk measures such as credit default swap (CDS) spreads, Merton (1974) distance-to-default (DD), balance sheet measures of risk such as liquidity over assets (L/A), and

[10] On August 9th, 2007 the Bank of Canada issued a statement that they were ready to provide liquidity. The ECB injected €95 billion overnight.

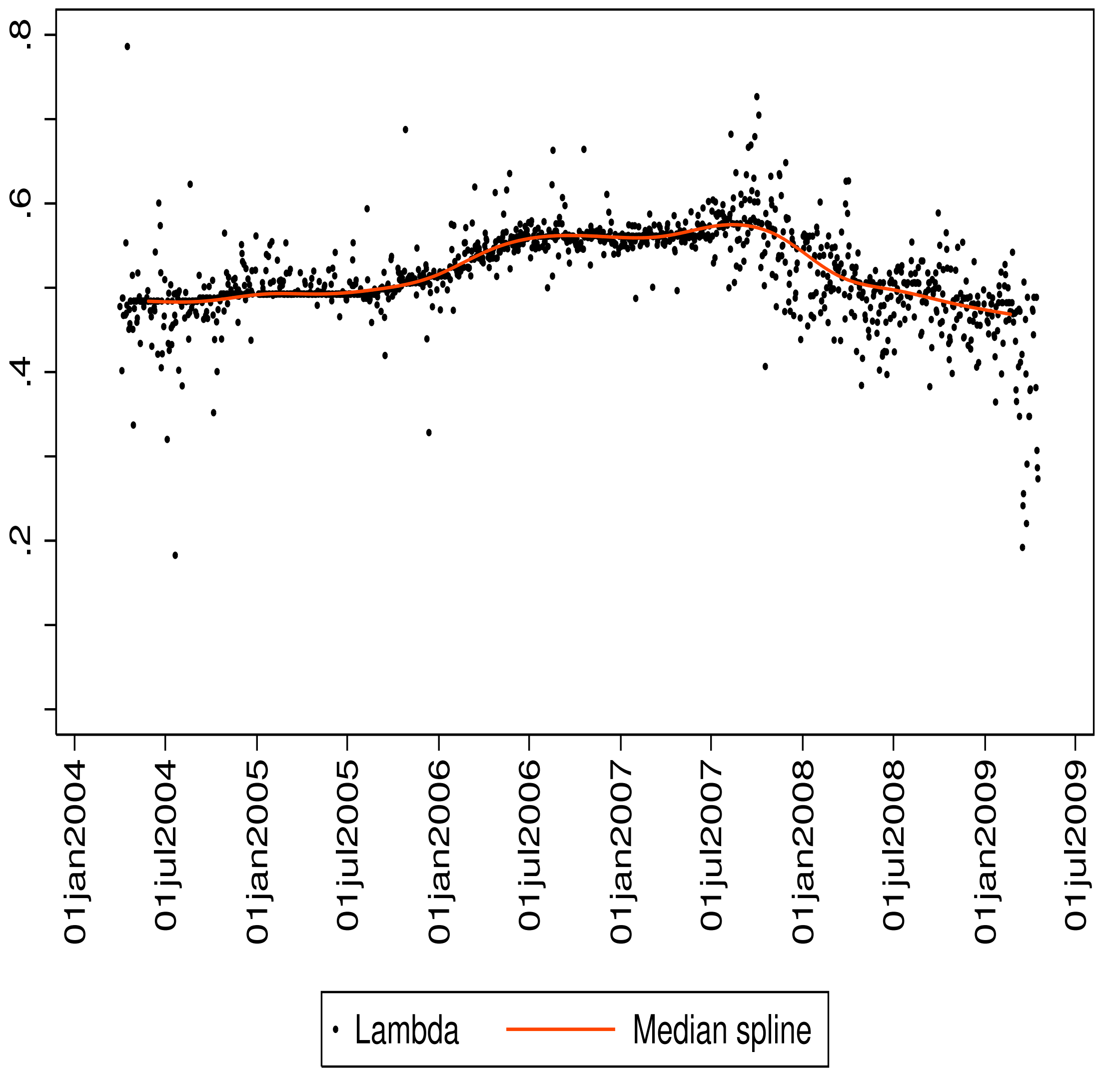


Figure 9: Bargaining Power

wholesale funding over assets (WF/A).[11] We also include an indicator variable for whether or not a financial institution accessed the Bank of Canada's term liquidity facility during the crisis (see Allen, Hortaçsu, and Kastl (2011)), and the Canadian government's Insured Mortgage Purchase Program (IMPP).[12]

Table 4: Summary Statistics

Variable	**Mean**	**Std. Dev.**	**N**
λ (bargaining power of lender)	0.522	0.054	9,519
av (percent of core violations)	4.7	8.5	9,519
av_2 (percent of core violations given $av \neq 0$)	7.6	9.7	5.907
Loan amount (in millions)	190.83	159.64	9,519
Loan over collateral	0.012	0.016	9.519
Hour sent	5:28pm	45minutes	9,519
Spread to target	0.0108	0.0553	9,519
Settlements	87.60	226.9	9,519
Number of borrowers	5.78	1.73	9,519
Number of lenders	4.29	1.50	9,519
Number of trades	8.97	3.14	9,519
Average coalitions per day	4,958	13,056	9,519
Costs (Money-on-the-table)	374.49	524.03	1,022
Costs (Optimal solution)	636.36	338.29	1,022
$CDOR_1 - OIS_1$	0.163	0.142	9,519
Distance to default	5.92	2.27	8,878
Liquid assets/total assets	0.186	0.138	9,516
wholesale funding/total assets	0.126	0.063	9,470
CDS	43.19	45.53	5,346

Notes: These are summary statistics for loans of 50 million dollar and above at or after 4:30pm.

Market trend or risk variables include the spread between the one month Canadian Dealer Offered Rate and one month Overnight Indexed Swap rate ($CDOR - OIS$), total number of lenders, borrowers and trades in LVTS on each day, and actual settlement balances in LVTS. The one month $CDOR$ is equivalent to one month $LIBOR$ in that it is indicative of what rate surveyed banks are willing to lend to other banks for one month. OIS is an overnight rate and is based on expectations of the Bank of Canada's overnight target rate. The spread is a default risk premium. We interpret increases in the $CDOR - OIS$ spread as increases in default risk of the banking industry generally

[11] Wholesale funding is defined as fixed term and demand deposits by deposit-taking institutions plus banker acceptances plus repos

[12] The IMPP is a government of Canada mortgage buy-back program aimed at adding liquidity to banks' balance sheets. On October 16, 2008 the government announced it would buy up to $25 billion of insured mortgages from Canadian banks. This represented about 8.5% of the banking sectors on-balance sheet insured mortgages. On November 12, 2008 this was raised to $75 billion, and subsequently raised to $125 billion on January 28, 2009.

and not related to any specific institution as DD, CDS, L/A, or WF/A measurements are.

As discussed in section 2.2, settlement balances are important since they are actively managed by the Bank of Canada. To manage minor frictions and offset transactions costs the Bank typically allows excess balances of $25 million. Figure 3 shows this to be the case. The figure also shows that balances can be negative (that is the Bank of Canada left the system short), which they were 15 times between March 2006 and February 2007. Figure 3 also shows that the Bank kept settlement balances substantially above $25 million for almost the entire time between the summer of 2007 and early 2009.

Another potentially important factor determining the fraction of efficient coalitions and bargaining power is pledgable collateral. Each day LVTS participants pledge collateral to the system in case of default. At the end of the day participants who have long or net zero positions withdraw their collateral, possibly using it in the overnight repo market. Participants that are short must borrow from the Bank of Canada at unfavorable rates and pledge collateral. Depending on the amount of collateral and the size of their short position a participant might be short collateral. If this is the case, a participant negotiating for an overnight loan is in a relatively weak bargaining position with the long participant. The long participant knows that the short participant does not have sufficient collateral to borrow from the Bank of Canada and can therefore charge a premium for lending unsecured.

4.2 Regression Results

4.2.1 Core Violating Regressions

We are interested in explaining a couple of phenomena. (i) What drives violations of the core? How big are these violations? (ii) What are the main determinants of bargaining power? We consider Poisson regressions for the percent of violations in a day and probit regressions for whether or not there was a violation on a given day. We present results for three sub–samples, where an observation is a day in one of the following periods: (i) April 1, 2004 to February 28, 2006, (ii) March 1, 2006 to February 14, 2007, and (iii) August 9, 2007 to April 20, 2009. The samples are chosen based on important demarcations of events. August 9th, 2007, marks the beginning of the financial crisis.

Table 5: Regressions on Violations of Core Inequality Restrictions

The dependent variable is in columns (1)-(3) is av, which is the percentage of violations of the core restrictions per day. The dependent variable in columns (4)-(6) is $I(av \neq 0)$. ^{a} $p < 0.01$, ^{b} $p < 0.05$, ^{c} $p < 0.1$

	(1)	(2)	(3)	(4)	(5)	(6)
	Percent of core violations			Violation (Y/N)		
VARIABLES	Apr 1 2004-Feb 28 2006	Mar 1 2006-Feb 14 2007	Aug 9 2007-Apr 20 2009	Apr 1 2004-Feb 28 2006	Mar 1 2006-Feb 14 2007	Aug 9 2007-Apr 20 2009
Lagged violations	0.0295^b	0.0868^a	0.0382^a			
	(0.0119)	(0.0120)	(0.00374)			
1 month CDOR minus OIS	-16.37^a	0.798	-0.584^a	-6.247^b	-2.170	0.281
	(1.826)	(2.227)	(0.182)	(2.477)	(3.301)	(0.485)
Number of lenders	0.454^a	0.190^a	0.315^a	0.357^a	0.373^a	0.344^a
	(0.0466)	(0.0589)	(0.0230)	(0.0807)	(0.0930)	(0.0732)
Number of borrowers	0.470^a	0.0534	0.200^a	0.337^a	0.180^b	0.164^b
	(0.0491)	(0.0556)	(0.0253)	(0.0806)	(0.0886)	(0.0746)
Number of trades	-0.267^a	0.0302	-0.128^a	0.0338	0.0264	0.0588
	(0.0400)	(0.0377)	(0.0169)	(0.0631)	(0.0669)	(0.0532)
Actual LVTS settlements	0.0773^c	0.0294	0.0393^a	0.170	0.00613	0.0547^b
(100 millions)	(0.0439)	(0.0312)	(0.00690)	(0.122)	(0.0721)	(0.0272)
Constant	-1.027^a	-1.565^a	-0.191	-3.015^a	-2.346^a	-2.497^a
	(0.174)	(0.373)	(0.139)	(0.313)	(0.526)	(0.379)
Observations	463	231	397	469	240	416

April 20, 2009 is the day before the Bank of Canada operated an interest rate policy at the effective lower bound, making analysis after this day more complicated. March 1, 2006 to February 14, 2007 is when the Bank of Canada committed to reducing settlement balances to zero and not fully neutralizing it's Sale and Repurchase Agreement operations in order to order reinforce the target rate (Reid (2007)). April 1, 2004 is the first day that our data exists.

The explanatory variables used to explain violations of the core restrictions (equations (2) and (3)) are at the market level. We include $CDOR - OIS$, as well as the number of borrowers, lenders, and trades. We also include actual cash settlements in the system. The results are presented in Table 5. The percentage of violations we observe in the data are decreasing in the $CDOR - OIS$ spread and increasing the number of participants. These findings are reasonable as the first suggests that multilateral bargaining becomes more focused as market risk increases and therefore it is more likely that the bargaining mechanism results in an efficient outcome. The opposite is true when there are a large number of participants. The more players involved in the game, the greater the percentage of violations, which suggests there is more likely to be an inefficient outcome when a larger group tries to negotiate than when there is a smaller group. Finally, we find that an increase in cash balances by the central bank is correlated with an increase in core violations. Liquidity injections, therefore, appear to increase the probability of inefficiency as well as the number of inefficient allocations. Consistent with Goodfriend and King (1988), the financial market is efficient at allocating credit without the central bank holding large cash balances.

4.2.2 Bargaining Regressions

For bargaining power we estimate a linear time-series regression with a long list of explanatory variables: we include a lagged dependent variable because bargaining power is relatively persistent, as well as the number of lenders, number of borrowers, total number of transactions, actual LVTS settlements in the system, one month $CDOR - OIS$ spread, cash allocations from the Bank of Canada liquidity facility (term PRA), IMPP allocations, distance-to-default, CDS spreads, liquidity to assets at month $t-1$, wholesale funding to assets at month $m-1$, and borrower fixed effects.

Table 6: Bargaining Regressions – Full Sample

The sample is from April 1, 2004 to April 20, 2009. The dependent variable is $100*(1-\lambda)$, i.e. the bargaining power of the borrowers. Robust standard errors are in parentheses. [a] $p < 0.01$, [b] $p < 0.05$, [c] $p < 0.1$.

VARIABLES	(1)	(2)	(3)	(4)
$(1\text{-}\lambda)_{t-1}$	0.411[a]	0.513[a]	0.378[a]	0.375[a]
	(0.0415)	(0.0430)	(0.0428)	(0.0431)
Percent of core violations	0.159[a]	0.193[a]	0.180[a]	0.188[a]
	(0.0614)	(0.0638)	(0.0635)	(0.0635)
Number of lenders	-0.0860	-0.107	0.115	0.0832
	(0.148)	(0.154)	(0.146)	(0.146)
Number of borrowers	-0.306	-0.202	-0.118	-0.384
	(0.485)	(0.510)	(0.577)	(0.580)
Number of trades	-0.202[b]	-0.200[b]	-0.233[b]	-0.203[b]
	(0.0927)	(0.0994)	(0.0989)	(0.0983)
Actual LVTS settlements (100 millions)	0.00549	-0.0254	-0.0183	-0.0195
	(0.0828)	(0.0875)	(0.0819)	(0.0838)
1 month CDOR minus OIS	-6.139[a]	-1.573	-5.573[a]	-5.320[a]
	(1.438)	(1.322)	(1.431)	(1.450)
I(Term PRA allocation at t-1>0)	0.897	2.126[a]	0.408	0.210
	(0.652)	(0.721)	(0.673)	(0.631)
I(IMPP allocation at t-1>0)	0.00662	1.376	-0.617	-0.979
	(2.200)	(2.139)	(2.046)	(2.079)
Distance to default	-0.846[a]			-0.406
	(0.119)			(0.258)
Liquidity/assets at m-1	1.425	-5.169[c]	0.878	2.490
	(3.172)	(3.070)	(4.720)	(4.854)
Loan amount/borrower's LVTS collateral	-31.69	-69.44[b]	1.438	5.159
	(26.63)	(27.68)	(32.50)	(33.37)
Wholesale funding/assets at m-1	-5.086	-31.45[a]	-8.525	-2.205
	(8.992)	(8.718)	(11.20)	(11.41)
CDS			0.0516[a]	0.0288[c]
			(0.00647)	(0.0172)
Constant	37.43[a]	30.89[a]	29.01[a]	31.48[a]
	(3.141)	(3.326)	(3.089)	(3.505)
Observations	1208	1208	862	862
R^2	0.498	0.464	0.589	0.603
Borrower FE	✓	✓	✓	✓

Table 7: Bargaining Regressions

The dependent variable is $100 * (1 - \lambda)$, i.e. the bargaining power of the borrowers. Robust standard errors are in parentheses. ^{a} $p < 0.01$, ^{b} $p < 0.05$, ^{c} $p < 0.1$.

VARIABLES	Apr 1 2004-Feb 28 2006	Apr 1 2004-Feb 28 2006	Apr 1 2004-Feb 28 2006	Mar 1 2006-Feb 14 2007	Mar 1 2006-Feb 14 2007	Mar 1 2006-Feb 14 2007	Aug 9 2007-Apr 20 2009	Aug 9 2007-Apr 20 2009	Aug 9 2007-Apr 20 2009
$(1\text{-}\lambda)_{t-1}$	0.116^b	0.0893	0.0901	-0.0690	-0.00182	-0.0717	0.282^a	0.338^a	0.282^a
	(0.0470)	(0.0606)	(0.0596)	(0.0889)	(0.0884)	(0.0896)	(0.0628)	(0.0592)	(0.0627)
Percent of core violations	0.0632	0.465	0.466	-0.201^c	-0.181	-0.203^c	0.242^a	0.207^a	0.242^a
	(0.170)	(0.370)	(0.373)	(0.112)	(0.112)	(0.111)	(0.0702)	(0.0711)	(0.0705)
Number of lenders	-0.354	-0.0680	-0.0665	0.0465	-0.0357	0.0534	0.250	0.343	0.253
	(0.269)	(0.288)	(0.291)	(0.149)	(0.141)	(0.149)	(0.268)	(0.278)	(0.267)
Number of borrowers	-0.515	-0.203	-0.188	0.435	0.416	0.399	-0.995	-0.551	-0.986
	(0.560)	(0.787)	(0.825)	(0.429)	(0.534)	(0.425)	(0.962)	(1.008)	(0.967)
Number of trades	-0.00713	-0.228	-0.232	-0.0706	-0.0174	-0.0607	-0.101	-0.229	-0.103
	(0.166)	(0.241)	(0.242)	(0.129)	(0.115)	(0.128)	(0.165)	(0.173)	(0.165)
Actual LVTS settlements (100 millions)	-0.108	-0.0118	-0.0295	0.132	0.106	0.134	-0.00878	-0.0348	-0.00867
	(0.186)	(0.300)	(0.340)	(0.0984)	(0.102)	(0.103)	(0.0938)	(0.100)	(0.0938)
1 month CDOR minus OIS	-15.73^b	-17.34	-16.88	-1.191	0.958	-1.481	-2.646^c	-4.228^a	-2.689^c
	(7.206)	(13.73)	(15.23)	(5.519)	(5.412)	(5.449)	(1.532)	(1.610)	(1.563)
I(Term PRA allocation at t-1>0)							-0.0664	-0.0133	-0.0747
							(0.646)	(0.700)	(0.653)
I(IMPP allocation at t-1>0)							-1.452	-0.812	-1.447
							(1.985)	(1.896)	(1.989)
Liquidity/assets at m-1	-1.621	-28.43	-28.75^c	-6.508	-15.61^b	-8.314	2.926	-4.930	2.746
	(4.920)	(17.23)	(16.59)	(5.674)	(7.236)	(6.304)	(10.76)	(10.95)	(10.84)
Distance to default	0.878		-0.171	2.011^a		1.951^a	-2.197^a		-2.155^a
	(0.546)		(1.292)	(0.474)		(0.471)	(0.272)		(0.448)
Wholesale funding/assets at m-1	-21.35	-67.07	-66.28	-32.21^a	-30.38^b	-35.38^a	58.69^a	15.41	58.09^a
	(14.83)	(48.16)	(51.32)	(12.37)	(13.20)	(13.22)	(22.02)	(20.53)	(21.87)
Loan amount/borrower's LVTS collateral	-33.55	61.21	62.32	-31.47	-30.00	-30.04	44.82	37.37	45.43
	(25.63)	(66.63)	(66.71)	(38.16)	(40.29)	(38.14)	(57.03)	(58.31)	(57.61)
CDS		-0.136	-0.126		-0.307	-0.170		0.0685^a	0.00176
		(0.612)	(0.649)		(0.217)	(0.200)		(0.00989)	(0.0154)
Constant	44.35^a	59.79^a	60.81^a	38.18^a	54.65^a	41.32^a	34.33^a	25.12^a	34.15^a
	(5.195)	(16.42)	(15.11)	(4.744)	(6.893)	(6.352)	(5.284)	(5.364)	(5.662)
Observations	463	117	117	231	231	231	397	397	397
R^2	0.134	0.324	0.324	0.215	0.152	0.218	0.596	0.572	0.596
Borrower FE	✓	✓	✓	✓	✓	✓	✓	✓	✓

We present two tables of results. We report the full sample results in Table 6 and sub-sample results in Table 5. Table 6 column (4) includes the full set of variables but because some of the risk variables are highly collinear in columns (1)-(3) we present slight deviations, dropping one or more of these risk factors. Overall, we find that the bargaining power of the borrower is persistent, increasing in the number of core violations, and decreasing in the number of trades. The negative coefficient on the $CDOR - OIS$ spread suggests that bargaining power is decreasing in market risk. There are negative correlations between distance-to-default and bargaining power and wholesale funding and bargaining power. At the bank-level, therefore, an increase in risk is correlated with less bargaining power. However, we find a positive correlation between CDS spreads and bargaining power, suggesting the opposite effect of the other risk factors - that an increase in risk is correlated with an increase in bargaining power.

Table 5 decomposes the full sample results into the same 3 sub-samples as in the Poisson and probit regressions presented above. Presenting the data in this manner illustrates a striking change in behavior in the interbank market during the financial crisis. In the "normal" periods 2004-2006 and 2006-2007, the coefficients attached to the risk measures suggest that riskier institutions enjoy less bargaining power. However, during the financial crisis period (post-2007), bargaining power becomes *negatively* correlated with distance-to-default and *positively* correlated with CDS spreads and wholesale funding exposure. Thus riskier institutions enjoyed more bargaining power during these troubled times.

What are possible explanations? One possibility is that mark-to-market accounting and bank interconnectedness means that some banks were concerned with their positions vis-á-vis the riskier banks (e.g. Bond and Leitner (2010)). The short-term cost of lending to a risky bank at a discount to an interconnected bank might be far less than the cost of having to mark down assets linked to a failed institution. Another reason is that market participants may simply want to prevent government intervention. The cost of government intervention might be deemed too high for many participants, given the future regulatory burden that would come with the failure of a Canadian financial institution would likely be high.

The possibility that financial institutions were lending to riskier institutions out of self-interest can be analyzed by looking at transition probabilities from being a lender one day and a borrower the next. Table 8 presents summary statistics of transition probabilities for both borrowers transitioning to lenders ($Pr(X' > 0|X < 0)$) and lenders transitioning to borrowers ($Pr(X' < 0|X > 0)$). The top panel presents transitions using the full set of data while panels 2-4 present information on sub-periods. The median probability in the first case is approximately 68% where the median probability in the latter case is approximately 45%. This indicates that the incidence that a particular institution is a "lender" or "borrower" is not persistent, and suggests that lenders may, in fact, be willing to support or subsidize troubled borrowers out of concern that they might find themselves in a similar situation in the future.[13]

The summary statistics from the sub-periods suggests there is not a great deal of change in persistence over time, except for the probability of transitioning from lender to borrower it smaller at the lower quantile in period 3. Overall the lack of any significant change in the transition probabilities suggests that bargaining power increased for borrowers in general, and not for any particular set of borrowers. A careful look at the bank-level transition probabilities, not presented here, does not reveal overwhelming evidence to suggest any particular borrower received preferential treatment.

Table 8: Transition Probabilities

	Minimum	1st Quartile	Median	Mean	3rd Quartile	Maximum
Full Sample						
$Pr(X' > 0\|X < 0)$	0.37	0.56	0.68	0.69	0.86	0.96
$Pr(X' < 0\|X > 0)$	0.00	0.20	0.45	0.40	0.60	0.77
Period 1: April 1, 2004 - Feb 28, 2006						
$Pr(X' > 0\|X < 0)$	0.33	0.50	0.70	0.69	0.87	1.0
$Pr(X' < 0\|X > 0)$	0.00	0.22	0.39	0.40	0.66	0.72
Period 2: March 1, 2006 - Feb 14, 2007						
$Pr(X' > 0\|X < 0)$	0.31	0.54	0.64	0.68	0.87	0.95
$Pr(X' < 0\|X > 0)$	0.00	0.17	0.45	0.40	0.63	0.82
Period 3: August 9, 2007 - April 20, 2009						
$Pr(X' > 0\|X < 0)$	0.28	0.50	0.63	0.66	0.87	1.0
$Pr(X' < 0\|X > 0)$	0.00	0.06	0.41	0.37	0.65	0.73

Notes: $Pr(X' > 0|X < 0)$ denotes the probability an FI is a lender today conditional on that FI being a borrower the last time they were in the overnight market. $Pr(X' < 0|X > 0)$ denotes the probability of an FI being a borrower today conditional on that FI being a lender the last time they were in the overnight market.

[13] Such reciprocal relationships among financial institutions has been documented elsewhere by Ashcraft and Duffie (2007) as well as in the popular press, cf, the importance placed on relationships among U.S. investment banks during the collapse of LTCM in 1998 and the more recent financial crisis.

5 Economic Significance of Results

Given the results from the regressions above, especially the evidence supporting a (weak) "too big to fail" story, we next quantify the size of these effects. First, consider a two-standard deviation decrease in a bank's distance-to-default, which implies an increase in this bank's riskiness as a borrower. If we use the estimated coefficient in column (6) of Table (1.951) – for the pre-crisis period – this leads to an 8.86% decrease in bargaining power. By construction, there is a linear relationship between the bargaining power measure λ and the interest rate y; specifically, a movement from $\lambda = 0$ to $\lambda = 1$ corresponds to the 50 basis point movement from the bank rate b to the deposit rate d. Hence, each percentage point decrease in bargaining power for the borrower corresponds to a *half basis point increase* in the implied interest rate. Therefore, the 8.86% decrease in bargaining power here corresponds to a 4.4 basis point increase in the interest rate faced by the borrowers.

In contrast, during the crisis period, we find that the same decrease in distance-to-default leads to a increase in bargaining power of 9.78% (using the point estimate 2.155) – this was the TBTF results that we highlighted earlier. This corresponds to a 4.9 basis point decrease in the interest rate faced by borrowers. Evaluated at the average overnight loan size of $190 million, this implies that lending banks reduced interest payments for risky borrowers during the crisis period by an amount of $259 (=(0.00049/360)*$190 mill). This is roughly equal to 2.4% of the average cost of an overnight loan (assuming an average overnight rate of 2%, which is the Bank of Canada target).

Similarly, calculations can be done with the other risk measures used in the bargaining regressions. Using the wholesale funding variable, we find that, during the crisis period, a two-standard deviation increase in this variable would lead to a 7.32% increase in bargaining power, corresponding to a 3.66% decrease in interest rate. This implies that, on average, lenders "cut the slack" for risky borrowers by an amount of $187.40 during the crisis.

To highlight the magnitudes of these effects, we perform counterfactual exercise in which we use the second-period (pre-crisis) regression coefficients, coupled with the observed loans in the third period, to predict what bargaining power *would have been* in the third period, in the absence of the TBTF results in the third period regressions. These counterfactual bargaining power measures are presented in Figure 10. The top line in this graph presents the counterfactual values of λ.

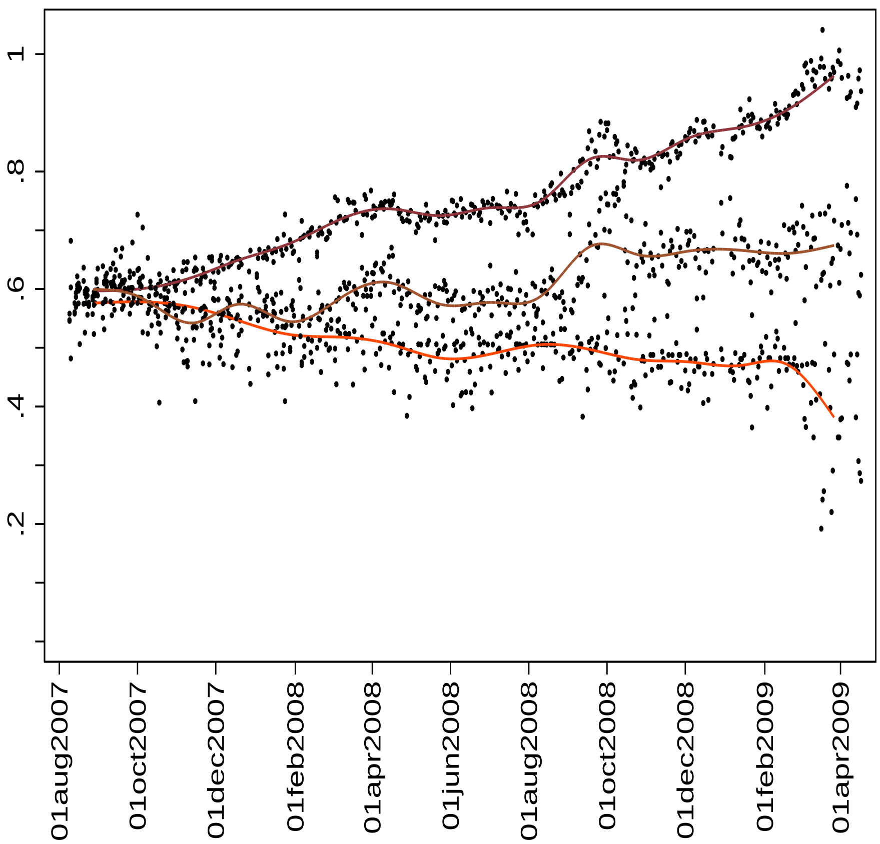


Figure 10: Actual versus counterfactual bargaining power for crisis-period loans

Top line: counterfactual bargaining weights (λ) using second-period regression coefficients; Middle line: counterfactual bargaining weights (λ) using first-period regression coefficients; Bottom line: actual bargaining weights (λ) using third-period regression coefficients.

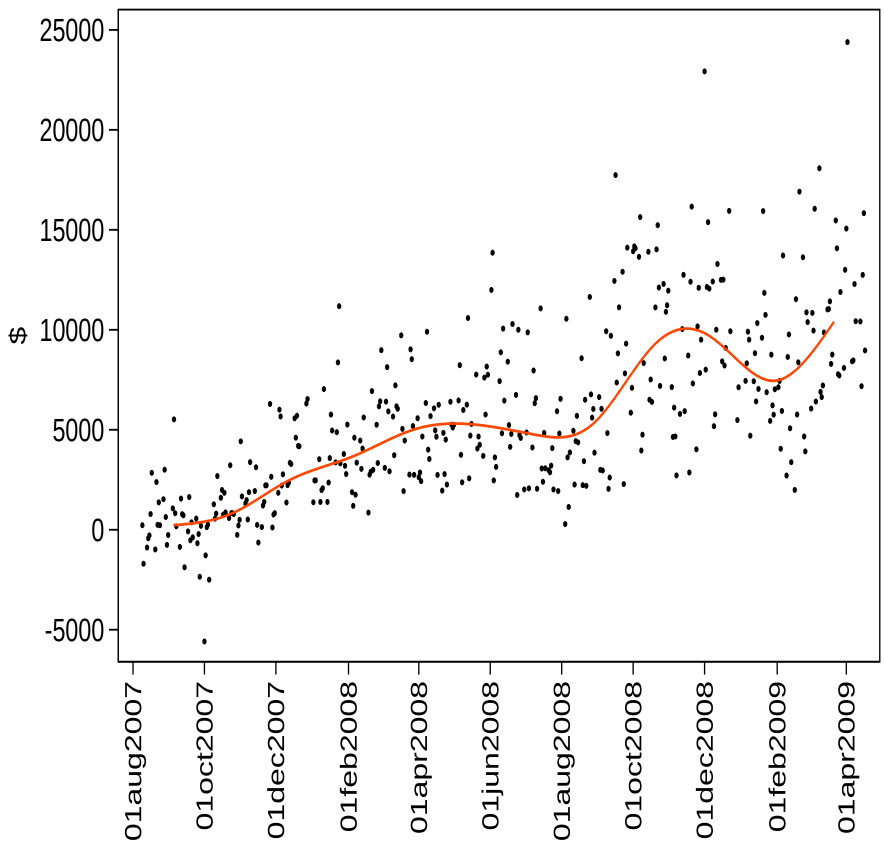


Figure 11: Costs of TBTF

This is a graph of the difference in the second-period counterfactual bargaining power and the actual bargaining power multiplied by the average loan size on each day and the one-day interest cost, i.e. 50bps/360.

Obviously, this line trends upward over time, reaching the upper bound of 1 near the end of the sample, indicating that, in the absence of the TBTF effects, bargaining power would have shifted almost entirely to lenders between August 2007 and February 2009.

For comparison, the actual bargaining weights for the crisis-period loans, computed using the third-period regression coefficients, are also presented in the graph. The divergence between the actual and counterfactual results is remarkable: the actual bargaining weights steadily become more favorable to the borrowers, as the crisis proceeds.

To put this in monetary terms, we plot, in Figure 11, the "costs" of the TBTF effects, in terms of the difference in interest payments which borrowers would have had to pay if their bargaining power followed the counterfactual path during the crisis, as compared to the actual path. Corresponding to the results in Figure 10, we find that these costs increase steadily over crisis period. A cost of $10,000 represents 90% the average cost of an overnight loan at a target rate of 2%. Measured this way, the effect of TBTF on bargaining are substantial.

6 Conclusion

In this paper we examine efficiency and bargaining power in the Canadian interbank loan market. This market, however, is complicated. The players are engaged in an imperfect competition game in which their actions are restricted by trading conventions making it difficult to characterize the equilibrium of such a game, which is a prerequisite to any analysis of bargaining and efficiency. Instead of modeling the multilateral trading environment in detail, we instead impose a very general and classical equilibrium concept: that of the *core*. This simply imposes a type of *ex-post* no-arbitrage condition on the observed outcomes.

We study efficiency and bargaining power of financial institutions in the Large Value Transfer System (LVTS) in Canada. Our results indicate that while the interbank market in Canada is fairly efficient, there is a systemic inefficiency that is persistent through our sample. Importantly, the efficiency of the system deteriorates with the liquidity interventions of the central bank. This result is in line with the views put forth by Goodfriend and King (1988) on the efficiency of the interbank market.

While we find that bargaining power is about equal between lenders and borrowers throughout the sample, during the financial crisis there was a shift in bargaining power *favoring borrowers*. Regressions confirm that as counterparty risk increased during the financial crisis, the riskier borrower banks were able to obtain better rates. There are a number of possible explanations, however, our findings are most consistent with a "weak" version of the too-big-to-fail (TBTF) hypothesis whereby banks within the Canadian overnight market continued to lend to risky counterparties despite the increasing risk in the market. The main hypothesis put forth is that banks are tightly interconnected, which we confirm using borrower-to-lender transition probabilities. A more speculative view is that financial institutions acted to conserve the existing market structure rather than risk the possibility of one institution defaulting and the survivor's facing more stringent regulation.

In ongoing work, we plan to explore the extent to which the repeated and dynamic interactions among the banks underly this result.

References

Acharya, V., D. Gromb, and T. Yorulmazer (2010). Imperfect competition in the inter-bank market for liquidity as a rationale for central banking. forthcoming, *American Economic Journal: Micro*.

Acharya, V. and O. Merrouche (2009). Precautionary hoarding of liquidity and inter-bank markets: Evidence from the sub-prime crisis.

Afonso, G., A. Kovner, and A. Schoar (2011). Stressed, not frozen: The federal funds market in the financial crisis. *Journal of Finance 66*, 1109–1139.

Afonso, G. and R. Lagos (2011). Trade dynamics in the market for federal funds. mimeo.

Allen, J., A. Hortaçsu, and J. Kastl (2011). Crisis management: Analyizing default risk and liquidity demand during financial stress. mimeo.

Ashcraft, A. and D. Duffie (2007). Systemic illiquidity in the federal funds market. *American Economic Review 97*, 221–225.

Bech, M., J. Chapman, and R. Garratt (2010). Which bank is the "central" bank? *Journal of Monetary Economics 57*(3), 352–363.

Becker, G. S. (1983). A theory of competition among pressure groups for political influence. *Quarterly Journal of Economics 98*, 371–400.

Becker, G. S. (1985). Public policies, pressure groups, and dead weight costs. *Journal of Public Economics 28*, 329–347.

Bond, P. and Y. Leitner (2010). Market run-ups, market freezes, and leverage. Federal Reserve Bank of Philadelphia Working Paper No. 10-36.

Chapman, J., D. McAdams, and H. Paarsch (2007). Bounding best-response violations in discriminatory auctions with private values. mimeo.

Duffie, D. (2012). *Dark Markets: Asset Pricing and Information Transmission in Over-the-Counter markets*. Forthcoming - Princeton University Press.

Duffie, D. and N. Gârleanu (2005). Over-the-counter markets. *Econometrica 73*, 1815–1844.

Duffie, D., N. Gârleanu, and L. Pedersen (2007). Valuation in over-the-counter markets. *Review of Economic Studies 20*, 1865–1900.

Flannery, M. (2010). What to do about TBTF? mimeo.

Furfine, C. (1999). The microstructure of the federal funds market. *Financial Markets, Institutions, and Instruments 8*, 24–44.

Goodfriend, M. and R. King (1988). Ifinancial dergulation, monetary policy, and central banking. *Federal Reserve Bank of Richmond Economic Review*, 3–22.

Hendry, S. and N. Kamhi (2009). Uncollateralized overnight lending in canada. *Applied Financial Economics*, 869–880.

Ho, T. and A. Saunders (1985). A micro model of the federal funds market. *Journal of Finance 40*, 2977–988.

Krugman, P. (2010). Financial crisis 101. New York Times Op-Ed.

Merton, R. (1974). On the pricing of corporate debt: The risk structure of interest rates. *Journal of Finance 2*, 449–470.

O'Hara, M. and W. Shaw (1990). Deposit insurance and wealth effects: The value of being "too big to fail". *Journal of Finance 45*, 1587–1600.

Osborne, M. and A. Rubinstein (1994). *A Course in Game Theory.* MIT Press.

Reid, C. (2007). The canadian overnight market: Recent evolution and structural changes. *Bank of Canada Review*, Spring 2007.

Rochet, J.-C. and J. Tirole (1996). Interbank lending and systemic risk. *Journal of Money, Credit and Banking 28*, 733–762.

Sorkin, A. (2009). *Too Big to Fail.* Viking Adult.