High-Frequency Analysis of Financial Stability

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Motivation

- **Large-value payment systems are fundamental for the financial system**
  - Quadrillions in annual transfers
  - Designated by regulators as systemically important in all countries
- **Efficiency-stability trade-off in the design of a payment system**
  - Using collateral reduces risk but is costly
  - Using credit saves on collateral, but introduces risk
- **Canada's large value payment system is unique in the world**
  - Allows banks to choose collateral-based or credit-based payments
  - Very efficient, high level of trust, relies mostly on intraday credit
  - Argued to function normally during the crisis
  - If adopted by other countries can save trillions of collateral
- **We evaluate Canada's LVTS financial stability**
  - Develop new high-frequency measures of intraday liquidity risk
  - Rely on more than 500 trillion CAD of payments
  - Utilize second-by-second intraday evolution of payments, credit limits, and collateral

The Role of a Payment System in the Economy

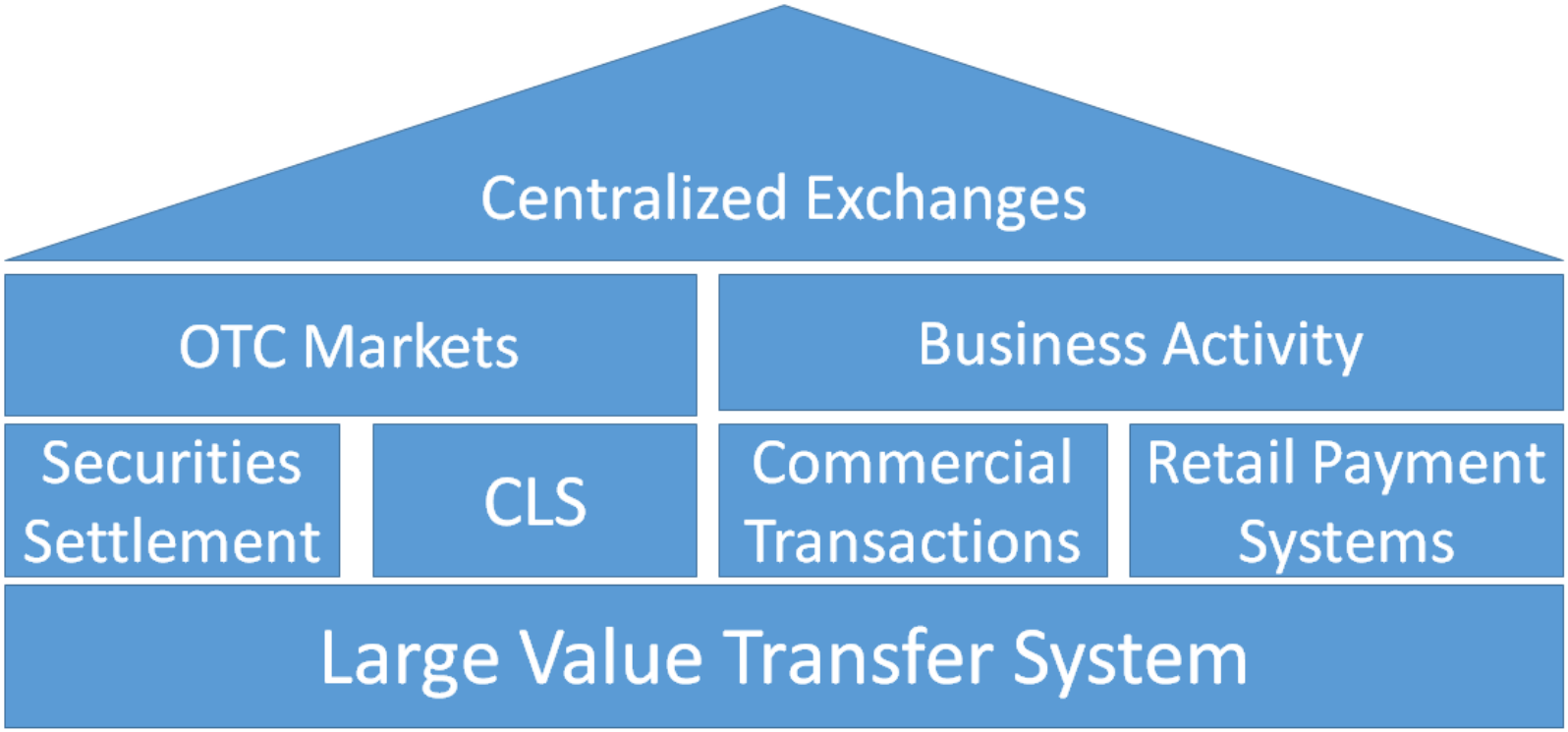


Figure: An Illustration of a Financial System

Payment System Design: Efficiency-Stability Trade-Off

- **Real Time Gross Settlement System (RTGS)**:
  - each payment is fully collateralized (high stability, low efficiency)
  - stable, but inefficient because requires collateral
  - used in most countries, $3.1 quadrillion in 2009. Examples: Fedwire in US ($835 trillion in 2015), Target2 in Europe (€470 trillion in 2015).

- **Deferred Net Settlement System (DNS)**:
  - each payment draws on a credit line (high efficiency, low stability)
  - ultra-short counterparty risk with ultra large losses given default
  - EURO1 in Europe (€50 trillion in 2015).

- **A Hybrid system (HS) attempts to combine RTGS's stability with DNS's efficiency**
  - banks decide in real-time whether to use collateral (like RTGS) or credit limits (like DNS) when sending payments. Banks adjust credit limits in real-time.
  - The only HS in the world is Canada's LVTS ($43 trillion CAD in 2015)

Main Insights

- **Intraday liquidity shortage can cause a systemic risk**
  - The systemic risk in Canada's LVTS is global because of the international participants and critical payments to other systems (e.g., CLS)
  - Requires a real-time monitoring to allow for a timely intervention
- **Need high-frequency measures to identify high-frequency systemic risk**
  - Bilateral credit limits can be cut any second, if not enough collateral payments are rejected/delayed
  - A flash crash in credit limits can me more severe than a slow change because less predictable and less time to respond
  - Credit limits can change for non-fundamental reasons
- **Efficiency-stability trade-off in a hybrid system vs. RTGS**
  - If enough excess collateral to operated without credit then no efficiency benefit relative to RTGS
  - If not enough excess collateral at the system or bank levels, then less stable than RTGS because of rejected payments

LVTS Description

- **Payments**: large-value or/and time-sensitive (e.g. interbank loans; settlement of FX derivatives). Payments are processed continuously.
- **Collateral vs. Credit**: Banks can send payments either via Tranche 1 (T1) or Tranche 2 (T2). T1 requires collateral. T2 utilizes bilateral credit limits (BCLs). Collateral & BCLs are set at the beginning of the day and are updated intraday.
- **Default**: If a bank defaults, losses are allocated to surviving banks proportional to max intraday BCL they granted to the failing bank. Bank of Canada covers losses beyond the first default.

The Data

- **Payment-level info:** size, sender, receiver, tranche, jumbo ($\geq \$100M$ CAD), time (sent/settled), bank/customer (2013-2014), success/failure.
- **Bank-level info:** bilateral credit limits (interday/intraday), collateral (interday/intraday), payment flows (interday/intraday).
- **Participants**:
  - The big six Canadian banks: RBC, CIBC, TD, Bank of Nova Scotia, Bank of Montreal, National Bank of Canada
  - Four foreign banks: HSBC, BNP Paribus, Bank of America, State Street
  - Four other participants: La Caisse Centrale Desjardins Du Qubec, ATB Financial, Laurentian Bank of Canada, and Central 1 Credit Union.
  - The Bank of Canada

Summary Statistics

	2003 - 2017 Mean
Annual volume (million)	5.84
T2 (credit-based)	98.56%
T2 without Bank of Canada (credit-based)	**99.44%**
Jumbo ($\geq$ 100M CAD)	1.46%
Non-Jumbo	98.54%
Customers' payments (2013-2014)	63.37%
Bank's payments (2013-2014)	36.63%
Annual value (trillion CAD)	36.61
T2 (credit-based)	82.11%
T2 without Bank of Canada (credit-based)	**89.85%**
Jumbo ($\geq$ 100M CAD)	61.07%
Non-Jumbo	38.93%
Customers' payments (2013-2014)	22.17%
Bank's payments (2013-2014)	77.83%

Systemic Risk from Failure to Process Payments

- Binding credit limits (in the extreme case all credit limits are reduced to zero)
  - A payment needs to pass both multilateral and individual credit constraints
- Binding collateral constraints
  - If firms have excess collateral at the Bank of Canada they can use it to relax the constraint. Any additional collateral cannot be injected during the same day.
- If both credit limits and collateral constraints are binding payments are delayed/rejected.
  - Rejected critical payments can cause a (global) crisis

Our High-Frequency Risk Measures

- Binding credit or collateral constraints
  - Rejected payments
  - Delayed payments
  - Slack in the constraints
  - **Intuition: when constraints are binding, payments cannot be processed → systemic risk**

- Intraday changes in bilateral credit limits (BCLs)
  - Difference between end of the day and beginning of the day aggregate BCLs
  - Volatility of intraday changes in aggregate BCLs
  - **Intuition: when the risk is high, banks adjust BCLs intraday**

- Fraction of credit-based payments: T2/(T1+T2)
  - If the ratio is 1 then all payments rely on credit (high level of trust)
  - If the ratio is 0 then all payments rely on collateral (lack of trust)
  - The risk is in an abrupt drop in the ratio
  - **Intuition: if trust evaporates and not enough collateral, payments freeze.**

Current View about Payment Systems in 2007-2008

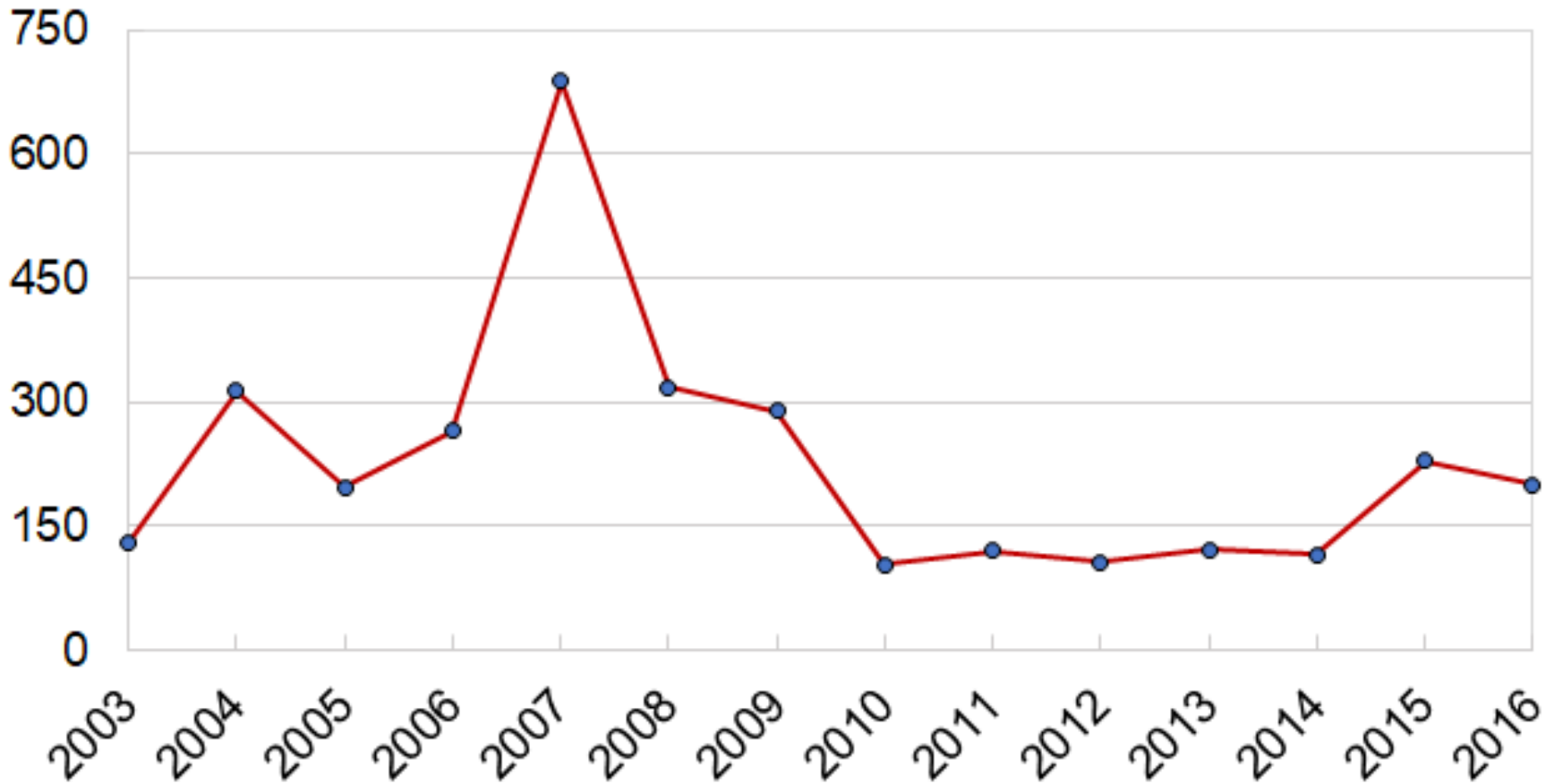
- **Canada:** "..our payments system has functioned smoothly and reliably, despite the enormous shocks to our financial system over the past two years" (Mark Carney, former governor of the Bank of Canada, on March 30, 2009).

- **US**: "The U.S. payment and settlement systems continued to function smoothly during the 2007-2008 period of market stress." (IMF Report , May 2010)

- **Europe**, Banque de France report (Q1, 2009):
  - "During the financial crisis of the last few months, transfer systems have been faced with extreme, even unprecedented, operating conditions ..."
  - "... transfer systems continued to function well, which is very positive given their importance for financial stability."
  - "the crisis has helped us to become fully aware of the significance and scale of the interdependencies between transfer systems."

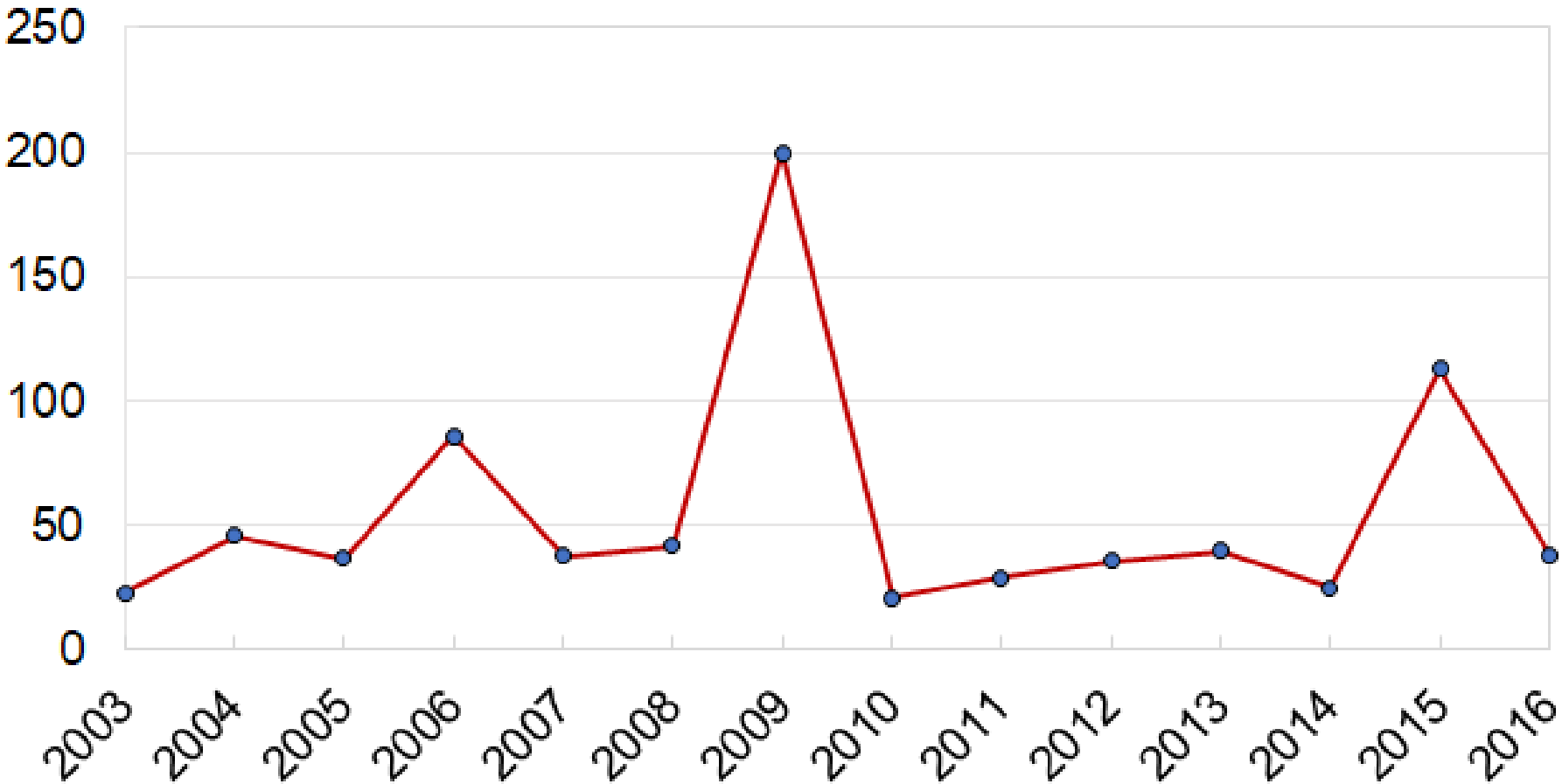
Rejected Payments

Figure: Number of Rejected Payments Due to Binding Credit Limits or Collateral Constraints

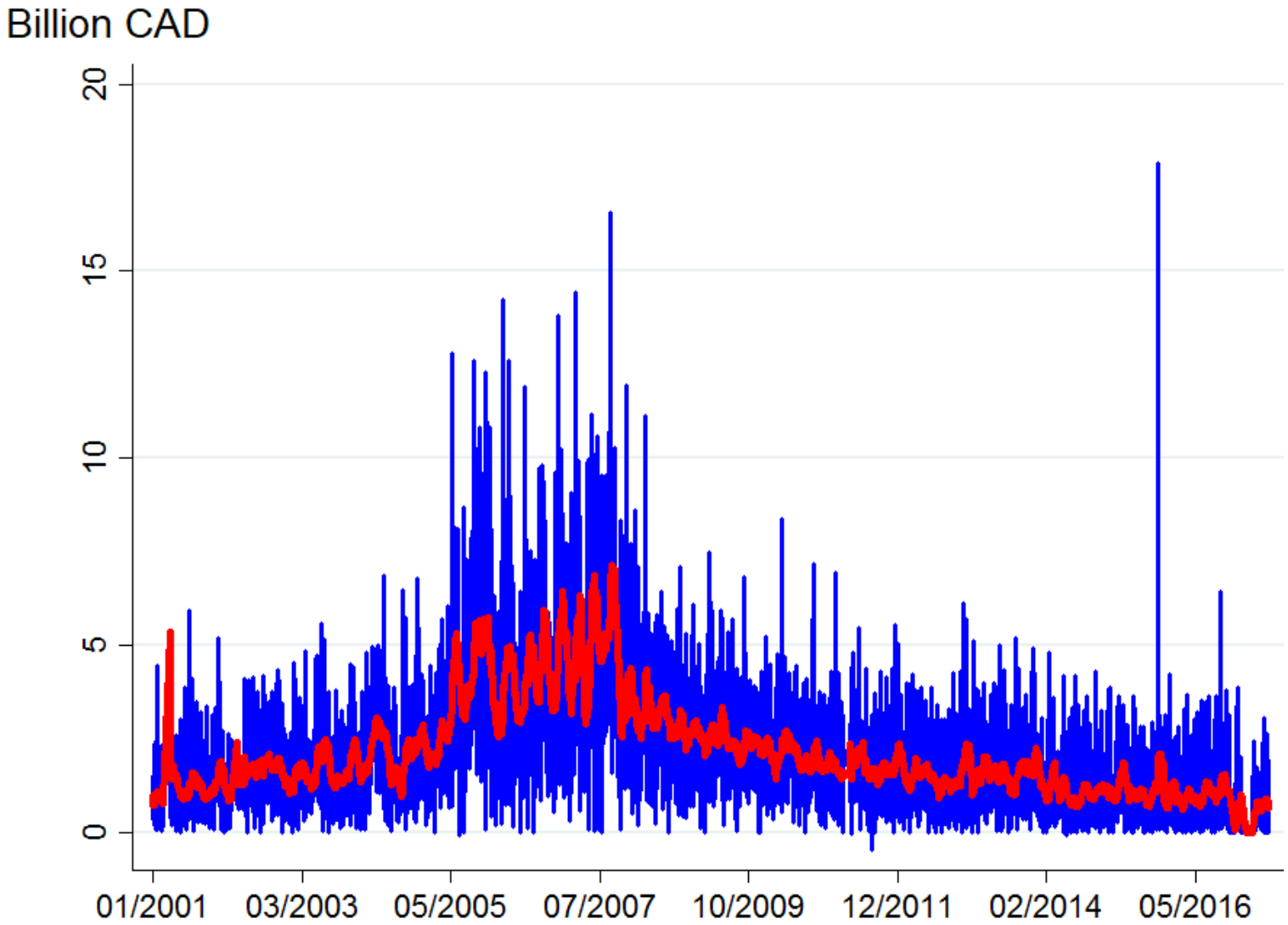


Rejected Payments to the Bank of Canada

Figure: Number of Rejected Payments Due to Binding Credit Limits or Collateral Constraints

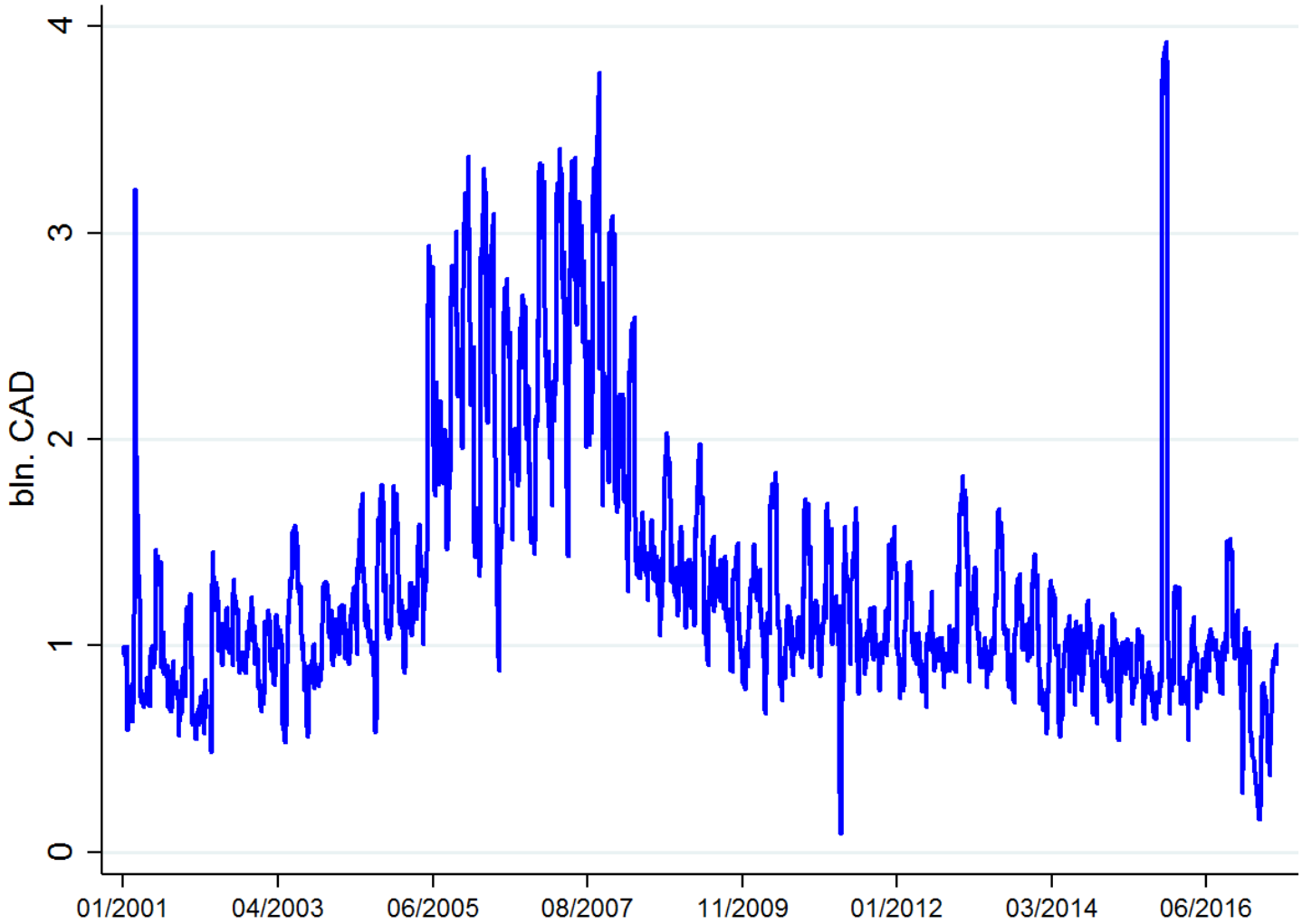


Intraday BCL Adjustments (ΔBCL)



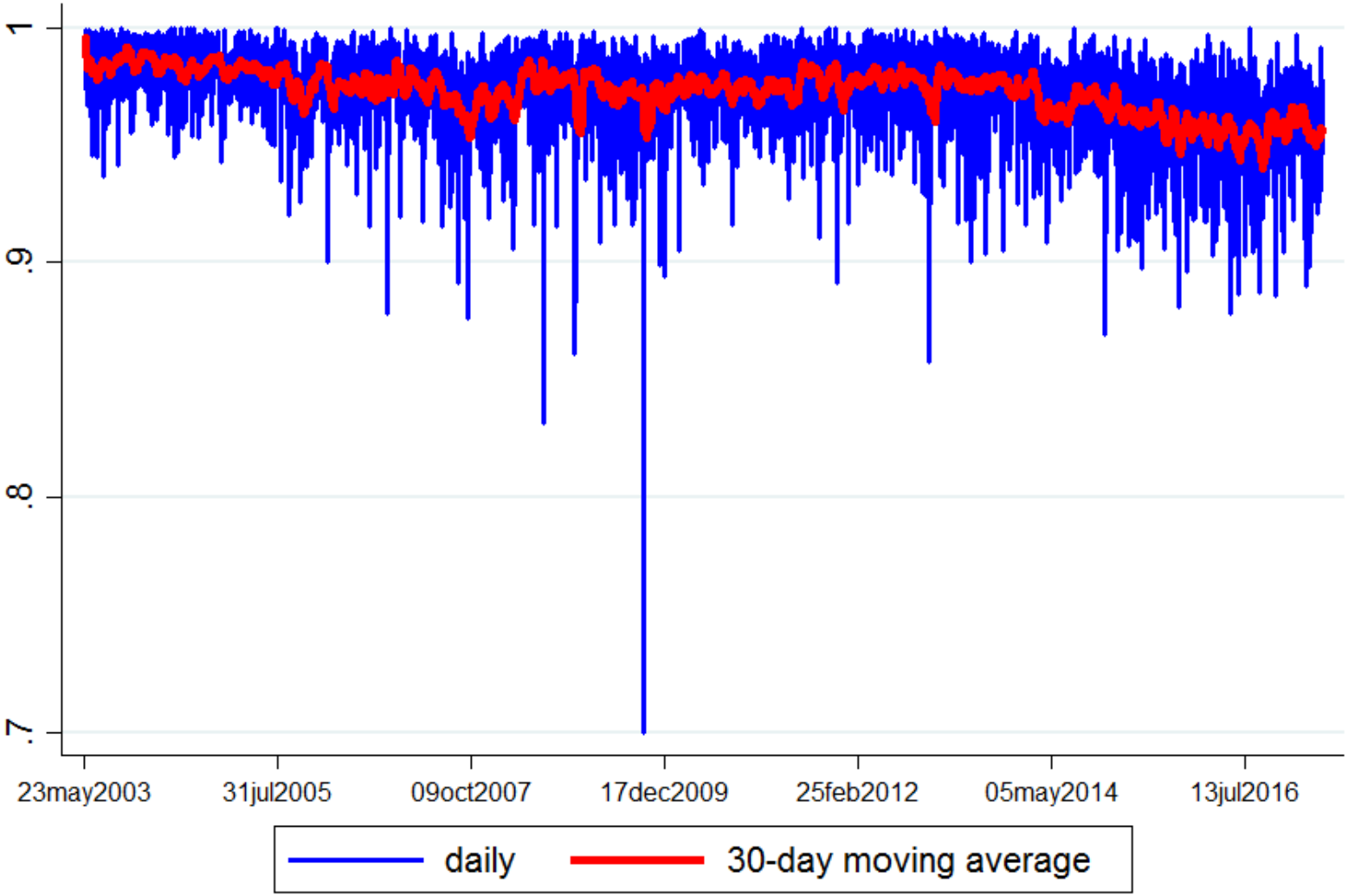
blue line: ΔBCL red line: 30-days moving average

Volatility of Intraday BCL Adjustments



blue line: 30-days rolling std. dev. of ΔBCL

A Daily Fraction of Credit-Based Transactions [T2/(T1+T2)]

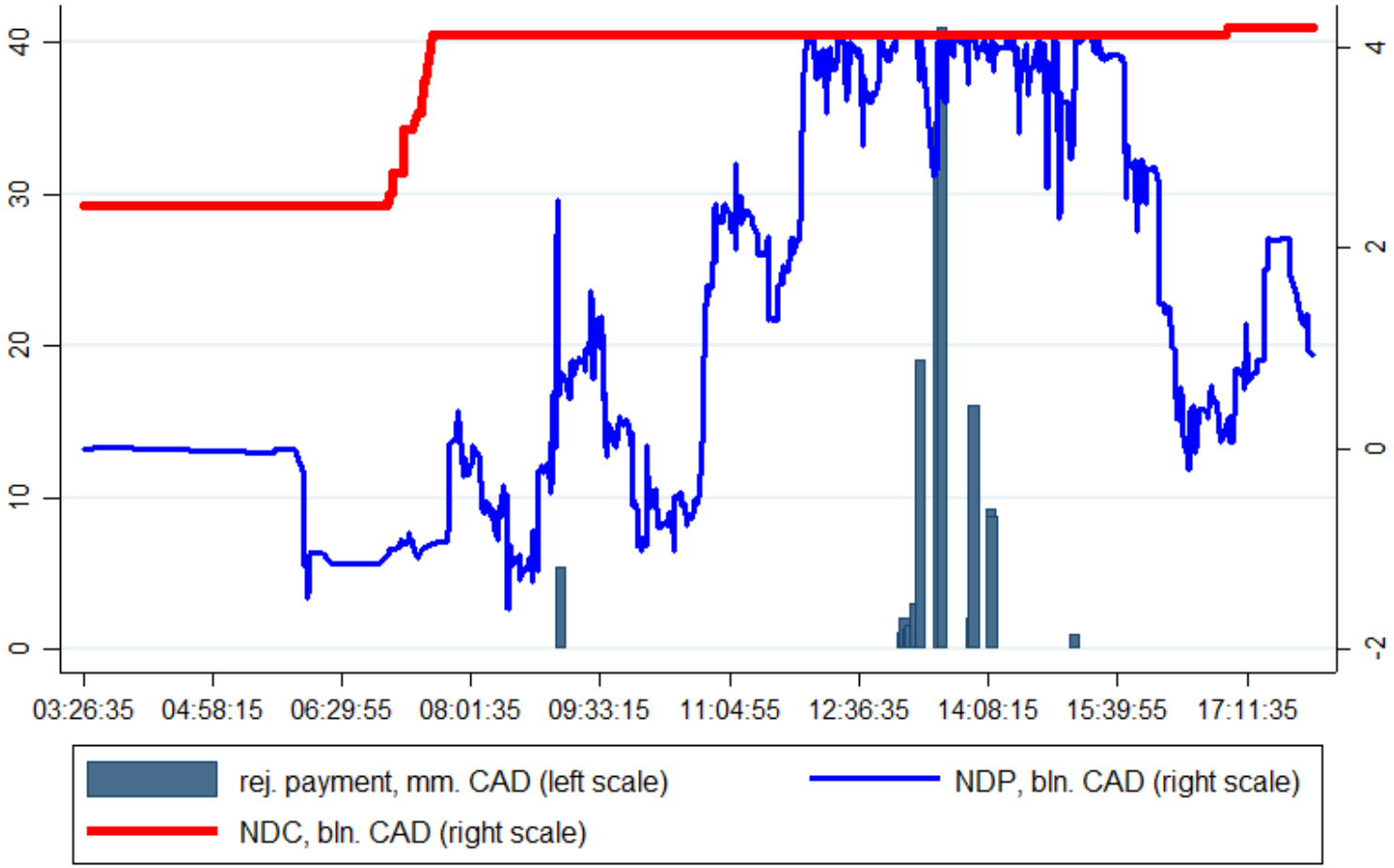


LVTS and Lehman's Failure

- **September 15, 2008**
  - 4 payments with total value of $160M CAD by Bank 10 to three other banks fail risk controls and get rejected.
  - Delays in settlement of T1 (binding collateral constraint) and T2 (binding credit limit) valued $5B CAD.
  - The only delayed T1 payment in September 2008.
- **September 16, 2008**
  - 32 payments with total value of $163M CAD by Bank 1 to seven other banks fail risk controls and get rejected.
  - Delays in settlement of T2 payments valued $4.5B CAD, $2.8B sent by Bank 1.
  - Bank 6 temporary increased a BCL to Bank 1 by $200M CAD.

Second-by-second analysis of LVTS day after Lehman's failure

Figure: Bank 1 experiences stress on September 16th, 2008



Flash Crash in 2008

- Day 1: Bank A reveals large losses linked to the US sub-prime mortgages market.
- Day 2: Bank A cuts credit limits to six banks by 20%
  - From 13:14pm to 13:52pm, one of the six banks, Bank H, experiences 30 rejected payments
  - Bank A & Bank H significantly delay sending T1 payments.
  - In total, 10 T2 jumbo payments of **$8B** by three banks are queued and settled with an average delay of 10 minutes. Bank H experiences the longest delay of 38 minutes on its $500M payment.
- Days 3-4: Three of the six banks reciprocate by cutting credit limits by 20%
  - One jumbo T1 payment is queued and rejected. In total, 27 T2 jumbo payments of **$19B** are queued and delayed, 1 queued and rejected.
  - Bank J temporary increases standing BCL to Bank B by 167%.

Without high frequency data: (1) the flash crash would not be observed as it lasted only several days, (2) we could conclude that the original write-down caused credit limits reduction to this bank.

Bank of Canada Interventions During the Crisis

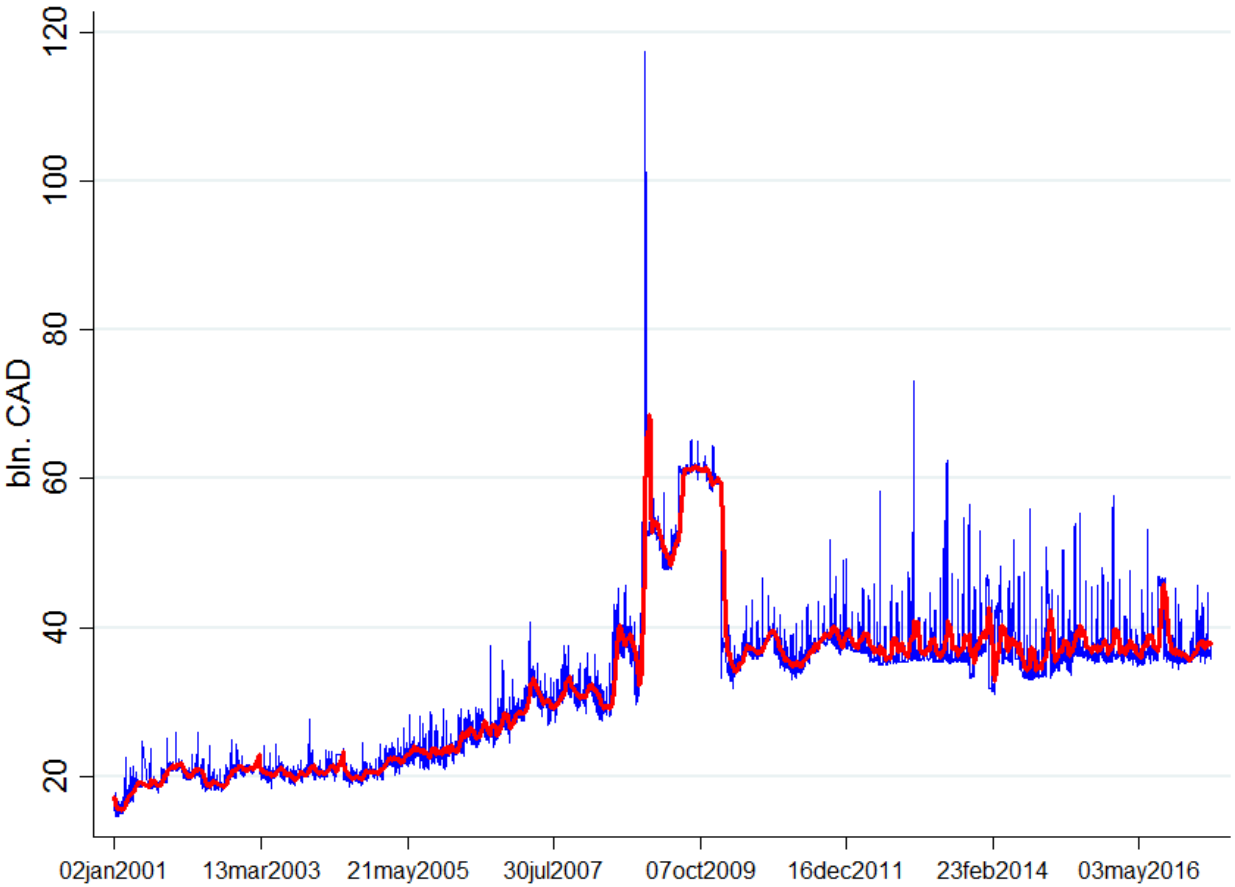
Collateral in LVTS:

- **March, 2008**: expansion in the class of acceptable collateral, such as ABCP, that is used by LVTS participants to secure intraday liquidity
- **June, 2008**: allowing U.S. Treasury securities to be used as collateral
- **October, 2008 - March 2010**: further expansion in the class of acceptable collateral to include the Canadian-dollar non-mortgage loan portfolios (NMLP) of LVTS direct participants
- **February, 2009**: investment-grade corporate bonds added to the list of acceptable collateral

Other Interventions:

- **December 2007 - July 10, 2008**, purchase and resale agreements (PRAs)
- **May 1, 2008**: system wide percentage in LVTS is increased from 24% to 30%, increases throughput of credit-based payments by 25%.
- **September, 2008**: resumption of term PRAs.
- **November, 2008**: term loan facility at a penalty rate for LVTS direct participants secured by NMLP

Aggregate Value of Pledged Collateral



blue line: daily aggregate collateral, red line: 30-days moving average

- Intervention during the crisis substantially increased the amount of collateral

Policy Implications

- **The frequency of the risk measures should match the frequency of the risk that they are trying to capture.**
  - Real-time monitoring is required to allow real-time intervention.
  - Stress tests by a central bank should evaluate whether banks have enough collateral to process payments without disruption.

- **Binding credit or collateral constraints constitute risk that (critical) payments will be delayed or rejected.**
  - A transition from binding credit constraints to binding collateral constraints can happen instantaneously.
  - Not only the aggregate collateral matters, but also who holds this collateral.

- **Central bank's policy about acceptable collateral is an important regulatory tool, especially in a hybrid payment system**
  - A timely injection of new collateral to the system can avoid systemic risk.
  - Accepting lower quality collateral transfers risk to the central bank.

Conclusion

- Most of the payments in Canada's LVTS rely on credit, saving the need for collateral. [Higher efficiency]
- Our high-frequency stability measures show that Canada's LVTS faces a risk of failed payments if credit lines and collateral constraints are binding. [Lower stability]
- We highlight an important efficiency-stability trade-off in a hybrid payment system by relying on high frequency analysis of Canada's LVTS.