The Impact of Central Clearing on the Interest Rate Swaps Market

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# Introduction

The 2006-2008 financial crisis, the most severe downturn since the Great Depression, led to the passage of the Dodd-Frank Wall Street Reform and Consumer Protection Act (DFA). A key provision of the DFA required certain financial contracts to be cleared through a central counterparty (CCP). This study investigates the causal impact of this clearing mandate on prices, volatility, and liquidity in the interest rate (IR) swaps market, a major derivatives market used for hedging or speculating on interest rate risk. Despite extensive theoretical literature on central clearing, empirical studies are limited. Earlier research focused on the credit default swaps (CDS) market using event studies. Event studies cannot isolate causal impacts due to potential confounding factors. This study addresses the gap in the literature by (1) examining the IR swaps market, which is larger and more widely used than the CDS market and (2) using a difference-in-differences approach to identify causal effects of the clearing mandate. Leveraging the fact that initial central clearing rules targeted IR swaps in the four largest currencies traded in the US, but did not apply to other currencies or regions, this research plausibly identifies the causal impact of the regulation on pricing, liquidity, and price volatility in the IR swaps market.

The paper is organized as follows: section 2 provides background on the IR swaps market, the financial crisis, and the clearing mandate's role in post-crisis market reforms; section 3 develops the theory of pricing, price volatility and liquidity for IR swaps under a clearing mandate; section 4 discusses the identification strategy; section 5 details my data; section 6 discusses the results and section 7 concludes.

# Background

## Interest Rate Swaps

IR swaps are financial derivatives used to hedge or speculate on interest rate movements. The three most common types of IR swaps include vanilla fixed-for-floating swaps, basis swaps, and cross-currency basis swaps. Vanilla fixed-for-floating swaps are the most prevalent. In this type of swap, one party exchanges fixed-rate coupon payments for floating-rate payments on a notional principal (the notional principal is never exchanged). Firms can use these instruments to convert floating-rate risk to fixed-rate risk, and vice versa. As a concrete example, imagine firm A can borrow at the London Interbank Offer Rate (LIBOR, a common variable interest rate used by banks when lending money to each other) or a fixed rate of 2.0%, while firm B can borrow at LIBOR + 0.25% or a fixed rate of 1.75%. Suppose firm A prefers borrowing at a fixed-rate and firm B prefers borrowing at a floating-rate (this could be because firm A owns assets such as fixed-income securities while firm B owns assets that pay a variable rate, and the firms would like to match their assets with their liabilities). Despite their preferences, firm A has a comparative advantage in borrowing at a floating-rate, and firm B in borrowing at a fixed-rate. To achieve their preferred arrangements, the firms can enter into an IR swap agreement with a $1M notional[[1]](#footnote-2) principal, where firm A receives a floating rate of LIBOR from firm B and pays a fixed rate of 1.75% to firm B. This transforms firm A's floating-rate liability into a fixed-rate one and vice versa for firm B. The IR swaps market allows firms to borrow in the market they have a comparative advantage in and trade for their preferred interest rate arrangement.

IR swaps can be bespoke contracts, customizable to individual economic needs. As the largest over-the-counter (OTC) swaps market, it accounted for $465 trillion of the $601 trillion global OTC swaps market in 2010 (von Kleist and Mallo 2011) (the IR swaps market had increased to $715 trillion by June 2023 according to an updated version of the same report). For many currencies, there are “standardized” contracts, which have common features and are the most heavily traded. During the period of study, the standard US Dollar (USD)-denominated IR swaps contract had semiannual payments for one leg and quarterly payments for the other leg (that is either trading quarterly fixed-rate payments for semiannual floating rate payments, or vice-versa), with the 3-month USD-LIBOR curve used both as the floating-rate reference and for discounting future cash flows (see section 3 for further explanation). The standard Canadian Dollar (CAD)-denominated contract used 3-month CDOR as the reference floating rate. There are many other contract details such as day-count conventions, settlement and termination rules that need to be specified, and these are listed in more detail in Appendix A. Both Canadian and US dollar denominated standard contracts used the ISDA master agreement, which specifies settlement, termination, and other contract specifications. Contract specifications can be customized to meet the requirements of the counterparties, but such non-standard contracts are likely to be less liquid than the standard contracts. Standard contracts denominated in other currencies (e.g. Euro [EUR], British Pound [GBP], and Japanese Yen [JPY]) have their own conventions as well.

The IR swaps market is dealer-dominated, with dealer-customer and dealer-dealer trades accounting for 80% of notional value (Bolandnazar 2020). Bolandnazar finds that 50% of trades (by notional value) are executed by the largest seven dealers, indicating market concentration among a few dealers. This concentration can impact pricing and market stability in several ways. Larger dealers might be able to reduce search costs by easily finding a counterparty from their large client base. They could also reduce costs by economizing over administrative and warehousing costs of contracts. However, because of their market position, they might have market power and be able to charge a premium over the price that would prevail in competitive markets. The failure of a large dealer (or a dealer’s major counterparty) could also drastically reduce liquidity in the system and increase transactions costs.

## Central Clearing

When a swap is cleared, the initial contract between the two parties is replaced by two contracts between each party and a central clearinghouse/derivative clearing organization (CCP, DCO or clearinghouse). The clearinghouse becomes the counterparty for each leg (that is, paying the fixed leg to the initial party receiving fixed-leg payments and paying the floating leg to the party receiving the floating leg-payments. It also receives the floating leg from the initial party paying the floating rate and the fixed leg from the initial party paying the fixed leg). If one party fails to meet their contractual obligation, the clearinghouse can still make sure the other party gets paid. For this purpose, CCPs practice risk-control measures and have additional resources to make a counterparty whole in case of default. When counterparties clear[[2]](#footnote-3) their trade through a clearinghouse, they must put up collateral (initial margin) and contribute to a default fund. Non-clearing counterparties. In case the risk position of the counterparty changes, it can be required to put up additional collateral (variation margin). The CCP also has default fund contributions of other members, its own equity (CCP capital), and access to other lines of credit (such as the Federal Reserve discount window). The combination of these resources makes it unlikely that the failure of one counterparty would drastically affect the whole market. Since clearing members can lose their contribution to the default fund in case of the failure of a counterparty, clearing mutualizes counterparty risk among the members of the CCP.

In addition to these financial resources, CCPs exercise prudent risk control measures such as monitoring members trading positions and liquidating distressed assets in an orderly fashion. Since the CCP can observe all trades that it is clearing, it has a better picture of overall riskiness. Compare this to a bilateral market, where one party is generally unaware of other trades its partner is entering, and thus does not have a thorough understanding of its partner’s riskiness.

Clearing can reduce demand for collateral through a practice called netting. There are two types of netting practices common in the industry: cross-product netting and multilateral netting. For a CCP that clears multiple types of contracts (e.g. interest rate swaps, forward rate agreements, overnight-index swaps, credit default swaps, etc.) cross-product netting involves netting across different derivatives products. For example, if firm A owes the CCP $10 million in collateral for IR swaps, but the CCP owes firm A $8 million for CD swaps, then firm A can just pay the CCP $2 million in net collateral.

Multilateral netting involves netting payments across multiple firms. For example, consider the following series of obligations: firm A owes firm B $100 million and firm C $200 million; firm B owes firm A $50 million and firm C $150 million; firm C owes firm A $100 million and firm B $100 million. Without multilateral netting, the firms can still engage in bilateral netting. In a bilateral netting regime, the following payments would need to be made: firm A would need to pay firm B ($100 - $50) = $50 million and firm C ($200 - $100) = $100 million; firm B would need to pay firm C ($150 - $100) = $50 million. The total collateral demand would be $200 million. With multilateral netting by the CCP, the $50 million payment from firm A through firm B to firm C can be eliminated. Firm A would pay the CCP $150 million and the CCP would pay firm C $150 million (while firm B would not make any payments at all). The total collateral demand would be $150 million.

Figure 1 (a) Example of obligations between three firms without netting and (b) with bilateral netting and (c) with multilateral netting

[Figure 1 about here]

Originally created for members of futures and equities exchanges, clearinghouses became more significant with regulations like the DFA (2010) and European Market Infrastructure Regulation (EMIR, 2012) mandating central clearing of derivatives. Mandated clearing can have macro and micro effects on the swaps market. At the macro level, clearing could reduce volatility but also strain the market through collateral demand during volatile or illiquid periods. Large enough losses could threaten clearinghouse solvency, transmitting effects to all members. At the micro level, central clearing may change the types of trades firms enter, potentially leading to riskier trades due to mutualized default risk (adverse selection) and riskier post-trade activities (moral hazard). Clearing is subject to economies of scale and scope, which could lead to natural monopolies. However, regulators are likely to prevent this through antitrust regulations and “local clearinghouse” requirements (that is, even though a single clearinghouse for both the US and Europe might have lower costs, regulators might require separate clearinghouses in each jurisdiction). While clearinghouses can reduce default risk and collateral demand, they also require resources for risk management activities, which may increase trading costs.

## Regulatory Background

### US Context

Following the financial crisis, Congress passed the DFA to enhance the US financial system's reliability. Since OTC derivatives markets played a role in the crisis, DFA aimed to significantly reform this market. Key objectives included improving trade data availability for regulators and market participants, requiring real-time reporting of certain trade characteristics, and mandating confidential trade data reporting to swaps data repositories and regulators.

To reduce default risk for large swaps dealers, DFA requires dealers to register with the Commodities Futures Trading Commission (CFTC) or the Securities and Exchange Commission (SEC), adhere to internal business conduct standards and maintain adequate capital. To enhance liquidity, price discovery and transparency, it encourages trading to take place in centralized Swaps Execution Facilities (SEFs, usually electronic trading venues) or Designated Contract Markets (DCMs). To make trade data more readily available, it requires real-time reporting of price information to swaps data repositories (SDRs) and submitting additional data (called primary economic terms) to SDRs and regulators in a timely fashion. Furthermore, the DFA mandates most contracts be centrally cleared (and for uncleared contracts, requires parties to post margin to mitigate default effects). Table 1 summarizes the CFTC key rulemaking in these areas.

Table 1 Major Dodd-Frank Act Rulemaking Areas

[Table 1 about here]

### International Context

Considering the global nature of the financial system, regulators collaborated internationally to harmonize regulatory requirements. In Europe, the EU passed EMIR in 2012, which shares similar aims as the DFA, while the Bank of England (BoE) issued regulations mandating clearing for most trades involving UK-based entities. In Asia, the Japanese Financial Services Authority (JFSA) required yen-denominated IR swaps and certain CD swaps to be cleared by the end of 2012; the Monetary Authority of Singapore (MAS) and the Securities and Futures Commission (SFC) of Hong Kong released consultation papers expressing their intentions to clear swaps denominated in certain Asian currencies. Table 2 summarizes the international context:

Table 2 Summary of Central Clearing Requirements in Major FInancial Centers

[Table 2 about here]

## Review of Literature

### Interest rate swaps

Formal swap agreements were first seen in financial markets in 1981/1982. Bicksler and Chen (1986) find three uses of interest rate swaps in the market: (1) to manage mismatches in assets and liabilities (for example, depository institutions in the US hold long-term fixed rate assets such as mortgages and short-term liabilities such as demand deposits; on the other hand, insurance companies have long-term fixed rate liabilities and often invest in short term assets such as money market funds); to lower fixed-rate borrowing costs (borrowers with poor credit can often borrow at a lower cost in the floating rate market) and to manage their debt mix. The primary economic rationale for the existence of interest rate swaps is differences between firms’ costs to borrow at fixed rate vs. variable rate arising due to market imperfections (differences in regulations or credit market imperfections can give firms comparative advantage in borrowing in one market over another).

Smith, et. al. (1988) present two models of pricing swaps. One model replicates the payoff of a swap through a portfolio of forward or futures contracts. The other model replicates the payoff through a portfolio of floating rate and fixed rate corporate bonds. They note that for a portfolio of bonds, there is an exchange of the principal at the end of the bond term, while for an interest rate swap the principal is usually not exchanged (that is, it is a “notional” principal). Thus, the impact of a default is greater for a corporate bond than for an interest rate swap. Futures contracts on the other-hand are exchange-traded, cleared, and settled daily, so the risk of loss due to counterparty default is close to zero. For forwards, the contract value is realized only at the end of the contract period and has greater potential for counterparty default than for futures. An interest rate swap is somewhere in-between: it is periodically settled (on the payment dates).

Minton (1997) examines these valuation models. He finds that the fixed rate of the interest rate swap is discounted by ~4 bps compared to a replicating portfolio of Eurodollar futures (Eurostrips) and that movements in swap rates and Eurodollar futures rates are highly correlated. When evaluating the portfolio of bonds model, he finds that actual swap rates fall between the rate derived from a portfolio of corporate bonds and the rate derived from Eurodollar futures. Proxies for counterparty credit quality also have a significant explanatory power, suggesting counterparty risk is a factor in observed swaps pricing.

### Liquidity

Biais (1993) proposes a model for a dealer intermediated market and derives the optimal bid-ask spreads quoted by dealers with constant absolute risk aversion (CARA) (note that this is a model of general asset pricing in dealer-intermediated markets, and not specific to the IR swap market). A basic version of Biais' model motivates the liquidity model in section 3. Several papers empirically examine liquidity in the interest rate swap market: Sun, et. al. (1993) examine the effect of dealer credit rating on bid-ask spreads using data from Merrill Lynch and AIG Financial Products. They find that dealers with AAA credit ratings charge a spread of around ~10 bps while lower rated dealers only charge a spread of ~4 bps. Boudiaf, et. al (2024) examine the impact of monetary policy tightening on liquidity of EUR denominated swaps using a variety of liquidity measures. They find that their liquidity measures are impacted by monetary policy (specifically volatility in key policy rates reduces liquidity in the swaps market). Liu, et al (2006) decompose the “spread” between interest rate swaps and corresponding treasury bills into a credit spread and liquidity spread (arising from the lower liquidity of swaps over US government bonds). They find that the credit component of the spread is ~31 bps while the liquidity component is ~7 bps. Benos, et. al (2020) examine the impact of another Dodd-Frank mandate (trading on SEFs) on swap liquidity. They find a 12%-19% improvement in liquidity in the post-regulation market, driven by competition among dealers. Loon and Zhong (2014) examine liquidity in the credit default swap (CDS) market following the passage of the Dodd-Frank Act. They find that central clearing in the CDS market is associated with more liquidity.

### Price Volatility

Compared to studies of pricing and liquidity, studies of price volatility in the interest rate swap market are rare. Azad, et. al (2012) decompose volatility in the US and UK market into high-frequency and low-frequency components using asymmetric spline GARCH (AS-GARCH). They then regress the low frequency component of the volatility against several macroeconomic variables (volatility of consumer price index, volatility of industrial production, volatility of short-term interest rates, volatility of foreign exchange rates, slope of the term-structure, unemployment rate and money supply). They find that volatility of short-term interest rates affects IR swap price volatility. In addition, for GBP based contracts, the money supply is negatively associated with IR swap volatility. For USD based contracts, the volatility of industrial production and the slope of the yield curve also affects IR swap volatility.

### Systemic Risk and Contagion

Jackson and Pernoud (2021) outline two main avenues of contagion (that is financial distress at one institution spreading throughout the financial system): firstly, through defaults and firesales of assets that diminish the value of interconnected financial institutions (the network channel) and secondly, through feedback effects such as bank runs and credit freezes. For the first avenue, consider the case when a large financial institution fails. The values of other institutions that do business with the failing institution are also diminished and can cause a cascading series of failures. Each failure leads to additional bankruptcy costs and the final cost to the system at the end of the process can vastly exceed the size of initial shock. Such models are explored by Rochet & Tirole (1996) and Allen & Gale (2007; 2000).

Another way that financial institutions are interconnected are through the assets they trade. That is, even though two financial institutions might not directly do business with each other, they might own assets that are highly correlated. When a bank becomes insolvent, it often must sell assets at distressed prices. Such sales can also depress prices of related assets and drive institutions that hold those assets to insolvency. A prominent real-world example of this scenario is the 1998 crisis at Long Term Capital Management (LTCM). LTCM was a hedge fund that used a highly leveraged portfolio of interest rate swaps and foreign bonds (especially Russian bonds) to earn high market returns. When Russia defaulted on its debt in 1998 and devalued the Ruble, LTCM’s portfolio took a large loss. In addition, market participants became more risk-averse and stopped lending to any institutions that employed a similar trading strategy to, or held similar assets as, LTCM. This created a system-wide credit crunch. The Federal Reserve eventually organized a bailout of the fund to prevent further damage to the financial system. Other prominent examples of this type of contagion are the Asian and Eurozone financial crises, where the potential default of one country led to distressed financial conditions in neighboring countries, as market participants became more risk averse. This type of models are explored by Kiyotaki & Moore (1997) , Cifuentes et al. (2005), Gai & Kapadia (2010), Capponi & Larsson (2015) and Greenwood et al. (2015).

Besides the network avenue, contagion can also occur through feedback loops and multiple equilibria. The classic Diamond and Dybvig (1983) model illustrates how multiple equilibria can lead to panic and bank runs. Banks lend out money long term and take in deposits for short terms. If enough depositors demand to withdraw their funds at once, the bank cannot repay all of them. In fact, if depositors believe a bank is insolvent (or they believe that other depositors believe that the bank is insolvent), they have an incentive to be the first in line to pull their funds out. Thus, a change in belief about the solvency of a bank can lead to a self-fulfilling insolvency, without any decrease in the value of the bank’s actual portfolio of loans. Similarly, banks’ beliefs about the creditworthiness of their counterparties can lead them to pull back their lending, leading to the very adverse credit condition and defaults that they were anticipating. This chain of defaults can cast doubts about the solvency of other banks, eventually leading to a systemwide freeze where banks stop lending to each other. This type of models are explored by Bebchuk & Goldstein (2011), Brunnermeier (2009) and Diamond and Rajan (2011).

### Central Clearing

The policy and market implications of a central clearing mandate are discussed extensively by Pirrong (2011). Per Pirrong, CCPs should clear liquid, standardized products, as illiquid products can pose substantial risks to the CCP. CCP’s can reduce the disruptive effect of defaults by drawing on additional sources of capital and facilitating orderly liquidation of positions. However, they can also increase systemic risk by requiring additional margin during periods of financial stress. In addition, by mutualizing the risk of default, they can induce market participants to take more risk (moral hazard and selection issues). CCPs are also subject to economies of scale and scope (that is, the market will converge to one or few large CCPs that can economize over costs of warehousing and multiproduct netting). Since a CCP is likely to become a systemically important financial institution, regulators must monitor it closely and have prudent measures (such as a resolution plan if the CCP collapses).

Duffie and Zhu (2011) show that theoretically concentrating clearing to one CCP can economize on collateral. Benos et al. (2019) explore the issue of economies of scale/scope among CCPs. Regulators in Europe and United States have required “local CCPs” to clear contracts that originate in their jurisdiction. They find that the same contracts trade at different prices when cleared through two different clearinghouses (LCH in the UK/Europe and CME Clearing in the US) and suggest that this difference arises due to increased collateral costs when clearing is fragmented.

Bernstein, et al. (2019) look at the impact of central clearing on equities pricing by examining the prices of the same stocks traded on New York Stock Exchange (NYSE) and Consolidated Stock Exchange (CSE). The NYSE established a clearinghouse in 1892 while the CSE did not. They find that the same stocks on the NYSE traded for 90-173 premium over the CSE price.

# Theory

## Pricing of Interest Rate Swaps

### Pricing without credit risks

An interest rate swap can be thought of as an exchange of a series of fixed payments by one party for a series of variable (floating) payments by the other party involved in the swap. For the fixed leg, the present value of the payments is given by (Skarr and Szakaly-Moore 2007):

|  |  |  |
| --- | --- | --- |
|  |  | (1) |

where: CF is the (fixed) cash flow, is the risk-free rate for period , is the time at which CF will be received and is the tenor (total length of the swap contract)

The present value of the floating leg is:

|  |  |  |
| --- | --- | --- |
|  |  | (2) |

where: is the floating leg payment at period , and all the other variables are as defined previously.

The present value of the contract for the party paying the fixed leg and receiving the floating leg is:

|  |  |  |
| --- | --- | --- |
|  |  | (3) |

*(The counterparty's value is given by a similar formula, but with the signs reversed on the right-hand side.)*

Floating rate payments are unknown in advance but are usually forecasted by a relevant yield curve. For instance, if the floating leg payment is based on USD LIBOR, a USD LIBOR curve, constructed by interpolating short-term deposit rates, medium-term Eurodollar futures, and long-term instruments like forward rate agreements and existing swaps, is used. At the outset of the contract, its value () is zero. This is achieved by determining the present value of the floating leg using the forecasted payments (using the LIBOR yield curve), and then setting the fixed rate payment in (3) such that the present values of both legs equal.

### Pricing with counterparty Risk and Credit Valuation Adjustment/Debit Valuation Adjustment

The interest rate swap market is dominated by a handful of substantial swap dealers (SDs) and Major Swap Participants (MSPs) rather than many atomistic market participants(Bolandnazar 2020). These SDs and MSPs offer buy and sell quotes for swaps, potentially finding other participants to balance their swap exposures. Figure 2 depicts a hypothetical network model of such a market.

[Figure 2 about here]

Figure 2 Dealer based market without central clearing

In the figure, three dealers (D) each engage with their set of clients (C). Note that dealers might engage in interdealer trading (indicated by bi-directional arrows between dealers) and bulk futures markets trading (not shown) for cash flow or risk management purposes. Customers can trade with multiple dealers (indicated by arrows going from C to multiple Ds) or occasionally engage in bilateral trades (indicated by arrows going from C to C) amongst themselves. However, bilateral trades typically have low volume. It is believed that the dealer-centric network structure lowers search costs compared to a direct customer-to-customer market.

In practice, customers and dealers must account for the risk associated with counterparties defaulting. The "risk-free" present value pricing above needs to be adjusted for this risk. If *Si*​ represents the survival probability of the counterparty at period , the expected present value of the fixed leg is:

|  |  |  |
| --- | --- | --- |
|  |  | (4) |

The fixed rate payment needs to account for the modified PV of the floating leg.

(Note that a swap's valuation with counterparty risk requires two adjustments. Only the credit valuation adjustment [CVA] is shown above. However, if one’s counterparty defaults, one no longer has to make his/her obligated payments to the other party either, which would increase the value of the contract. This adjustment is called the Debit Value Adjustment [DBA] and not shown above).

### Pricing under Central Clearing

The structure of a dealer-dominated market means that a dealer's failure (possibly due to inadequate risk management or correlated customer defaults) could affect other dealers and potentially the entire market. To counter this, regulators introduced central counterparties (clearinghouses). These clearinghouses void (novate) the initial swap contract and establish two new contracts, mirroring the original, with each counterparty. Now participants only need to be concerned about the clearinghouse's potential default, rather than their counterparties. Owing to their robust capitalization, regulation, and sound risk management, clearinghouses are perceived to decrease default and contagion risks. Figure 3 visualizes a hypothetical market structure with mandated central clearing.

[Figure 3 about here]

Figure 3 Market with Central Clearing

If clearinghouses can reduce or eliminate counterparty risk, swaps values should be closer to the risk-free case rather than the case with counterparty risk. However, even if clearinghouses are successful at eliminating counterparty risk, additional cost of compliance (such as clearing fees and margin requirements) could keep swaps prices from reaching the risk-free valuation.

## Model of Liquidity (Bid-Ask Spreads)

### Liquidity with no Counterparty Risk

I adapt the model from Biais (1993) for centralized trading where all market participants can observe the bids, asks and market orders of their market participants. The model is a sequential game. In the first stage, two competing dealers (liquidity providers) receive a random inventory position in the risky asset between [-R, R]. In stage 2, the dealers set their bid and ask prices. In the next stage there is a liquidity shock with probability . If there is a liquidity shock, a liquidity trader (liquidity demander) receives an inventory of quantity with probability (or a short position of size with the same probability). The liquidity trader then decides the size of the optimal market order, which is executed at the best bid or ask price posted by the dealers. If there is no liquidity shock, no trade takes place. In the final stage, the price of the risky asset is realized, and players receive their utility.

I assume that the two dealers are identical except for their inventory positions. All market participants have constant absolute risk aversion (CARA) utility , where is the trader’s wealth and is a risk-aversion parameter. If there is a liquidity shock, the liquidity trader observes the market prices and selects the quantity (size) of the market order. The final price of the risky asset is , where .

I analyze the case where the liquidity trader receives a liquidity shock (the case where the liquidity trader receives a shock will be analogous). At the end of the game, once the asset price is realized, this trader receives wealth:

|  |  |  |
| --- | --- | --- |
|  |  | (5) |

where is the net position of the trader in the risky asset at the end of the game and is the cash from selling units of the risky asset at the best (highest) bid price. The liquidity trader will maximize his expected utility . The optimal quantity is:

|  |  |  |
| --- | --- | --- |
|  |  | (6) |

where I have used the fact that

If dealer 1 has the best price, s/he receives the order flow and has wealth:

|  |  |  |
| --- | --- | --- |
|  |  | (7) |

where: is the bid price set by dealer 1, is the size of the market order and is his random inventory position (a number between ). If dealer 1 does not have the best price, s/he receives:

Dealer 1 is indifferent between trading and not trading when the expected utility from both actions is the same. This happens when:

|  |  |  |
| --- | --- | --- |
|  |  | (5) |

|  |  |  |
| --- | --- | --- |
|  |  | (6) |

where the price is subscripted with to emphasize it is the reservation price. A similar analysis holds for the ask price:

|  |  |  |
| --- | --- | --- |
|  |  | (7) |

and in general, for dealer , the reservation prices are:

|  |  |  |
| --- | --- | --- |
|  |  | (8) |

I analyze the case of the optimal bid quote for dealer 1, assuming competing dealers do not observe the other’s inventory levels, but both assume that the others inventory is drawn uniformly from . By increasing his/her bid quote, a dealer increases his/her probability of winning the order flow but must balance this against the fact that s/he pays more for each unit acquired. S/He would not like to increase the quote beyond his/her reservation price. The optimal bid quote is:

|  |  |  |
| --- | --- | --- |
|  |  | (9) |

Similarly, the optimal ask quote is:

|  |  |  |
| --- | --- | --- |
|  |  | (10) |

and in general, the optimal bid and ask quotes for dealer are:

|  |  |  |
| --- | --- | --- |
|  |  | (11) |

The observed bid ask spread is:

|  |  |  |
| --- | --- | --- |
|  |  | (13) |

#### note: Under competition with many dealers, the second term on the RHS of the (11) approaches as , and the bid ask quotes become the reservation quotes.

### Liquidity with counterparty risk

Under the scenario where there is counterparty risk, if the counterparty defaults the value of the asset is impaired (the holder of the non-defaulting leg no longer receives expected cash flows). However, for the defaulter, the value of the asset is enhanced (as he no longer needs to make payments). I model this as an additional shock to the realized value of the asset: . The analysis remains essentially the same, but the optimal market order size, reservation prices, and optimal quotes now become:

|  |  |  |
| --- | --- | --- |
|  |  | (14) |

|  |  |  |
| --- | --- | --- |
|  |  | (15) |

|  |  |  |
| --- | --- | --- |
|  |  | (16) |

|  |  |  |
| --- | --- | --- |
|  |  | (17) |

|  |  |  |
| --- | --- | --- |
|  |  | (18) |

## Models of Price Volatility

### Volatility without Counterparty Risk

I develop an original model of price volatility. There are two sets of agents: market-makers who post bid and ask prices, and liquidity traders who post market orders. Assume that order-flow (net market-buy or market-sell orders) in one period are i.i.d Normal with variance :

|  |  |  |
| --- | --- | --- |
|  |  | (19) |

Market-makers adjust their next period price based on the current period’s observed order-flow:

|  |  |  |
| --- | --- | --- |
|  |  | (20) |

where: is a parameter for the market-makers sensitivity to order-flow.

The expression for the volatility in this case is:

|  |  |  |
| --- | --- | --- |
|  |  | (21) |

### Price Volatility in Markets with Counterparty Risk

I modify the above model to include additional order-flow dynamics related to counterparty risk. Assume that when the current period’s order-flow is negative, there is additional sell-off of the risky asset in the next period due to (perceived) additional counterparty risk, and when the current period’s order flow is positive, there is additional buying of the risky asset in the next period due to (perceived) reduction in counterparty risk. The order-flow dynamics are now given by:

|  |  |  |
| --- | --- | --- |
|  |  | (22) |

Where:

The expression for the price chance becomes:

|  |  |  |
| --- | --- | --- |
|  |  | (23) |

|  |  |  |
| --- | --- | --- |
|  |  | (24) |

|  |  |  |
| --- | --- | --- |
|  |  | (25) |

|  |  |  |
| --- | --- | --- |
|  |  | (26) |

where I have used the fact on the 3rd line and that .

# Identification Strategy

## Pricing

I investigate the causal impact of the central clearing mandate on the interest rate swap prices by comparing the premium above the fair rate (that is, the difference between the “riskless fixed rate” described in 0 and the observed fixed rate on an actual contract) on USD denominated swaps versus the premium on CAD denominated swaps before and after the mandate. I employ a difference-in-differences (DiD) identification strategy, with the CAD denominated swaps acting as the control group, which allows me to plausibly isolate the causal effect of the mandate on the swap premiums by exploiting the variation in the timing of the policy implementation.

I begin by selecting a sample of interest rate swaps denominated in both USD and CAD from the ten trading days before and after the central clearing mandate was implemented. I create two groups based on the currency of denomination: (1) the treatment group, consisting of USD denominated swaps that were affected by the central clearing mandate, and (2) the control group, consisting of CAD denominated swaps that were not subject to the mandate during the same period. By comparing the swap premiums between these two groups before and after the mandate, I can plausibly identify the causal effect of the policy on swap premiums if both groups would have followed parallel trends in the absence of the clearing mandate.

To estimate the causal effect of the central clearing mandate on swap premiums, I employ a DiD regression model, which takes the following form:

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|  |  | (27) |

where is the swap premium for swap at time , is an indicator variable equal to 1 if the swap is denominated in USD (treatment group) and 0 otherwise (control group), is an indicator variable equal to 1 for the period after the mandate was implemented, and is a vector of control variables. The coefficient of interest is δ, which captures the causal effect of the central clearing mandate on swap premiums.

To ensure the validity of the identification strategy, I first test the parallel trends assumption by visually inspecting the pre-treatment trends of swap premiums for both treatment and control groups and conducting placebo tests. Additionally, I perform several robustness checks, such as using alternative control and experimental groups, and placebo DiD (described in the results section).

I begin by examining whether the parallel trends assumption holds by visually inspecting the swap rate (fixed rate of an interest rate swaps contract) prior to each phase of the implementation of the clearing mandate. I examine the three most common tenors of USD and CAD interest rate swaps (2-year, 5-year and 10-year swaps). The data is reported by Bloomberg and is usually the average of 11 or more contracts traded around 11:00 AM Eastern Time of the trading day that meet contract specifications (described earlier). Figure 4 shows these trends for the periods described above. The swaps rates show a parallel trend prior to the implementation of the clearing mandate, with the Canadian swaps rate being higher than the US rate. This is likely due to differences in key policy rates between the US (lower Fed Funds target rate 0%) and Canada (key policy rate target 1%). There was no change to these policy rates in 2013.

## Liquidity

Liquidity is a broad concept defined as how easily one can convert financial assets to cash with minimal impact to prices. Several measures try to capture this notion: *bid-ask spreads* measure the cost of trading (small quantities) of an asset at the best quoted sell and buy prices; *market depth* measures how much of an asset is available to trade at given price points; *price impact* measures how much prices react to buying and selling. As in the case of pricing (premium), I employ a difference-in-differences strategy to identify the impact of the central clearing mandate on liquidity, with CAD denominated contracts serving as the control group and USD denominated contracts serving as the treatment group. I use several measures of liquidity to capture the different notions of liquidity.

As discussed in section 3, risk-averse dealers adjust their bid-ask spreads in the face of market orders from liquidity traders. To be able to compare spreads for contracts with different prices, I calculate a relative bid-ask spread based on the contracts mid-price:

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|  |  | (28) |

where the numerator is the “raw” spread and the denominator is the mid-price. I collect end-of day bid and ask data from the Bloomberg terminal for US-dollar and Canadian-dollar denominated 2-year, 5-year and 10-year contracts for the ten-day trading period before and after the implementation of phase 1, phase 2 and phase 3 of the of the clearing regulation.

The bid-ask spread measure discussed above is “low frequency” and does not necessarily reflect the costs traders may face throughout the trading session. To estimate the intraday spread that traders may actually expernece, I use three proxies for the effective spread common in the literature. The first measure proposed by Roll (1984) estimates the effective spread using the time series of observed prices under assumptions of market efficiency:

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|  |  | (30) |

where is the first-order serial covariance of price changes. Two related measures of effective spread are presented by (Jankowitsch, Nashikkar, and Subrahmanyam 2011). The first, when mid-price data is available is:

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|  |  | (31) |

Secondly, when no mid-price data is available (as is the case for intra-day periods):

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|  |  | (32) |

where: is the number of contracts traded in period , is the notional volume of contract at period , is the total gross notional value in period , is the price of contract at period , is the end-of-period mid-price and is the average price of the contract in period . I calculate these measures for USD and CAD denominated contracts for two-, five- and ten-year tenors.

In general, market liquidity is a measure of “how easily” traders can exit or enter the market. The bid-ask spread is a common metric for how easily traders can enter or exit *small positions*. However, when trading larger positions, this liquidity may not be available (only a limited number of contracts may be available to trade at the best bid and ask prices, and dealers can change their quoted prices in the face of large market orders). A common measure of the “price impact” of a trade is the Amihud liquidity measure:

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|  |  | (29) |

where is the return on an asset at time and is the total volume of contracts traded (calculated as the sum of the gross notional contract value in period ). The Amihud liquidity measure, which normalizes inter-period price changes by the market size (volume) is a good measure of how much prices move, scaled by the trade size. As in the pricing section, I break up the trading day into four sessions and obtain the Amihud liquidity measure for US and Canadian two-year, five-year, and ten-year contracts.

For each liquidity measure discussed above, I run a simple difference-in-differences model:

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|  |  | (33) |

where is the liquidity measure of interest, is an indicator variable for whether the observation is in the treatment (US-dollar denominated market) or control (Canadian-dollar denominated market) group, is an indicator variable for whether the observation is in the post- or pre implementation period. is the parameter of interest.

For the identification strategy to be valid, the underlying variables must follow parallel trends if there was no intervention. I visually test this by plotting the time-series of the relative spread, Amihud measure, Roll measure and the two price dispersion measures for the twenty trading days before the period of the study. Figure \_\_ shows the path of this variable for 2-year, 5-year, and 10-year contracts for the US-dollar and Canadian-dollar denominated markets. As in the case for the price premium, the liquidity measures in the US and Canadian contracts generally follow a parallel trend before the implementation of the clearing mandate.

## Volatility

As is common practice in literature, I use the realized volatility as my measure of volatility. If the return on an asset in the period is defined as as:

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|  |  | (34) |

The (annualized) realized volatility of the return is then:

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|  |  | (35) |

where: is the number of trading days in the sample period and 252 is the approximate number of trading days in a year.

For each trading day, I select contracts with “whole number tenor years” between 1 and 10 years (that is, I exclude contracts that are “partial years” such as 18-, 21- and 30-month contracts), as well as 15- and 30-year contracts. For the Canadian market, these are the most actively traded contracts. Calculating volatility requires several observations of each tenor for each trading day. I group contracts by currency, tenor, and trading day (I exclude the Memorial Day and Labor Day holidays as too few contracts are traded on those days to calculate realized volatility). The filtered dataset captures 90% of Canadian contracts traded during the period of the study, and I can calculate volatility of several tenors for each trading day[[3]](#footnote-4). However, for several tenors (such as 4-year, 6-year, 8-year and 9-year contracts), no trades or only one or two trades occur in the Canadian market on certain dates, and I cannot calculate the volatility measure for that tenor for the Canadian-dollar denominated contract on that trading date. Ideally, I would have 24 observations for each of the 58 trading days (one for each currency, for each tenor between 1 and 10 years, 15 years, and 30 years). However, since no Canadian contract of a particular tenor is traded on certain dates, I end up with 914 observations in my data set.

Like liquidity and pricing calculations, I classify each observation as either in the control group (if currency is CAD) or treatment group (if currency is USD), and whether it is in the pre-treatment or post-treatment period. I then perform a difference-in-difference regression:

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|  |  | (36) |

where is the realized variance for contract specification in period and the rest of the variables are as described in the liquidity section. (the interaction between group and pre/post-treatment period) is the parameter of interest.

As with the other difference-in-differences specification, for the identification strategy to be valid, the two groups need to follow parallel trends in the absence of an intervention. I plot the time series (Figure \_\_) of the realized volatility measure for the 2-year, 5-year and 10-year contracts for the twenty trading days before the implementation of the clearing mandate. In general, the volatility measure follows a parallel trend for the US-dollar denominated and Canadian-dollar denominated markets.

# Data

The Commodity Futures Trading Commission's (CFTC) clearing mandate on IR swaps became effective on March 11, 2013. The regulation was implemented in three phases. Phase 1 mandated clearing for certain IR swaps involving swap dealers (SD), major swap participants (MSP), or active funds. Phase 2 extended the mandate to additional entities, including commodity pool operators, banks and other financial institutions, while Phase 3 covered all remaining entities (unless exempted, for example if the swap user is a non-financial entity that uses swaps to hedge commercial risk). The CFTC defined contract specifications for swaps that must be cleared. These specifications included the currency (USD, GBP, EUR, JPY), the contract tenor (28 days to 50 years for USD, GBP and EUR based contracts, 28 days to 30 years for JPY bases contracts), and the floating leg reference (LIBOR or EURIBOR). It also specified “negative” characteristics (that is, swaps having these characteristics do not need to be cleared) including no dual currencies, no conditional notional amount and no optionality. The IR swaps covered by the mandate were the largest categories by volume.

I compare prices, price volatility, and liquidity before in each of the three phases, comparing USD and CAD denominated swaps – the largest regulated and unregulated markets, respectively. To minimize the impact of interest rate policy and other macroeconomic variables, I analyze a small ten-day trading window before (Feb 25 – Mar 8, May 27 – Jun 7 and Aug 26 – Sep 6) and after (Mar 11 – Mar 22, Jun 10 – Jun 21 and Sep 9 – Sep 20) the regulation's effective date in each phase. The data are reported by the Depository Trust and Clearing Corporation Swaps Data Repository (DTCC SDR) and obtained using the SDR screen of the Bloomberg terminal. For the main part of the dissertation, I restrict my dataset to observations where the premium is within ±50 bps of the Bloomberg reported price of a swap with similar characteristics. Swaps that have a much higher premia are likely to have unseen characteristics (such as early termination clauses, conditional notional amounts, etc.) that are not observable in the dataset. In an appendix, I show that my results are robust to including these outliers.]

Note that before the regulation is passed, (voluntary) clearing in USD-denominated swaps is a little less than 61%. After phase 1 implementation, clearing increases to around 78%. After phase 2 implementation, clearing jumps to 89% and remains at that level after phase 3. The CAD-denominated market is much smaller (both in number of trades, and notional value). Clearing in Canadian IR swaps hovers around 48% prior to Phase 1. It reaches a high of around 56% in phase 2 and diminishes back to 48% after phase 3. Note that clearing in CAD denominated swaps is voluntary.

To calculate the theoretical counterparty-riskless price of IR swaps, I forecast future floating rate payments and discount the payments using the appropriate yield curve. I use a single curve method, the prevalent pricing method during the study period (subsequently, the market switched to a dual-curve method of pricing swaps, where one curve was used to calculate future floating-rate payments, and another curve to discount those payments to their present value). For USD swaps, I obtain the USD semiannual fixed-floating rate curve (curve S23) for each trading day from Bloomberg. I similarly obtain the Canadian yield curve (curve S\_\_) from the Bloomberg Terminal for pricing Canadian swaps.

I use the QuantLib-python library to construct the forward curve. For the USD swaps curve, the short-end (3M or less) of the curve is anchored by LIBOR rates; the medium-end (6M – 18M) of the curve is anchored by Eurodollar futures; and the long-end (24M onward) of the curve is anchored by US swap rates. Table 3 shows sample data for CAD and USD yield curves on September 11, 2013. Note that futures rates need to have a convexity adjustment applied since futures payoffs differ from payoffs for other instruments. The values reported in the table have this convexity adjustment applied. Values between the “pillars” (data points) of the yield curve need to be interpolated. I use piecewise linear interpolation. I verify the curve by pricing contracts using my constructed curve and comparing against calculations by Bloomberg SWPM function. I can match the output of SWPM up to 4 decimal places.

The contract characteristics reported in the DTCC SDR include swap currency, trade date and time, effective date, maturity date, fixed rate, payment frequencies, clearing status, notional value, and capped notional indicator. For USD swaps, USD LIBOR is the floating rate index for 98% of swaps, while for CAD swaps, CDOR is the index for 99% of swaps. I exclude certain swaps that make a single payment at maturity (i.e., payment frequency is 1T), which should actually be classified as an FRA. Table 4 shows the notional value and number of trades captured in my data, by clearing status and reference floating leg rate.

Table 5 shows summary statistics of the control variables used in the regression. Only contracts using LIBOR as the floating reference leg are included. Additionally, contracts that were “voluntarily cleared” prior to the mandate or “exempt from clearing” after the mandate are excluded. The leftmost column (unfiltered dataset) shows the statistics from this dataset. For the main part of the paper, I further filter this data to swaps whose fixed rate is within 50 bps of the Bloomberg calculated fixed rate. The rightmost column shows the statistics for this filtered dataset. Note that this filtering does not substantially alter the characteristics of the control variables. Wednesday was the most active trading day and Monday and Friday were the least active trading days. The dataset includes two trading holidays (Monday May 27, 2013 was Memorial Day and Monday, September 2, 2013 was Labor Day). I split the trading day into 4 sessions (corresponding roughly to the trading times on the NYSE) based on the reported trade time: 8:00 AM – 10:59 AM (Morning), 11:00 – 1:59 PM (Mid-Day), 2:00 PM – 4:59 PM (Afternoon) and 5:00 PM – 7:59 AM (After Hours). The mid-day trading session was most active. About 16% of contracts were traded during the off-hour trading session. The median notional value of the contract was $50M (with a range between $1,000 and $260M). The median tenor was about 7 years (with a range between 2 months and 43 years).

There are several limitations to the DTCC SDR dataset. Firstly, the dataset does not identify the counterparties. The identity of the counterparty (and more importantly, its creditworthiness) could have a significant impact on the swap price. In addition, the dataset does not mark which counterparty is the dealer (that is, whether the dealer is receiving the fixed rate or paying the fair rate). When receiving the fixed rate (and paying the floating leg), the dealer is likely to require a premium over the fair price. When paying the fixed rate, the dealer is likely to pay a discount below the fair price. I am also unable to observe non-standard contract characteristics such early termination previsions, collateral arrangements and day-count and settlement conventions. The standard-version of the interest rate swaps contract uses the International Swaps and Derivatives Association (ISDA) Master Agreement for specifying these contract terms. Deviations from the ISDA master agreement could affect the liquidity of the

Table 3: Sample data for USD and CAD yield curves

[Table 3 about here]

Table 4 Number of trades and notional value of USD and CAD denominated IR swaps

[Table 4 about here]

Table 5 Selected characteristics of control variables

[Table 5 about here]

# Results

## Prices

For analyzing the impact of the clearing mandate on prices, I compare the USD LIBOR denominated contracts against the CDOR contracts. The USD LIBOR contracts are subject to the CFTC clearing mandate (note that USD denominated contracts using another floating rate index such as the Federal Funds Rate is not subject to the clearing mandate, but these contracts can be voluntarily cleared.

Table 6 lists the DiD results for the swap premium. Column 1 shows a basic model without any controls for contract characteristics. The clearing mandate causes a ~14 bps rise in premia. As expected, reducing the riskiness of the contract increases its price. Column 2 shows the effects additional controls, such as the (log) notional value of the contract, day and period of trading and whether the notional value was “capped” (i.e. the exact value was not reported to the trade repo). In this model, premia rise by ~ 13 bps. Thus, the results are robust to such controls.

Using Wednesday as the reference level, I note that there is a 1-3 bps increase in the premium depending on the trading day. There is also a 1.0-1.3 bps decrease in the premium for trading in morning, afternoon or off hours trading sessions (as compared to mid-day). Note that both results contrast with assumptions of “efficient markets”, where there should be no arbitrage opportunities by trading during special days or times. A one-year increase in the tenor is associated with a 0.03 bps increase in the premium. A one percent increase in the notional value is associated with a 0.77 bps increase in the premium. Again, these result contrast with expectations from “efficient market” assumptions because arbitrage opportunities exist (for example, a dealer can make a riskless profit by agreeing to receive a fixed rate on a higher-priced a “large” contract and agreeing to pay the fixed-rate for two lower-priced “small” contracts). However, these differences could be related to liquidity or counterparty risk, or other contract characteristics of larger and longer swaps, which is not observable in our data. Although statistically significant, the magnitude of the effects are small, ranging from 0.03 to 3 bps.

Table 7 shows the result of running the simple model on each phase of the data separately. In phase 1, there is no effect of the clearing mandate on the premium. As noted previously, in phase 1, the clearing mandate only applied to a limited set of market participants (dealers, major swaps participants and active funds). Although the volume of contracts that were cleared increased after the phase 1, perceptions of counterparty risk apparently did not, likely due to the limited number of participants who were affected. In phase 2 and phase 3, a larger set of market participants fell under the mandate, and the premium increased, as would be expected if clearing diminished counterparty risk.

Table 8 shows the results from a placebo difference-in-differences regression. I pick the 20 trading days before the periods studied above (60 trading days in total across three phases). I create a “placebo” difference-in-differences, as if there was a transition to clearing mandate on Feb 11, May 13 and Aug 12. The results do not show any effect from this placebo DiD, further strengthening our belief that the increase in premia seen in the actual DiD is real.

Table \_\_ shows the results of analyzing an alternative currency pair. GBP-denominated contracts fell under the clearing mandate while CHF-denominated contracts did not. Similar to the USD-CAD comparison, GBP contracts show a ~7-8 bps rise in premia following the passage of the mandate.

Figure 4: Bloomberg Reported Swap Rates for USD and CAD denominated interest rate swaps. From left-to-right and top-to-bottom: 2-year swaps during phase 1 (implementation date Mar 11, 2014), phase 2 (implementation date June 10, 2013), and phase 3 (implementation date September 9, 2013); 5-year swaps during phase 1, phase 2 and phase 3; 10-year swaps during phase 1, phase 2 and phase 3

[Figure 4 about here]

Table 6 Difference-in-Difference Result

[Table 6 about here]

Table 7 By Phase DiD Results

[Table 7 about here]

Table 8 Placebo difference-in-difference

[Table 8 about here]

## Liquidity

Table 9 shows the results of difference-in-difference regression for the liquidity metric (bid-ask spread as a percentage of mid-price). Note that since the period of study is short (ten trading days before and ten trading after the clearing mandate implementation), and since liquidity is a “market wide”, rather than an individual contract-based measure, the opportunity to control for other variables that impact liquidity is limited. If a longer period were being studied, other variables that impact liquidity, such as monetary policy and credit availability could be added as controls. However, these variables do not change significantly during the short period studied.

The clearing mandate does not impact the liquidity as measured by bid-ask spreads. As noted in the theory section, we should expect reductions in counterparty risk of interest rate swaps to cause a narrowing of the bid-ask spread (the spread is charged by dealers to offset their expected losses from holding inventory). However, the spread is also driven by supply and demand conditions in the market. As explored in the pricing section, a reduction in riskiness of IRS increases their demand. If the swaps market is monopolistic (that is, new swaps dealers face barriers to entry), then incumbent dealers can choose not to lower their bid-ask spreads and pocket the additional profits from the high demand.

## Price Volatility

Table 10 shows the results of the price volatility difference-in-difference regression. Price volatility (as measured by realized volatility) is not affected by the clearing mandate. During “normal” trading periods, prices appear to follow a random walk, which makes it difficult to analyze the impact of the clearing mandate on volatility. Only during periods of market stress would we expect the volatility measure to behave differently in cleared vs. uncleared markets. However, since periods of market stress are unique events, this does not lend itself to difference-in-difference type analysis. As an alternative, I perform an “event study” type analysis, looking at the volatility in USD and CAD denominated contracts around the time of the (second) “Grexit” vote. Caution should be exercised when interpreting these results, as the “control group” (CAD contracts) have different exposure to the Greek economy than the “treatment” group. Nonetheless, we observe that the USD contracts had much lower price volatility during this period compared to CAD contracts.

# Conclusion

Conclusion goes here

Allen, Franklin, and Douglas Gale. 2000. “Financial Contagion.” *Journal of Political Economy* 108 (1): 1–33. https://doi.org/10.1086/262109.

Allen, Franklin, and Douglas M. Gale. 2007. “An Introduction to Financial Crises.” SSRN Scholarly Paper. Rochester, NY. https://doi.org/10.2139/ssrn.1008311.

Azad, A. S. M. Sohel, Victor Fang, and Chi-Hsiou Hung. 2012. “Linking the Interest Rate Swap Markets to the Macroeconomic Risk: The UK and Us Evidence.” *International Review of Financial Analysis* 22 (April):38–47. https://doi.org/10.1016/j.irfa.2012.03.001.

Bebchuk, Lucian A., and Itay Goldstein. 2011. “Self-Fulfilling Credit Market Freezes.” *The Review of Financial Studies* 24 (11): 3519–55. https://doi.org/10.1093/rfs/hhr086.

Benos, Evangelos, Wenqian Huang, Albert J. Menkveld, and Michalis Vasios. 2019. “The Cost of Clearing Fragmentation.” SSRN Scholarly Paper ID 3502465. Rochester, NY: Social Science Research Network. https://papers.ssrn.com/abstract=3502465.

Benos, Evangelos, Richard Payne, and Michalis Vasios. 2020. “Centralized Trading, Transparency, and Interest Rate Swap Market Liquidity: Evidence from the Implementation of the Dodd–Frank Act.” *Journal of Financial and Quantitative Analysis* 55 (1): 159–92. https://doi.org/10.1017/S0022109018001527.

Bernstein, Asaf, Eric Hughson, and Marc Weidenmier. 2019. “Counterparty Risk and the Establishment of the New York Stock Exchange Clearinghouse.” *Journal of Political Economy* 127 (2): 689–729. https://doi.org/10.1086/701033.

Biais, Bruno. 1993. “Price Formation and Equilibrium Liquidity in Fragmented and Centralized Markets.” *The Journal of Finance* 48 (1): 157–85. https://doi.org/10.1111/j.1540-6261.1993.tb04705.x.

Bicksler, James, and Andrew H. Chen. 1986. “An Economic Analysis of Interest Rate Swaps.” *The Journal of Finance* 41 (3): 645–55. https://doi.org/10.2307/2328495.

Bolandnazar, Mohammadreza. 2020. “The Market Structure of Dealer-to-Client Interest Rate Swaps.” SSRN Scholarly Paper 3752367. Rochester, NY: Social Science Research Network. https://doi.org/10.2139/ssrn.3752367.

Boudiaf, Ismael Alexander, Immo Frieden, and Martin Scheicher. 2024. “The Market Liquidity of Interest Rate Swaps.” SSRN Scholarly Paper. Rochester, NY. https://doi.org/10.2139/ssrn.4745740.

Brunnermeier, Markus K. 2009. “Deciphering the Liquidity and Credit Crunch 2007-2008.” *Journal of Economic Perspectives* 23 (1): 77–100. https://doi.org/10.1257/jep.23.1.77.

Capponi, Agostino, and Martin Larsson. 2015. “Price Contagion through Balance Sheet Linkages.” *The Review of Asset Pricing Studies* 5 (2): 227–53. https://doi.org/10.1093/rapstu/rav006.

Cifuentes, Rodrigo, Gianluigi Ferrucci, and Hyun Song Shin. 2005. “Liquidity Risk and Contagion.” *Journal of the European Economic Association* 3 (2–3): 556–66. https://doi.org/10.1162/jeea.2005.3.2-3.556.

Diamond, Douglas W., and Philip H. Dybvig. 1983. “Bank Runs, Deposit Insurance, and Liquidity.” *Journal of Political Economy* 91 (3): 401–19. https://doi.org/10.1086/261155.

Diamond, Douglas W., and Raghuram G. Rajan. 2011. “Fear of Fire Sales, Illiquidity Seeking, and Credit Freezes \*.” *The Quarterly Journal of Economics* 126 (2): 557–91. https://doi.org/10.1093/qje/qjr012.

Duffie, Darrell, and Haoxiang Zhu. 2011. “Does a Central Clearing Counterparty Reduce Counterparty Risk?” *Review of Asset Pricing Studies* 1 (1): 74–95.

Gai, Prasanna, and Sujit Kapadia. 2010. “Contagion in Financial Networks.” *Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences* 466 (2120): 2401–23. https://doi.org/10.1098/rspa.2009.0410.

Greenwood, Robin, Augustin Landier, and David Thesmar. 2015. “Vulnerable Banks.” *Journal of Financial Economics* 115 (3): 471–85. https://doi.org/10.1016/j.jfineco.2014.11.006.

Jackson, Matthew O., and Agathe Pernoud. 2021. “Systemic Risk in Financial Networks: A Survey.” *Annual Review of Economics* 13 (1): 171–202. https://doi.org/10.1146/annurev-economics-083120-111540.

Kiyotaki, Nobuhiro, and John Moore. 1997. “Credit Cycles.” *Journal of Political Economy* 105 (2): 211–48. https://doi.org/10.1086/262072.

Kleist, Karsten von, and C. Mallo. 2011. “OTC Derivatives Market Activity in the Second Half of 2010.” Bank of International Settlements. https://www.bis.org/publ/otc\_hy1105.pdf.

Liu, Jun, Francis A. Longstaff, and Ravit E. Mandell. 2006. “The Market Price of Risk in Interest Rate Swaps: The Roles of Default and Liquidity Risks.” *The Journal of Business* 79 (5): 2337–59. https://doi.org/10.1086/505237.

Loon, Yee Cheng, and Zhaodong Ken Zhong. 2014. “The Impact of Central Clearing on Counterparty Risk, Liquidity, and Trading: Evidence from the Credit Default Swap Market.” *Journal of Financial Economics* 112 (1): 91–115. https://doi.org/10.1016/j.jfineco.2013.12.001.

McPartland, John W. 2009. “Clearing and Settlement of Exchange Traded Derivatives.” *Chicago Fed Letter* 267 (2). https://fraser.stlouisfed.org/files/docs/historical/frbchi/policydiscussion/frbchi\_policy\_2009-02.pdf.

Minton, Bernadette A. 1997. “An Empirical Examination of Basic Valuation Models for Plain Vanilla U.S. Interest Rate Swaps.” *Journal of Financial Economics* 44 (2): 251–77. https://doi.org/10.1016/S0304-405X(97)00005-6.

Pirrong, Craig. 2011. “The Economics of Central Clearing: Theory and Practice.”

Rochet, Jean-Charles, and Jean Tirole. 1996. “Interbank Lending and Systemic Risk.” *Journal of Money, Credit and Banking* 28 (4): 733–62. https://doi.org/10.2307/2077918.

Roll, Richard. 1984. “A Simple Implicit Measure of the Effective Bid-Ask Spread in an Efficient Market.” *The Journal of Finance* 39 (4): 1127–39. https://doi.org/10.1111/j.1540-6261.1984.tb03897.x.

Skarr, Doug, and Kristin Szakaly-Moore. 2007. “Understanding Interest Rate Swap Math & Pricing.” California Debt and Investment Advisory Commission. https://www.treasurer.ca.gov/cdiac/publications/math.pdf.

Smith, Clifford W., Charles W. Smithson, and Lee Macdonald Wakeman. 1988. “The Market for Interest Rate Swaps.” *Financial Management* 17 (4): 34–44. https://doi.org/10.2307/3665765.

Sun, Tong-sheng, Suresh Sundaresan, and Ching Wang. 1993. “Interest Rate Swaps: An Empirical Investigation.” *Journal of Financial Economics* 34 (1): 77–99. https://doi.org/10.1016/0304-405X(93)90041-9.

1. The principal is “notional” because unlike a real bond it is never exchanged. It is only used to calculate fixed and floating rat payments. [↑](#footnote-ref-2)
2. The clearing counterparty is usually a dealer who is a clearing member at the CCP. “A clearing member is usually a trade intermediary that can deal directly with the CCP. Trade intermediaries that are not clearing members must clear their trades through a trade intermediary that is a clearing member” (McPartland 2009). Trade intermediaries that are clearing members will collect collateral from their non-clearing member clients and pass it on to the CCP. [↑](#footnote-ref-3)
3. I exclude discussion regarding the data availability of US-dollar denominated contracts. In general, there are enough contracts traded for each trading day and contract specification that a realized volatility measure can be calculated for each. The availability of data for the US market is not a limiting factor in my analysis. [↑](#footnote-ref-4)