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COUNTERPARTY RISK AND THE ESTABLISHMENT OF THE NEW YORK STOCK
EXCHANGE CLEARINGHOUSE

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ABSTRACT

Heightened counterparty risk during the recent financial crisis has raised questions about the role clearinghouses play in global financial stability. Empirical identification of the effect of centralized clearing on counterparty risk is challenging because of the co-occurrence of macro-economic turbulence and the introduction of clearinghouses. We overcome these concerns by examining a novel historical experiment, the establishment of a clearinghouse on the New York Stock Exchange (NYSE) in 1892. During this period the largest NYSE stocks were also listed on the Consolidated Stock Exchange (CSE), which already had a clearinghouse. Using identical securities on the CSE as a control, we find that the introduction of clearing reduced annualized volatility of NYSE returns by 90-173bps and increased asset values. Prior to clearing, shocks to overnight lending rates reduced the value of stocks on the NYSE, relative to identical stocks on the CSE, but this was no longer true after the establishment of clearing. We also show that at least $\frac{1}{2}$ of the average reduction in counterparty risk on the NYSE is driven by a reduction in contagion risk – the risk of a cascade of broker defaults. Our results indicate that clearing can cause a significant improvement in market stability and value through a reduction in network contagion and counterparty risk.

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“For more than a century, financial stability has depended on the resilience under stress of clearinghouses and other parts of the financial infrastructure. As we rely even more heavily on these institutions in the United States and around the world, we must do all that we can to ensure their resilience, even as our financial system continues to evolve rapidly and in ways that we cannot fully predict.”

– Federal Reserve Chairman Ben Bernanke April 4, 2011

1 Introduction

On September 14th, 2008 dealers from every major Wall Street firm involved in the \$600 trillion over-the-counter (OTC) derivatives market came into work on a Sunday for an unprecedented emergency trading session. The goal? A frantic effort the day before Lehman Brothers declared bankruptcy to try and net counterparty risk in their bilateral over-the-counter contracts with Lehman and limit the knock-on losses of its collapse on other financial institutions. Lehman’s global OTC derivatives position at the time was estimated at \$35 trillion in notional, which included being a counterparty in 930,000 derivatives transactions representing \$24 billion in counterparty liabilities¹. This ad-hoc attempt at clearing was described by market participants as “a bust”, with very little successful netting prior to Lehman’s bankruptcy filing². The result was an unprecedented rise in counterparty risk, contagion, and financial instability among global financial market participants exemplified by a dramatic increase in indicators of counterparty risk including the credit default swap-bond basis and deviations from covered interest rate parity³.

The collapse of Lehman Brothers and the subsequent spillovers raised concerns about the role counterparty risk plays in the stability of the financial system and the importance of clearinghouses in mitigating that risk. In particular, policymakers in the United States and European Union have tried to address counterparty risk concerns not only by substantially increasing counterparty risk-based capital requirements for banks with Basel III, but also by mandating centralized clearing of the majority of OTC derivatives via the Dodd-Frank and European Markets Infrastructure Regulation Acts. Prior to Lehman’s collapse, OTC derivatives were not required to engage in multilateral net settlement through a centralized clearinghouse and

¹ Lehman Brothers Holdings Inc. First Creditors Section 341 Meeting, January 29, 2009, Summe (2012), and their most recent 10Q filing on July 10th, 2008.

² Financial Times, “Dealers hold emergency trading session”, September 15, 2008.

³ Levich (2011) and Giglio (2013)

often relied on bilateral netting and ad-hoc margin requirements between counterparties. Under bilateral netting, traders can be exposed to additional counterparty risk through contagion, since if one trader defaults he can set off a cascade of additional defaults. All else being equal, when OTC derivatives contracts instead engage in multilateral netting, Cecchetti et al. (2009) estimate that gross notional exposures can be reduced by as much as 90 percent. Policy makers point to these potential ex-post netting benefits and the rise in counterparty risk concerns after Lehman's bankruptcy as evidence that mandated OTC derivative clearing would reduce the probability of an initial default as well as counterparty risk arising from contagion.

Despite the response of policymakers, academic evidence of the effects of clearing on financial stability and asset values are still unclear. From a theoretical standpoint Duffie and Zhu (2011) demonstrate that a single party clearing all assets should reduce counterparty risk, *ceteris paribus*, leading to lower volatility and higher asset value, but this result does not generalize to multiple clearinghouses or a single clearinghouse that doesn't clear all transactions. Acharya and Bisin (2014) establish that in the absence of a clearinghouse there can be a counterparty externality which encourages excess risk taking, but Pirrong (2009) shows that a clearinghouse itself can reduce monitoring incentives which subsequently increases moral hazard and counterparty risk. Biais et al. (2012) also note that a reduction in idiosyncratic risk from clearing may endogenously increase systematic risk taking and Menkveld, et al. (2013) point out that if the introduction of clearinghouse causes increases in collateral and margin requirements, then the effect of funding and market liquidity on asset prices makes the response of prices theoretically ambiguous (Garleanu and Pedersen 2011). Therefore, the effect of the introduction of a clearinghouse on asset prices remains inevitably an empirical question.

Unfortunately, empirical evidence on the role of clearing is still limited and the effects on counterparty risk are mixed. Examining the introduction of a clearinghouse for Nordic equities in 2009, Menkveld et al. (2013) find that clearing reduces asset values, but Loon and Zhong (2013) show that the clearing of credit derivative contracts in 2009 actually increased their values. Interpretation of these critically important and opposing empirical results can be challenging because in both cases clearing was driven by the collapse of Lehman Brothers in the fall of 2008 and the resulting financial crisis. It is hard to know if the introduction of a clearinghouse in those markets was co-incident with the subsequent deterioration or improvement in fundamental value and risk of those securities chosen to be cleared. It is precisely because the introduction of the clearinghouse was a response to a crisis that makes it problematic to attribute any changes in liquidity or counterparty risk to the clearinghouse and why it is important to control for economic conditions.

Fortunately, history provides an experiment to study the effects of a clearinghouse on counterparty risk where we can directly control for fundamental value. During the late 19th and early 20th centuries, the Consolidated Stock Exchange (CSE) was a major exchange that competed head-to-head with the Big Board, traded many NYSE-listed securities, and averaged more than a 50 market percent share during the 1890s. Located across the street from the NYSE, the CSE netted stock transactions through a clearinghouse starting in 1886, while the NYSE did not until May of 1892. Using exactly the same securities on the same dates, we compare relative prices on the NYSE with those on the CSE both before and after the introduction of the NYSE clearinghouse which allow us to control for changes in fundamental security value and volatility. This allows for clean identification of the causal effect on asset prices of the introduction of the clearinghouse by controlling for economic conditions in a way that is difficult to replicate with modern data⁴. We also examine the relative prices for more than 30 years following the introduction of clearing allowing us to observe the behavior during periods of relative calm and crisis, as well as allowing time for endogenous general equilibrium effects by market participants.

We find that the introduction of netting on the NYSE increased the value of stocks relative to the CSE by 24bps. Consistent with the findings in McSherry et al. (2013), who document a decline in broker defaults on the NYSE after the introduction of clearing, the empirical results suggest that clearing increases rather than reduces equity values. Because brokers had to fund positions overnight, daily borrowing rates were a major determinant of counterparty risk. Prior to the introduction of clearing, a one standard deviation (3.7 percentage point) increase in the overnight collateralized borrowing rate for brokers, also known as the call loan rate, is associated with an 8bp decline in the value of a stock on the NYSE relative to the identical security on the CSE. After the introduction of clearing, shocks to the call loan rate no longer affect prices on the NYSE relative to the CSE, suggesting a decline in the volatility of NYSE prices. Consistent with this prediction, we find that relative to the CSE, annualized NYSE return volatility is reduced by 90-173bps immediately following the introduction of clearing and remains low, even during subsequent financial crises, in the subsequent 34 years.

Clearing on the NYSE was also introduced in stages, so we also examine the staggered introduction and find that at least half of the average reduction in counterparty risk is driven by a reduction in contagion risk through spillovers in the trader network. We run a series of robustness tests to demonstrate that our results are driven by changes in counterparty risk coming from the

⁴ The beginning of multilateral net settlement through a clearinghouse on the NYSE in 1892 was driven by a variety of factors, most notably financial panics in the early 1890s (McSherry and Wilson 2013). This again highlights the need to use the CSE as a control to cleanly identify the effect of counterparty risk.

introduction of clearing, rather than changes in asynchronous trading, market liquidity improvements on the NYSE, a decrease in market liquidity on the CSE, or financial crises. Our results do not hold without the CSE control, demonstrating again the importance of controlling for macro-economic changes in fundamental value and volatility co-incident with the introduction of a clearinghouse. We also find that the introduction of mutualization of risk and a formal centralized counter party (CCP) by the NYSE clearinghouse in April of 1920 does not alter the benefits found from the introduction of centralized clearing with multi-lateral netting in 1892, providing additional evidence consistent with a role for CCPs in improving financial stability in asset markets.

Section 2 begins with a brief historical background on the introduction of clearing on the NYSE. We describe the data used in Section 3. In Section 4, we present the empirical methodology and predictions. We discuss the empirical results in Section 5. Section 6 concludes the paper.

2 Historical and Institutional Background

2.1 Trading on the NYSE Prior to Clearing

Like OTC derivatives today, NYSE equities settled on a bilateral rather than a multilateral basis prior to the introduction of a clearinghouse in 1892. In the absence of multilateral netting, brokers are required to write and receive checks/securities for every transaction. To illustrate, consider the hypothetical set of transactions in Example 1.

Example 1. Visual representation of bilateral trades between 3 brokers



Next day deliverables:
Shares: 200
Cash: \$20,100

Broker A sells 100 shares of stock for \$10,000 (\$100/share) to broker B and later in the day B sells 100 shares to C for \$10,100. In the absence of multilateral netting, broker C owes a check to broker B for \$10,100 and broker B would owe a check to broker A for \$10,000 resulting in \$20,100 of checks and 200 shares of stock being transferred. There are direct counterparty risks since, for example, if broker B defaults (and has no wealth) broker A loses \$10,000, but there is also a possibility of large spillovers causing contagion counterparty risk throughout the trading network. For example, if broker C defaults (and has no wealth) broker B loses \$10,100. If in

turn this pushes broker B into default (and again has no wealth) then A loses \$10,000. As we add more brokers into the network, the chain of defaults can multiply. Depending on how interconnected the trading network is, the spillover from contagion could be a substantial component of total counterparty risk. Eliminating counterparty risk for security A should also reduce the counterparty risk of security B even if it is unrelated because there is less chance of a broker, or brokers he is trading with, defaulting on positions. For clarity we refer to the counterparty risk caused by network spillovers as *contagion risk* and the remaining as *direct counterparty risk*.

At the time the NYSE clearinghouse was introduced, securities traded on the NYSE settled at time T+1, which meant all brokers were required to deliver gross checks/securities from trades by the next day at 2:15pm. Brokers engaged in transactions with numerous other brokers throughout the day, so they rarely had enough assets on hand to pay every single transaction. Customers also bought securities on margin so brokers would often have to borrow the additional funds necessary. Therefore, banks were forced to extend significant credit and day loans to brokers to allow them to fulfill their daily contracts. Brokers trading on behalf of customers trading on margin would hold the stock as collateral and these would then be used as collateral for short-term loans from banks. This practice was called overcertification since banks endorsed checks which certified an amount greater than the balance in the broker's account⁵, effectively providing short-term leverage to brokers to finance their daily positions. This bears a very strong similarity to modern broker-dealers who use the repo market and asset-backed commercial paper to provide short-term financing for trades in the OTC markets. McSherry and Wilson (2013) find that leverage, measured as the value of certified checks divided by total capital, for 9 "broker banks" increased from 1.4 to 9.0 from 1875 to 1882. Anecdotal evidence suggests even higher leverage ratios in the 1890s.

Just as short-term collateralized financing rates in the modern period are set by repo rates, the overnight collateralized borrowing rate to buy and sell securities on margin was known as the call loan rate in the late nineteenth and early twentieth century. The call loan rate could fluctuate wildly depending on the market environment. Short-term interest rates were prone to seasonal increases during the harvest months and tended to increase dramatically during late nineteenth and early twentieth century banking panics (Miron 1986, Bernstein et al. 2010). For example, the call loan rate reached a daily annualized value of 125 percent during the Panic of 1907 (Moen and Tallman 2003).

⁵ While technically illegal overcertification was endemic during the period and used by most brokers and banks to finance their overnight positions.

The volatility of funding costs to finance overnight positions led to a significant number of broker defaults and increased counterparty risk. McSherry et al. (2013), citing Michie (1986), succinctly summarize the counterparty risk problems on the NYSE and relationship with call loan rates:

“The daily settlement system tended to exaggerate crises. The short time before payment was due meant that it was difficult for either bankers or brokers to take measures to avoid crisis. Any tightening of the money available on the call-loan market had an immediate and all-embracing impact, since almost all borrowings were for day-to-day money. If stocks could not be immediately liquidated, or if prices dropped to the extent that loans were no longer covered, the brokers would be unable to repay the banks. For example, in 1890, when Decker, Howell & Co. failed, the Bank of North America had to suspend operations, leading to a general restriction of credit.”

Consistent with this description, McSherry et al. (2013) find evidence of a statistically significant relationship between spikes in call loan rates and broker insolvencies during this period.

Contemporaneous researchers, such as Sprague (1903), also blamed the immediacy of the liquidity requirements inherent in the NYSE system of daily settlement for broker failures; which tended to spike during periods of financial stress. During periods of panic buyers might walk away from buy orders, leaving brokers with losses and potential defaults on overcertified checks. Anticipating this outcome, Wall Street banks and trust companies that normally participated in overcertification might withdraw the privilege extended to brokers. This is exactly what happened in the Panic of 1873 when banks suspended overcertification to NYSE brokers. This action led to a suspension of trading for nine days and 57 broker failures (Eames, 1894). By early 1892, R. L. Edwards, the President of the Bank of the State of New York, threatened that certification for brokers would be cut unless decisive action was taken to lessen the strain on bank lending and clerks⁶. NYSE President Francis L. Eames subsequently pushed for the creation of the New York Stock Exchange Clearinghouse in May of 1892 (Pratt 1909) which engaged in multi-lateral netting across all NYSE members.

The NYSE clearinghouse function would then be extended in April of 1920 to include mutualization of risk by acting as a centralized counterparty on trades between all members. The staggered timing of the introduction of centralized clearing and then mutualization of risk provide an interesting setting to try and distinguish the effects of the two major functions of modern clearinghouses. The analysis in 1920 is made more challenging though since accusations of fraud on the Consolidated Stock Exchange in February of 1922, which led to its eventual downfall,

⁶ Meeker (1922) also documents that without the introduction of multilateral netting, it would have been physically impossible to maintain daily settlement. If, however, physical constraints rather than counterparty risk were the main reason for the introduction of multilateral netting, a perhaps more plausible response would have been to increase the settlement period.

limit our identification strategy in the post-mutualization period. We therefore focus our primary analysis on the introduction of clearing in 1892, but briefly examine the introduction of mutualization in 1920 as well.

2.2 Timing of Introduction of Clearing on the NYSE

On May 17th, 1892 the New York Stock Exchange introduced multilateral netting for four firms. The decision to introduce clearing was driven by the financial panics of the early 1890s, concerns that banks would restrict overcertification again, as well as evidence on the effectiveness of multilateral netting used on the Consolidated Stock Exchange⁷. Because many NYSE stocks were already clearing on the Consolidated Exchange, we can disentangle the effects of economic events from the effects of clearing on counterparty risk. As indicated in the clearinghouse meeting minutes, the NYSE had pre-scheduled meeting dates and decided “the list of stocks to be cleared will be enlarged as members become familiar with the clearing system.” Since having some NYSE stocks clearing had spillover benefits through a reduction in contagion risk for the remainder, the staged and independent timing of the introduction multilateral netting for different securities allows separate identification of contagion and direct counterparty risk. The NYSE continued to have meetings and clear additional stocks throughout the 1890s and by the end of 1893, most of the major securities were clearing⁸.

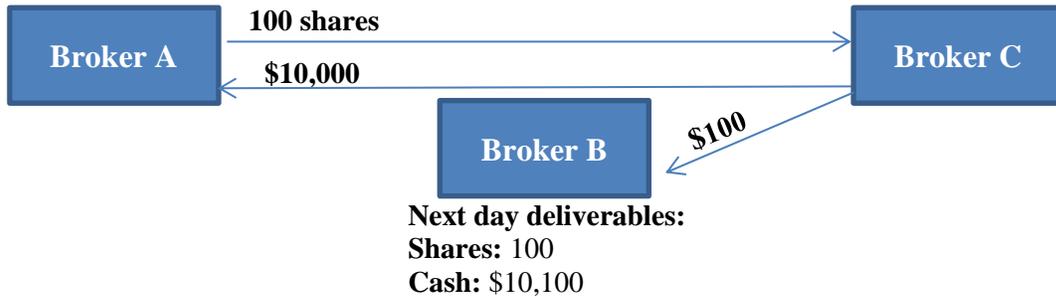
2.3 Trading on the NYSE after Clearing

To understand the benefits of the introduction of clearing on the NYSE, we examine multilateral netting between three brokers. A hypothetical set of transactions is shown in Example 2.

⁷ In fact, by 1892 there were numerous examples of effective clearing systems in the United States, including the establishment of a clearinghouse for New York City bank deposits in 1853 (Gorton 1985) and for commodity trading on the Chicago Board of Trade in 1883 (Kroszner 1999).

⁸ For example, by the end of 1893 more than 80% of NYSE volume in Dow Jones stocks was clearing.

Example 2. Visual representation of trades between 3 brokers w/ clearing



Each transaction a broker made was recorded on the broker's clearance sheet for a given day. In our example, A's clearance sheet had a single sale, C's clearing sheet had a single purchase, and B's clearance sheet had a purchase and a sale. It is at this stage that netting occurred – and here, netting occurred only for B. B bought 100 shares for \$10,000 and then immediately sold them for \$10,100⁹. The purchase and sale were netted out and B received the difference of \$100. Broker A had a balance to deliver 100 shares valued at \$10,000 and C had a balance to deliver of \$10,100. Therefore, A wrote a draft on the Clearinghouse of \$10,000; B wrote a draft for \$100, and C wrote a check to the Clearinghouse of \$10,100. By 10:00 a.m. the next day, the Clearinghouse returned a complete statement to each firm, specifying to whom a delivery must be made by 2:15 p.m. that day (here A delivered to C). Creditors to the Clearinghouse received checks for their remaining balances by noon, which were then deposited in the bank (American Bankers Association 1910)¹⁰.

Under gross bilateral clearing, there were \$20,100 worth of checks and 200 shares which could be defaulted on, but after multilateral netting there were only \$10,100 worth of checks and 100 shares to be transferred. In this case there is a reduction in direct ex-post counterparty risks since with multilateral netting, if broker B defaulted (and had no wealth) broker A lost nothing. There was also a reduction in spillovers causing contagion counterparty risk throughout the trading network. For example, if broker C defaulted (and had no wealth) broker A lost \$10,000 and if broker A defaulted (and had no wealth) broker B lost only \$100. With multilateral netting, typically the chain of defaults does not grow as quickly as it would with bilateral netting when we add more brokers into the network.

⁹ This simple example overlooks one complication. In reality for ease of netting, delivery prices were not simply what one paid or sold his or her shares for, but were instead determined by the Clearinghouse. At the end of each day, representatives set a price based on the quotation of the last day's sales, which was then announced over the ticker. Small additional checks were then written between parties to account for the differences between the delivery prices and the actual executed prices (Pratt 1909).

¹⁰ These exact times may have varied throughout the years, but they provide a rough picture of the daily operations of the Clearinghouse.

Anecdotal evidence suggests that the NYSE clearinghouse may have been successful in reducing counterparty risk on the NYSE in the years immediately following its establishment. In the post clearinghouse period (i.e. between 1892 and 1920), it has been estimated that the demand for day loans from certifying banks decreased by nearly 65 percent, and 90 percent of all checks were eliminated (Pratt 1909). On average, transactions in securities valued at \$25 million necessitated only \$5 million to change hands. In one case, 204,000 shares, valued at \$12.5 million were settled by a payment of only \$10,000 (Meeker 1922). NYSE president Frances Eames even noted that

“Bank officers have expressed the opinion that, during the Panic of 1893, failures in the Stock Exchange would have been vastly more numerous had there been no clearing system in operation...it was thought by some that, without the clearing system, the panic of that summer [1893] would have necessitated the closing of the Exchange” (statements by Frances Eames in 1894 and 1896)

Consistent with the contemporaneous accounts, McSherry et al. (2013) find that the average number of broker defaults declined from 1.96/month to 0.58/month following the introduction of netting through the clearinghouse. That being said, anecdotal evidence of the effect of multi-lateral netting on counterparty risk through contagion is mixed. The Chicago Board of Trade introduced a “ring” settlement system in 1883 similar to the one introduced on the NYSE and in 1902 the bankruptcy of member George Phillips led to losses for more than 42 percent of members of the Board (Kroszner 1999, Moser 1998). Direct measures of broker insolvencies also may not necessarily provide the full picture, since changes in counterparty risk caused by a clearinghouse could lead to differences in margin requirements, borrowing rates, and commissions between customers, brokers, and/or banks. The aggregate effect of all these channels should show up in prices, either through expected losses from counterparties or changes in the discount rate coming from volatility in counterparty risk and/or margin-driven asset pricing changes (Garleanu and Pedersen 2011). Another challenge in interpreting effects is controlling for the counterfactual changes in broker defaults and security value and volatility in the absence of a clearinghouse.

2.4 Consolidated Stock Exchange: An Ideal Control

As illustrated in the timeline in figure 1, the Consolidated Stock Exchange, also known as the “Little Board,” was established in New York City in 1885 with 2,403 members and provides an excellent control for our difference-in-difference analysis of the effect of the introduction of clearing. The Little Board competed head-to-head with the NYSE (Michie 1986). The rival

exchange averaged a respectable 23 percent market share (Brown et al. 2008) over its 40-year history although CSE stocks generally had less trading volume and market liquidity than the same security on the Big Board. While the NYSE waited until 1892 to introduce clearing, the CSE began multilateral net settlement in 1886. As noted by McSherry and Wilson (2013), one reason that the NYSE introduced clearing was that the CSE had “reduced financing needs and also lowered counterparty risk and broker defaults” by netting through a clearinghouse. They noted that:

“When the stringency came [in the panic of 1890 and 1891], many failures resulted from the impossibility of procuring the necessary loans. On the other hand, on the Consolidated Stock Exchange of New York, the failures were comparatively few... This difference was ascribed solely to the fact that one institution attempted to carry on its business by old fashioned methods, while the other was equipped with a modern clearing system. The explanation is easily accepted with the comparative ease with which the Stock Exchange has weathered similar troubles since the clearinghouse was adopted.”

We hand-collected information on broker defaults from the *Annual Reports of the Consolidated Stock and Petroleum Exchange of New York*. Consistent with the contemporaneous accounts, the CSE clearinghouse was successful in minimizing counterparty risk. We find that losses from broker defaults were less than 0.03% of total trading volume in 1893, a year that included one of the most severe financial panics in American history.

Therefore, prices on the CSE for NYSE-CSE dual-listed stocks provide an almost ideal control for the price response on the NYSE to the introduction of clearing. This is why the introduction of clearing on the NYSE can be used to identify the causal effects of multilateral netting. In addition to having cross-listed securities, we also benefit from the close proximity of the two exchanges. Since the two exchanges were across the street from each other, arbitrageurs could effectively prevent price discrepancies between the two exchanges not caused by “real differences” such as market illiquidity or counterparty risk premia. Nelson (1907) dedicates an entire chapter to the “expertise” of arbitrageurs on the Consolidated who were, he felt, only exceeded in their expertise by the arbitrageurs on the NYSE. Another benefit of their close proximity is that both exchanges paid in the same currency. Cross-listed securities in markets quoted in different currencies are confounded by the need to convert currencies using OTC foreign exchange (FX) markets. Normally this is not problematic, but since these markets are OTC, during times of financial distress, FX swaps may also include potentially significant counterparty risk. For example, Levich (2011) shows that immediately following the Lehman

bankruptcy covered interest rate parity in the highly liquid FX swap GBP/USD deviated from no arbitrage conditions (in the absence of counterparty risk) by hundreds of basis points¹¹.

3 Data Description

3.1 Security Market Data

We focus our empirical analysis on common stocks in the Dow Jones Indices using monthly data from September 1886 – December 1925 because these securities tended to be very liquid and traded on both the NYSE and CSE (Brown et al. 2008). We use the original Dow Jones Index from September 1886 until October 1896, when the index is then split into the Dow Jones Railroad Index and the Industrial Index. We use hand-collected data from the *New York Times* and *Commercial and Financial Chronicle* for each security in the index at a given point in time and rely on Farrell (1972) for changes in the composition of the indices. Data are sampled from the last trading day of each month. We collected firm-specific information on NYSE high, low, open, and closing transaction prices, bid and ask closing prices, and trading volume. For NYSE stocks listed on the CSE, we use data on CSE closing prices as well as CSE trading volume. We also use hand-collected monthly data on seat prices for the NYSE and CSE for the period 1888-1925 from the *Commercial and Financial Chronicle*. In addition, we collect daily closing bid and ask quotes on the NYSE starting in 1893¹². We also use end-of-month broker call loan rates from the NBER macro-history database for the entire sample period.

For robustness checks, we hand-collected daily data on high, low, close, and open transaction prices as well as trading volumes from January 1892- December 1901 for all stocks on both exchanges. We construct an absolute difference estimator using daily high, low, open, and closing transaction prices to estimate CSE bid-ask spreads and NYSE bid-ask spreads prior to 1893. Our estimated NYSE bid-ask spreads have an 88 percent correlation with actual bid-ask spreads on the Big Board from 1892-1925. Our estimator performs slightly better in-sample than

¹¹ Another benefit of proximity, besides the ones previously emphasized, is that since both exchanges were in the same time zone, daily data on opening and closing prices are easily comparable. This is not only because it reduces timing mismatches in the quotes, but also because they are comparable periods of the trading day. Oftentimes opening and closing price behavior can behave differently and while high frequency quotes allow for quotations across time zones at the same time of day this can't be done while also preserving the period of the trading day considered.

¹² Beginning on May 24, 1882, the *New York Times* reports NYSE bid-ask spreads on a daily basis. The data on daily bid-ask spreads continue through April 14, 1886. Between April 15, 1886, and May 12, 1893, the *New York Times* does not report bid-ask spreads for the NYSE. In this time interval, we gather monthly bid-ask spread data from the *Commercial and Financial Chronicle*. The bid-ask spread data are reported for Thursday trading and are matched with the appropriate trading volume data from the *New York Times*.

one used by Corwin and Schultz (2012), which has an 81 percent correlation with actual NYSE spreads over the same period. In addition, our estimator has the desirable property, since unlike that used by Corwin and Schultz, it is always positive, which was not the case for our Corwin-Schultz bid-ask estimates in our sample period. For more details on the methodology and a comparison of the bid-ask spreads see appendix A.

3.2 Clearinghouse Data

The NYSE started clearing securities in stages, beginning with four stocks in May 17th, 1892, followed by four additional stocks each week. By 1894, more than 90 percent of volume was cleared on the exchange and only a handful of stocks were added to the clearinghouse each year. The dates stocks were added and dropped from clearing on the NYSE were reported in the minutes of the *Committee on the Clearinghouse of the New York Stock Exchange* at the New York Stock Exchange archives. The minutes of the clearinghouse were useful for understanding the function and implementation of netting trades on the exchange. Data on broker defaults on the NYSE were collected from the NYSE archives *Committee on Admissions* and *List of Suspended Members*. Information on CSE broker defaults were collected from the *Annual Reports of the Consolidated Stock and Petroleum Exchange of New York*.

4 Empirical Methodology

4.1 Model

In the presence of counterparty risk and market liquidity costs, we can write the price of an asset as its fundamental value minus market liquidity costs and counterparty risk plus market microstructure effects:

$$P_{i,t,E} = P_{i,t}^{Fun} - P_{i,t,E}^{MktLq} - P_{i,t,E}^{CP} + \epsilon_{i,t,E} \quad (1)$$

where $P_{i,t,E}$ is the price on exchange E (either NYSE or CSE) for stock i at time t , $P_{i,t}^{Fun}$ is the firm fundamental value, which is independent of exchange, $P_{i,t,E}^{MktLq}$ is the discount caused by the market illiquidity premia which include both the explicit and implicit costs of trading¹³ and how they co-vary with the pricing kernel (Acharya and Pedersen 2005, Brunnermeier and Pedersen

¹³ The explicit costs includes commissions and the bid-ask spread, while implicit costs include price movement from larger orders (market depth) and borrowing costs to finance the trading position (margin).

2009, Garleanu and Pedersen 2011), $P_{i,t,E}^{CP}$ is the discount caused by the counterparty risk premium, and $\epsilon_{i,t,E}$ is market microstructure noise with mean zero, such as bid-ask bounce.

Therefore, for stocks on the NYSE,

$$P_{i,t,NYSE} = P_{i,t}^{Fun} - P_{i,t,NYSE}^{MktLq} - P_{i,t,NYSE}^{CP} + \epsilon_{i,t,NYSE}.$$

The expected change in the NYSE price after the introduction of clearing is therefore the change in the stock price caused by changes in the fundamental value and changes in the expected market illiquidity and counterparty risk premia, or equivalently:

$$E[\Delta P_{i,NYSE}] = E[\Delta P_i^{Fun}] - E[\Delta P_{i,t,NYSE}^{MktLq}] - E[\Delta P_{i,t,NYSE}^{CP}]. \quad (2)$$

Furthermore, if we assume that the expected market illiquidity premium is the same before and after the introduction of multilateral netting, which we will examine later explicitly, we can rewrite (2) as:

$$E[\Delta P_{i,NYSE}] = E[\Delta P_i^{Fun}] - E[\Delta P_{i,t,NYSE}^{CP}], \quad (3)$$

where expected changes in price are driven by changes in expected fundamental value and the counterparty risk premium.

We are interested in estimating $E[\Delta P_{i,t,NYSE}^{CP}]$, the change in the counterparty risk premium caused by the introduction of multilateral netting. If the introduction of the clearinghouse were exogenous, we could simply estimate a panel regression

$$P_{i,t,NYSE} = \alpha_i + D1_{\{clear,i,t\}} + \epsilon_{i,t}, \quad (4)$$

where $1_{\{clear,i,t\}}$ is a dummy variable indicating when a stock starts clearing and D is the average treatment effect of clearing on the stock price. The problem, as shown in equation (3), is that if the introduction of clearing coincides with changes in the fundamental value of the firm, omitted variables could be driving results and causal interpretation of D as the effect of clearing on counterparty risk is no longer valid. In other words, since the introduction of multilateral netting through clearing is typically driven by or coincident with financial crises and other major market events any changes in firm value could be driven by the events rather than any changes caused by the introduction of clearing. For example, the introduction of clearing on the NYSE was driven, in part, by financial panics in the early 1890s (McSherry and Wilson 2013). Without an alternative identification strategy, it would be impossible to identify the effect of the introduction of the NYSE clearinghouse. Fortunately, our historical experiment provides a unique opportunity to do exactly this.

4.2 Dual-Listed Security Prices on CSE as a Control

Ideally, to determine the effect of clearing on counterparty risk, we would have prices for identical securities which do not experience any change in counterparty risk as a control and run a differences-in-differences analysis. Fortunately, such securities exist. During the late 19th and early 20th centuries, stocks were dual-listed on the NYSE and CSE. Further, there was no change in the trading environment at the CSE at the time the NYSE introduced its clearinghouse. For the CSE price we have that

$$P_{i,t,CSE} = P_{i,t}^{Fun} - P_{i,t,CSE}^{MktLq} - P_{i,t,CSE}^{CP} + \epsilon_{i,t,CSE}. \quad (5)$$

Using the CSE prices as a control, the difference in prices between the dual-listed securities is:

$$P_{i,t,NYSE} - P_{i,t,CSE} = P_{i,CSE}^{MktLq} - P_{i,NYSE}^{MktLq} + P_{i,t,CSE}^{CP} - P_{i,t,NYSE}^{CP} + \epsilon_{i,t,NYSE} - \epsilon_{i,t,CSE} \quad (6)$$

where the fundamental value drops out of the equation. Then looking at the difference after the introduction of clearing we have

$$E[\Delta P_{i,t,NYSE}] - E[\Delta P_{i,t,CSE}] = E[\Delta P_{i,t,CSE}^{MktLq}] - E[\Delta P_{i,t,NYSE}^{MktLq}] - E[\Delta P_{i,t,NYSE}^{CP}], \quad (7)$$

so that the difference-in-differences between the expected prices on the two exchanges is caused by changes in the relative market illiquidity premium and changes in the counterparty risk premium on the NYSE. If there is no change in clearing on the CSE, then the expected change in the CSE counterparty risk premium, $E[\Delta P_{i,t,CSE}^{CP}]$, is zero and drops out of equation (7).

If the difference in expected market liquidity between the two exchanges is the same before and after the introduction of clearing on the NYSE¹⁴, then the difference-in-difference in prices can be written as

$$\Delta E[P_{i,t,NYSE}] - \Delta E[P_{i,t,CSE}] = -E[\Delta P_{i,t,NYSE}^{CP}], \quad (8)$$

which is a causal estimate of the effect of clearing on the counterparty risk premium. Formally, our baseline empirical specification is

$$\hat{P}_{i,t,NYSE} - \hat{P}_{i,t,CSE} = \alpha_i + D1_{\{clear,i,t\}} + X_{i,t}'\beta + \epsilon_{i,t}, \quad (9)$$

where $\hat{P}_{i,t,CSE}$ and $\hat{P}_{i,t,NYSE}$ are the normalized closing prices on the NYSE and CSE.

Throughout our analysis, we consider two normalizations for price: (1) dividing by the average closing prices on both exchanges and (2) dividing by the NYSE bid-ask spread. The former is natural since it is the percentage premium or discount an investor would require for holding the same stock on the NYSE relative to the CSE. The latter is also intuitive since it adjusts for the relative cost of trading the security and indicates how many bid-ask spreads the price on the NYSE deviates from the same security on the CSE. As discussed above, $1_{\{clear,i,t\}}$ is a dummy

¹⁴ Of course, trading might migrate to the NYSE since the clearinghouse improved the NYSE trading environment which might also result in a degradation of trading conditions on the CSE. We examine this however, and as we show trading volumes and spreads on both exchanges remained relatively stable after the NYSE clearinghouse was introduced.

variable indicating when a stock starts clearing and D is the average treatment effect of clearing on the relative normalized stock prices. In addition, we include stock-specific time varying controls, $X_{i,t}$, including bid-ask spreads and volumes.

It is important to note that in this core specification, we are implicitly assuming that there are no spillovers in counterparty risk reduction when only a fraction of NYSE stocks join the clearinghouse. That is, it is likely that counterparty risk for stocks not yet cleared will almost certainly experience some reduction in counterparty risk once a sufficient fraction of NYSE stock volume is cleared. Put another way, a stock A that starts clearing later on should experience a smaller change in price when it begins clearing relative to a stock B that begins clearing earlier because some counterparty risk due to contagion has already been eliminated, as stocks such as B have already been cleared for a while. We investigate this effect in section 4.4.

4.3 Price Volatility Induced by Counterparty Risk

Because counterparty risk was driven by the costs of financing overnight positions, we expect the counterparty risk premium to be small during periods of calm, but increase dramatically during times of financial market distress. Because the cost of financing overnight positions was likely much less after the onset of multilateral netting, its introduction may have significantly reduced or eliminated the impact of short-term financing shocks on NYSE stocks. Hence, interest rate shocks should not reduce stock prices on the NYSE relative to the CSE after the establishment of a clearinghouse¹⁵. We formalize this test by interacting call loan rates with the clearinghouse dummy to yield the following empirical model

$$\hat{P}_{i,t,NYSE} - \hat{P}_{i,t,CSE} = \alpha_i + D_1 1_{\{clear,i,t\}} + D_2 C_t \times 1_{\{clear,i,t\}} + \phi C_t + X_{i,t}' \beta + \epsilon_{i,t} \quad (10)$$

where C_t is the call loan rate, ϕ is the estimated effect of call loan rate spikes on NYSE relative prices pre-clearing, and D_2 is the estimated effect of the introduction of clearing on call loan rate sensitivity.

Before the introduction of the NYSE clearinghouse, interest rate volatility and the volatility of the NYSE-CSE price spread will move in response to fluctuations in counterparty risk. If we consider the change in volatility of the price difference, instead of the expectation, and

¹⁵ One might wonder whether the onset of multilateral netting might also affect the magnitude of interest rate shocks. Although this is theoretically a possibility, anecdotal evidence (see Meeker, 1922) suggests that the main driver of shocks to the call loan rate was the commercial paper market. Indeed Bernstein *et al.* (2010) find the correlation between the commercial paper rate and the call loan rate were over 90% during our sample period.

make slightly stronger assumptions (relative to those needed to arrive at equation 8)¹⁶ then we can rewrite equation (8) as follows:

$$\Delta\sigma[P_{i,t,NYSE} - P_{i,t,CSE}] = \Delta\sigma[P_{i,t,NYSE}^{CP}]. \quad (11)$$

Equation (11) indicates that the change in the volatility of the price premium provides an estimate of the change in counterparty risk volatility caused by clearing. We estimate the volatility of price spreads by taking the absolute value of the price differences between the exchanges on each date normalized by the average closing price on the exchanges and then scaling by a constant to generate an estimate for the volatility¹⁷. In our robustness analysis, we also consider the volatility estimator using the ratio of the high and low prices on each exchange presented in Parkinson (1980).

4.4 Counterparty Risk and Contagion

Counterparty risk can be divided into two parts: contagion risk and direct counterparty risk. Contagion risk is higher for an asset when a broker is more likely to default on their other positions, starting a cascade which results in default on a trade for that asset. When other stocks start to clear, contagion risk is smaller, even if the asset is traded through a clearinghouse. We define the reduction in direct counterparty risk as the direct effect of a stock clearing after accounting for any contagion risk reduction. One of the benefits of analyzing the introduction of clearing on the NYSE is that clearing was introduced in stages. Using prices on the CSE as a control again, we can decompose the volatility induced by counterparty risk by estimating the following model

$$|\hat{P}_{i,t,NYSE} - \hat{P}_{i,t,CSE}| = \alpha_i + D1_{\{clear,i,t\}} + \gamma PercClear_{i,t} + X_{i,t}'\beta + \epsilon_{i,t} \quad (12)$$

$PercClear_{i,t}$ is the percentage of stocks already clearing.¹⁸ We also include a dummy for the stock that is clearing which allows a natural interpretation for D as the change in counterparty

¹⁶ Previously we assumed no changes in the relative market illiquidity premium. In this case we need to assume no changes in the volatility of the market illiquidity premium, but in addition we have to assume no change in the volatility of relative market microstructure noise or in the covariance between the counterparty risk premia, market illiquidity premia, and/or market microstructure premia.

¹⁷ If $X \sim N(\mu, \sigma)$ then the absolute value of X is distributed folded-normally. Then if the expected normalized price difference is sufficiently small relative to the volatility then the volatility is proportional to the absolute value of X . In particular, $\sigma \approx \sqrt{\frac{\pi}{2}} E[|X|]$. In our analysis the expected normalized price difference is significantly smaller than the volatility so our estimated volatility using this approximation are within ~1bp of the change in volatility accounting for any changes in the mean normalized price difference. For a complete discussion of the estimator and its properties see appendix B.

¹⁸ We consider weights by both \$ sales and equally weighted, but focus on \$ sales for our primary analysis since it is more representative of the actual volume of trading of the security.

risk caused by direct counterparty risk, while γ is the percent caused by a change in contagion risk. Since the breakdown of these two types of risk depends on how connected traders of those securities are to the network of traders, we would expect these to vary across securities. In particular we would expect securities with traders who are more exposed to traders in the rest of the network, such as large firms with high volume securities, to be more exposed to contagion risk.

5 Results

We first compare the sign and volatility of the counterparty risk premium before and after the introduction of clearing on the NYSE. To do so, we reconsider equation (6):

$$P_{i,t,NYSE} - P_{i,t,CSE} = P_{i,CSE}^{MktLq} - P_{i,NYSE}^{MktLq} + P_{i,t,CSE}^{CP} - P_{i,t,NYSE}^{CP} + \epsilon_{i,t,NYSE} - \epsilon_{i,t,CSE}.$$

Because the NYSE is more liquid than the CSE (Brown et al. 2008 and Table 1 summary statistics), the price discount due to illiquidity should be smaller on the NYSE, $E[P_{i,CSE}^{MktLq} - P_{i,NYSE}^{MktLq}] > 0$. Therefore, when counterparty risk is small, stocks should trade at a premium on the NYSE relative to the CSE. In times of financial market crisis *before* stocks are cleared on the NYSE, stocks on the NYSE might well trade at a discount instead because during crises, counterparty risk might be much larger on the NYSE than on the CSE. Before the introduction of clearing on the NYSE then, stocks trade at a discount on the NYSE when the counterparty risk premium is high and at a slight premium otherwise. If the introduction of clearing on the NYSE eliminates (or substantially reduces) counterparty risk there, equation (6) implies that that after the onset of clearing, prices on the Big Board should be consistently higher than those on the CSE.

In figure 2, we plot the average for all Dow stocks of the 12-month moving average of the price on the NYSE minus the price on the CSE normalized by the NYSE bid-ask spread. Prior to the introduction of clearing this price difference is highly volatile, but after the introduction of clearing, stocks on the NYSE consistently trade at a premium. In Table 2, we estimate equation (9) to show that the introduction of clearing on the NYSE reduces the average counterparty risk premium by 24bps or 0.73 NYSE bid-ask spreads¹⁹. NYSE prices are 9bp lower on average than CSE prices prior to clearing, but 15bp *higher* afterward. This result is robust to including stock-specific time-varying market liquidity controls on the NYSE and CSE,

¹⁹ The specification includes firm fixed effects, clustering standard errors at the stock level, and using identical securities on the CSE as a control.

including the bid-ask spread on the NYSE, the dollar trading volume on the NYSE, and the dollar trading volume on the CSE. The result is not robust, however, to not using the CSE as control²⁰. This highlights the importance of using identical securities traded on the CSE to control for the changing macroeconomic environment.

The 24bps reduction is a substantial decline in the counterparty risk premium. This estimate for the reduction in the counterparty risk premium is on the high end of those obtained in analyses of modern counterparty risk in the credit derivative markets. Arora et al. (2012) note that estimates of the size of the counterparty risk premium for credit default swaps in the modern period range from 7-20bps. If we scaled the effects to size of the modern NYSE this would equate to approximately a \$40 billion increase in value caused by the reduction in counterparty risk from the introduction of a clearinghouse²¹.

We next investigate the drivers of the counterparty risk premium on the NYSE. Because brokers had to fund substantial levered positions overnight, shocks to overnight borrowing rates were an important determinant of counterparty risk prior to clearing on the NYSE. In figure 2, we also plot the 12-month moving average of the broker's call loan rate. As expected, prior to the introduction of clearing NYSE stocks tend to trade at a discount relative to identical securities on the CSE during periods when the call loan rate is high and at a premium when call loan rates are low.

In table 2, we formally investigate whether high call loan rates are associated with price discounts on the NYSE. We find that call loan rates appear unrelated to changes in the NYSE-CSE relative prices after the introduction of clearing. Column 4 shows that there is not a statistically significant relationship between the normalized difference in NYSE and CSE prices and the call loan rate for the full sample period. This is because the relationship is masked by the change in the relationship between call loan rates and counterparty risk after the introduction of clearing. In Column 5, we estimate equation (10). We find that before the introduction of clearing, a one standard deviation increase in the call loan rate in the pre-clearinghouse period is associated with approximately an 8bp reduction in the price on the NYSE relative to the CSE²². The effect is not statistically significant, however, after the introduction of clearing. As expected, we do not find evidence of a relationship between call loan rates and our normalized measure of relative NYSE-CSE prices after a stock joins the clearinghouse (see column 6). The result is consistent

²⁰ These results are available from authors upon request.

²¹ Market cap of \$16.6 trillion for NYSE taken from NYSE website as of August 2014.

²² We find that a one percentage point increase in the call loan rate is associated with more than a 2bps reduction in the relative price of NYSE stocks that also trade on the CSE and the standard deviation of the call loan rate was 3.7 percent before the introduction of the NYSE clearinghouse.

with the introduction of clearing mitigating the impact of overnight funding shocks on counterparty risk for NYSE stocks.

After the introduction of clearing on the NYSE, shocks to the call loan rate no longer affect prices on the NYSE relative to those on the CSE. Call loan rates continue to be volatile, however (see figure 7). Therefore, we would expect a decline in the volatility of NYSE returns given the reduction in the volatility of the counterparty risk premium. In figure 3, we observe a dramatic decline in the volatility of the counterparty risk premium after the introduction of clearing. In table 3, we show that the monthly average absolute price difference of the NYSE relative price falls 20bps or 0.93 NYSE bid-ask spreads after the introduction of clearing. These results are robust to including stock-specific time-varying market liquidity controls such as bid-ask spreads on the NYSE and CSE and the broker call loan rate interacted with a post-clearinghouse dummy. As we discussed previously, the results represent a lower bound on the effects of clearing since other stocks clearing reduce the counterparty risk for non-clearing stocks, reducing the estimated effect of clearing on counterparty risk. Since most stocks were already clearing by the end of 1893, we include a post-1893 dummy variable instead of the post-clearinghouse dummy. Post-1893, the average absolute price deviation fell by 40bps. Scaling the absolute values by $\sqrt{\pi/2}$ to obtain estimates of the change in standard deviation and then annualizing these monthly estimates suggests that the introduction of the clearinghouse reduced the annualized volatility of the returns on the NYSE by 90-173bps²³. Since, the average annualized volatility for stocks on the Dow Jones was 29.6% this represents a 3.0%-4.8% reduction in annualized volatility. Now if we assume further that approximately one-tenth of this is systematic risk and the slope of the security market line is approximately 0.3 then this would imply a decline in the counterparty risk premium of 9-14bps coming from the increased volatility or approximately one-third to one-half of the total decline in the counterparty risk premium we estimated²⁴.

In table 4, we attempt to distinguish the effects of contagion risk through network spillovers from the effects of direct counterparty risk. We first include monthly date fixed effects

²³ If instead of assuming normality we bootstrap from the original residual distribution we obtain similar estimates of 111-217bps decline in annualized return volatility. Since these results are similar to those obtained under normality and those under normality are slightly more conservative we focus primarily on that interpretation. We thank Neil Shephard for the suggestion.

²⁴ Based on statistics in McSherry et al (2014) it appears that as a percent of total NYSE trading volume initial reported losses from broker insolvencies fall approximately 42bps in the period after the introduction of a clearinghouse. If we account for subsequent partial recovery of those losses, this appears consistent in magnitude with the estimates we obtain for the fall in counterparty risk premium coming from the decline in expected losses with our formal difference-in-difference analysis of prices.

and find that the point estimate for the effect of clearing on the counterparty risk premium volatility falls from -0.93 (column 2 of table 3) to -0.37 (column 1 of Table 4) when normalizing by bid-ask spread, but only moves from -0.20 (column 3 of table 3) to -0.16 (column 2 of table 4) when normalizing by stock price. This suggests that the netting of other stocks increases the prices of stocks that have not yet cleared and that effect is picked up by the date fixed effects. The clearing dummy remains marginally significant only when we normalize by the bid-ask spread. If large firms have a high price, a low bid-ask spread, and large trading volume this is what we would expect because traders in those securities would be more exposed to traders in the rest of the broker network. To test this explicitly, in column 3 we remove the date fixed effects and replace them with a dummy for clearing for the percentage of all stocks clearing. We find the post-clearinghouse dummy is now a statistically significant -0.56 bid-ask spreads and the coefficient on the percentage of all stocks clearing is a marginally significant 0.51²⁵. Hence, spillover effects are likely to be important for the reduction of counterparty risk.

Since contagion risk depends on how connected traders of a given stock are to the rest of the trader network, we expect stocks trading higher volumes (relative to their average) on a particular day to be more affected by others stocks clearing because they are more connected to the network. In columns 5 and 6 of table 4 we consider the effect of the percentage of stocks clearing on the relative prices of stocks that have not yet cleared and include a dummy for high trading volume²⁶. Prior to clearing, on high volume days counterparty risk premium volatility is higher on the NYSE, but that effect disappears as more and more Dow stocks clear. In particular, the reduction in the counterparty risk (relative stocks on low-volume days) is 0.77 bid-ask spreads times the percentage of Dow stocks clearing (column 4) or 30bp times the percentage of Dow stocks clearing (column 5). If we combine the results of the high trading volume dummy and the interaction term, we can see that prior to clearing stocks with a high trading volume on a given day are associated with large volatility in the price difference, but after clearing the difference is no longer statistically significant. On low volume days, the volatility of the counterparty risk premium does not change in a significant way after the onset of clearing.

We run a number of robustness checks to test whether our results are driven by changes in counterparty risk coming from the introduction of clearing, or changes in asynchronous trading, market liquidity, or financial crises. If asynchronous trading declines after the introduction of clearing, this might confound interpretation of our results. In figure 5, we see that

²⁵ The co-efficient on the *percent of Dow Clearing* has a natural interpretation since it is the expected reduction in counterparty risk if 100 percent of all other stocks clear.

²⁶ The *High Volume* dummy is 1 for stocks with a trading volume higher than the median trading volume.

despite the sudden decline in counterparty risk (shown in figure 3), there is not a sudden increase in trading volume that would be consistent with a story about a decline or change in asynchronous trading for the two rival exchanges²⁷. The lack of any sudden change in volume is also inconsistent with results being driven by changes in relative market liquidity. In columns 1 and 2 of table 5 we do not find a significant change in relative trading volumes after the introduction of clearing. We also show in column 3 that there is little evidence of increased relative price impact since the Amihud illiquidity measure sees no statistically significant change. We also show in columns 4-6 of table 5 that all baseline results are robust to restricting our analysis to only days with at least 500 shares (5 standard contracts) traded on both exchanges and including non-linear relative measures of market liquidity on both exchanges for each stock as a control. In columns 1-3 of table 6, we show that the basic tenor of the results remain unchanged when we use daily data for all stocks on the NYSE or CSE. The results hold if we consider only stocks with at least 20 observations before and after the introduction of clearing, including estimated bid-ask spreads on the CSE as a control, and using open instead of closing prices. Again, the findings are not consistent with changes in asynchronous trading or market liquidity as drivers of the change in the relative NYSE-CSE price volatility after the introduction of clearing. We examine NYSE-CSE relative bid-ask spreads for the same securities in figure 6 and Column 6 of table 6. We again do not find evidence of a sudden change in the relative market liquidity between the NYSE and CSE. Even though there is not a statistically significant change in any of our market liquidity proxies it is still theoretically possible for them to affect pricing, so in column 6 of table 5 we include controls for $\$ Volume (NYSE-CSE)$, $Volume (\% CSE)$, the Amihud illiquidity measures on both exchanges and their ratio, seat prices on the NYSE and CSE and their ratio²⁸, and natural logs of dollar volume on both the NYSE and CSE. We find that no matter the market liquidity controls the post-1983 dummy is statistically significant suggesting that changes in the relative prices are not driven by any changes in the market liquidity on either exchange.

As a robustness check for our volatility estimator, in column 7 of table 6, we use the volatility estimator based on the high and low values on each exchange as the dependent variable. According to Parkinson (1980), the difference between the high and low values is proportional to volatility. The results in column 7 suggest that stocks on the CSE that also traded on the NYSE

²⁷ In addition to practical frictions which could slow any transition of volume from one exchange to another it has been shown that in the presence of limited competition, as existed during this period, market makers can earn positive profits and relationship dealers could prevent trading on either exchange from disappearing (Bernhardt et al. (2005) and Desgranges et al. (2005)).

²⁸ Since the number of seats on the NYSE were fixed the primary driver of seat prices were changes in trading volume. Thus changes in seat prices provide a good estimate of changes in expectations about future exchange trading volumes.

had 4% lower volatility when including market liquidity controls before the introduction of the clearinghouse. The difference in volatility between NYSE and CSE dual listed securities disappeared after the onset of clearing on the Big Board. The 4% reduction in the volatility of NYSE securities is statistically significant and consistent with the 3.0%-4.8% estimate obtained using the primary volatility estimator in this paper.

Another possibility is that the reduction in counterparty risk is driven by reduced macro-economic risk, independent of the introduction of clearing. First, we find that relative prices were no longer sensitive to call loan rate shocks after the introduction of clearing which suggests that changes the volatility of call loan shocks, even if they did occur, do not drive our results. The possibility also seems unlikely because in the period after clearing there were numerous major panics, including the Panic of 1907, where call loan rates increased precipitously. Indeed, the incidence of financial crises did not fall until the introduction of the Federal Reserve (see Bernstein et al. 2010 and Figure 5). In 1911, Shea noted that “the clearing system of the exchange was severely tested during the Panic of 1907, and its efficiency was fully demonstrated.” The results are also robust to restricting our analysis to the period prior to the passage of the Aldrich-Vreeland Act in 1908 and the subsequent introduction of the Federal Reserve (Column 7 of table 5). This leaves a 17 year period after the introduction of clearing on the NYSE where financial crises were as frequent as the period prior to 1892.

Examining the period prior to 1907 also shows the results are not driven by the introduction of the mutualization of risk on the NYSE clearinghouse in April of 1920, accusations of fraud on the Consolidated Stock Exchange beginning in February of 1922, or the subsequent decline in volume on the CSE. In table 7 we explicitly examine the introduction of mutualization of risk in April of 1920 prior to the accusations of fraud on the CSE in February of 1922. We do not find statistically significant evidence of changes in counterparty risk driven by mutualization of risk. These results should be interpreted with caution given the limited post-mutualization period. We do not find any evidence that the reduction in counterparty risk caused by introduction of clearing in 1892 were negated, or significantly improved, by the separate introduction of mutualization of risk.

6 Conclusion

The dramatic rise in counterparty risk in the OTC derivatives markets during the recent financial crisis has brought the role clearinghouses play in reducing market turbulence to the

forefront of public policy debate. In this paper, we show that a clearinghouse can improve financial stability in asset markets by reducing counterparty risk. We use a novel historical experiment to cleanly identify the change in counterparty risk of NYSE stocks after the introduction of a clearinghouse in 1892. We can identify the effect of introducing clearing for NYSE stocks because the same securities were trading concurrently on the Consolidated Stock Exchange, a rival exchange that already had centralized clearing. This is important, because the introduction of clearing is usually driven by macro-economic turbulence, so that before vs. after comparisons can be contaminated by changes in fundamental security value and risk. In our setting, however, changes in counterparty and illiquidity risk can be more easily attributed to the introduction of a clearinghouse. Our results suggest that prior to the introduction of net settlement on the NYSE, identical stocks on the NYSE traded at a discount of 9bp relative to the Consolidated Stock Exchange, the NYSE's principal competitor. After the establishment of a clearinghouse, NYSE stocks traded at a premium of 15bp. The difference of 24bp is statistically significant. Furthermore, the change can be attributed almost entirely to the reduction in counterparty risk.

Before the establishment of the NYSE clearinghouse, the NYSE traded at a premium relative to the same stocks on the CSE the majority of the time. However, when overnight collateralized borrowing rates rose sharply, prices on the NYSE fell precipitously relative to those on the CSE. A one standard deviation increase in interest rates (3.7 percentage points) reduced the value of stocks on the NYSE by 8bp, relative to identical stocks on the CSE. After the introduction of clearing, the difference between prices on the NYSE and the CSE were no longer affected by changes in these overnight funding rates. Call loan rates remained volatile, but annualized NYSE stock return volatility fell dramatically after clearing by 90-173bps. We also use the staggered introduction of clearing on the NYSE to show that at least half of this reduction in counterparty risk is driven by a reduction in contagion risk through spillovers in the trader network.

Overall, our results indicate that clearinghouses can play a significant role in improving market stability and increase asset values by reducing network contagion and counterparty risk. Two of the primary functions of clearinghouses are netting and mutualization of risk. We demonstrate that even in the absence of a centralized counterparty, policies aimed at introducing centralized clearing through a clearinghouse can substantially increase netting and subsequently improve global financial stability.

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Appendix A: Estimating CSE Bid-Ask Spreads

For some of robustness checks we consider daily data from 1892-1901, which include estimated bid-ask spreads from the Consolidated Stock Exchange (CSE) for our robustness tests that are shown in Figure 4 and reported in table 6. We estimate the bid-ask spreads since historical data on CSE bid and ask prices do not exist for this period. Daily data on open, high, and low transactions prices were hand collected from the *New York Times* from 1892-1901.

For our analysis, we consider a daily estimator of the bid-ask spread based on daily high and low prices presented by Corwin and Schultz (2012), which we will refer to as the CS estimator. We also constructed our own estimator which uses absolute differences (AD) of open and closing prices in addition to high and low prices to arrive at an estimate of the bid-ask spread. This is referred to as the AD estimator. We focus on estimators that utilize high and low prices, rather than time series covariance estimators, like in Roll (1984). Corwin and Schultz (2012) find that the standard deviation of their estimates is $\frac{1}{4}$ to $\frac{1}{2}$ as large as the estimator presented in Roll (1984).

The high minus low price spread on a given day combines both the fundamental variance of a stock price as well as any bid-ask spread, but while the variance grows proportionally with time, the bid-ask spread does not. This is the basic insight behind the CS estimator which gives an estimate of the bid-ask spread by comparing the high-low price ratio over two consecutive days to the high-low price ratio on each of those days. In particular let, β , be the sum of the squared difference between the log of the high, H , and low prices, L , on two consecutive days, t and $t+1$,

$$\beta = E \left[\sum_{j=0}^1 \left(\ln \left(\frac{H_{t+j}^0}{L_{t+j}^0} \right) \right)^2 \right] \quad (13)$$

and γ be the squared log difference of the high and low price over the two days,

$$\gamma = \left[\ln \left(\frac{H_{t,t+1}^0}{L_{t,t+1}^0} \right) \right]^2 \quad (14)$$

then the CS estimate, S , for the bid-ask spread is

$$S = \frac{2(e^\alpha - 1)}{1 + e^\alpha} \quad (15)$$

where α is the following function of β and γ :

$$\alpha = \frac{\sqrt{2}\beta - \sqrt{\beta}}{3 - 2\sqrt{2}} - \sqrt{\frac{\gamma}{3 - 2\sqrt{2}}} \quad (16)$$

Corwin and Schultz find that this estimator has excellent properties, including a time series correlation between high-low spread estimates and true spreads of about 0.9. We find that even in

our period, 1892-1901, there is an 83% time series correlation between the monthly average actual bid-ask spread on the NYSE and the CS estimated bid-ask spreads. One of the unfortunate properties of this estimator is that estimates of the bid-ask spread can be negative. In simulations, Corwin and Schultz show that for stocks with a true bid-ask spread of 50bps, setting negative values to zero results in an average estimate of the bid-ask spread of 143bps. As the true bid-ask spreads become larger, the number of negative values diminishes and the bias becomes negligible. Unfortunately, this does not appear to be the case in our analysis. When we use the CS estimator from 1892-1901, we find that more than $\frac{1}{2}$ of all bid-ask spread estimates are negative. This is especially problematic in our analysis since in one of our normalization methods we divide by the bid-ask spread, so we need the bid-ask spread to be strictly positive. To avoid this issue we set negative values to the minimum bid-ask spread on the NYSE, $1/8^{\text{th}}$.

Since in our period more than half of all observations require this ad-hoc adjustment, we considered another bid-ask estimator as a robustness check. In particular, we estimate the bid-ask spread by taking the minimum non-zero pair-wise absolute differences (AD) between the open, close, high, and low prices on two consecutive days. The insight for the estimator is that if we observe two prices and there is no change in fundamental value, or the change is small relative to the minimum tick size, then if the prices differ, the absolute difference between them is equal to the bid-ask spread. In our period the tick sizes were $1/8^{\text{th}}$ which means that as long as fundamental value between two prices differ by less than $1/16^{\text{th}}$ and observed prices differ we can recover the exact bid-ask spread. Unlike the CS estimator the AD estimator is never negative, by construction, since the estimate is bounded below by the minimum $1/8^{\text{th}}$ tick size. In addition, Figure A1 shows that the AD estimator does a good job of predicting actual bid-ask spreads during this period. For NYSE stocks from 1892-1901, we find an 88 percent time series correlation between the monthly average actual bid-ask spread on the NYSE and the AD estimated bid-ask spreads and a 75 percent correlation in changes in the averages. This compares favorably with the CS estimator which has correlations of 83 percent and 57 percent in levels and changes respectively, which is why we use the AD estimator in our primary analysis. The bid-ask spread estimates using the AD and CS estimators have over an 80 percent correlation during this period. As suggested by the high correlation between the estimates, also displayed in Figure A2, the results are robust to using either estimator²⁹.

²⁹ Results using CS estimator are available upon request.

Figure A1. Validity of Estimated Bid-Ask Spreads for CSE and NYSE 1892-1901

This figure shows bid-ask spreads for security market data hand collected at a daily frequency from the *New York Times* from January 1892 – Dec 1901 for all stocks on the NYSE or CSE. To be included in the analysis a security must trade at least 200 shares on both exchanges on a given date. All data is winsorized at the 1st and 99th percentile. The blue line is the actual bid-ask spread on the NYSE. The red and green lines are the estimated bid-ask spread on the NYSE and CSE respectively using the absolute difference (AD) method. For a description of the estimation method see the appendix.

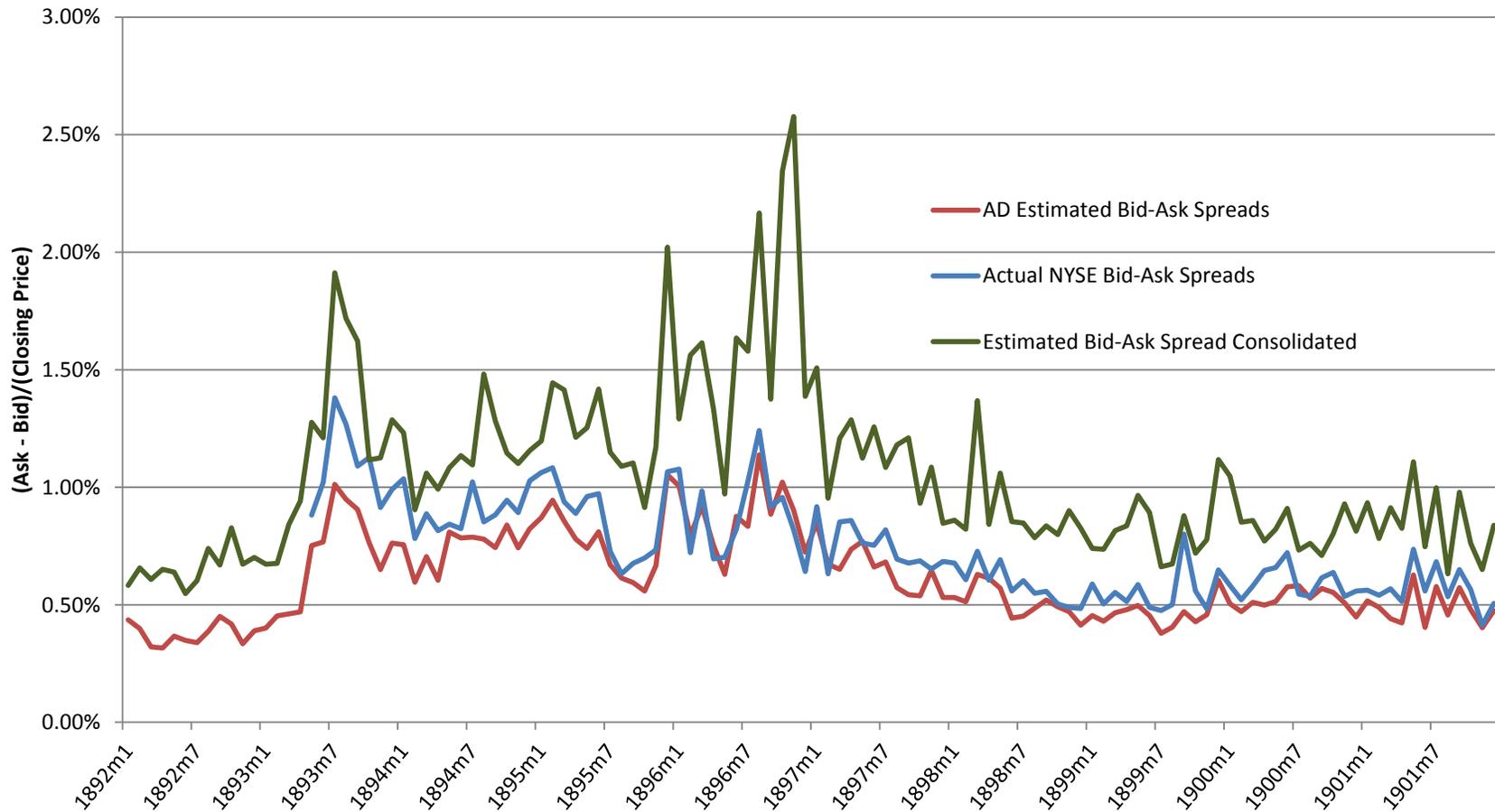
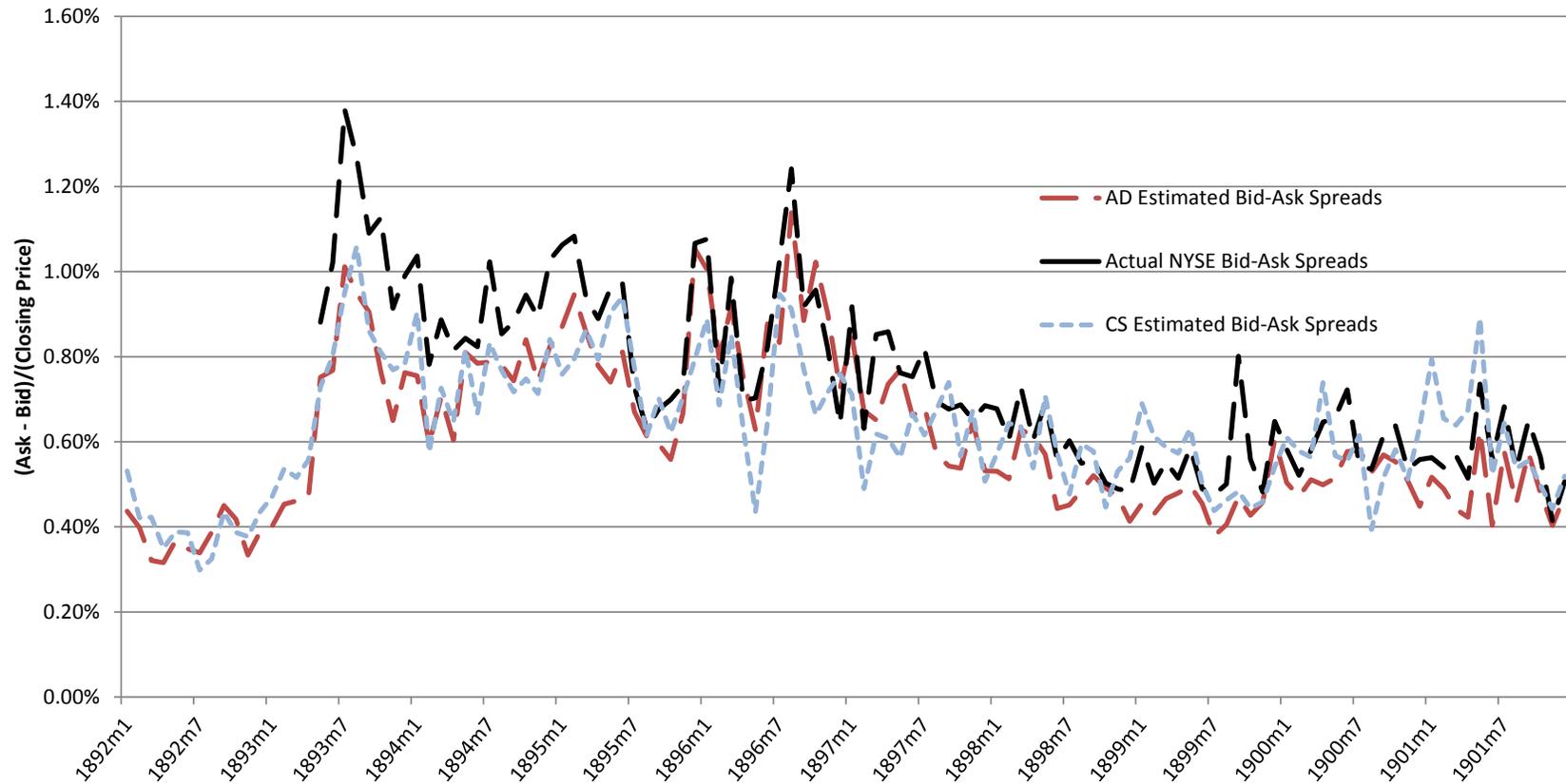


Figure A2. CS vs. AD vs. Actual Bid-Ask Spreads for NYSE 1892-1901

This figure shows bid-ask spreads for security market data hand collected at a daily frequency from the *New York Times* from January 1892 – Dec 1901 for all stocks on the NYSE or CSE. To be included in the analysis a security must trade at least 200 shares on both exchanges on a given date. All data is winsorized at the 1st and 99th percentile. The solid black line is the actual bid-ask spread on the NYSE. The solid red and dashed blue lines are the estimated bid-ask spread on the NYSE using the absolute difference (AD) and Corwin-Schultz (CS) estimators, respectively. For a description of the estimation methods see appendix A.



Appendix B: Estimating Change in Volatility

Let X be defined as the price difference between the NYSE and CSE normalized by the average price on the two exchanges so that, $X \equiv \hat{P}_{i,t,NYSE} - \hat{P}_{i,t,CSE}$, is the return required to equalize the price on both exchanges and let $Y \equiv |X|$. Now if we assume that $X \sim N(\mu, \sigma)$ then Y is distributed folded normal and

$$E[Y] = \sigma \sqrt{\frac{2}{\pi}} e^{-\frac{1}{2}\left(\frac{\mu}{\sigma}\right)^2} + \mu \left(1 - 2\Phi\left(-\frac{\mu}{\sigma}\right)\right) \quad (\text{B1})$$

Therefore any change in the expectation of the absolute value is a function of any change in the mean and/or volatility of X . Under the additional assumption that $\mu \ll \sigma$ the expectation of a folded normal distribution becomes

$$E[Y] \approx \sigma \sqrt{\frac{2}{\pi}} \quad (\text{B2})$$

so that the absolute value is just proportional to σ , which is the primary estimator for the change in volatility used in our paper.

From Table 2 we estimated that prior to the clearinghouse $\mu = -9\text{bps}$ and afterwards it is 15bps and from summary statistics computed separately we have that our estimate of $E[Y]$ prior to the introduction of the clearinghouse is approximately 73bps and 52bps afterwards. Using the change in μ and the change in $E[Y]$ we have that the implied σ from equation B1 is 94bps pre-clearing and 64bps afterwards, which is a reduction of 30bps . If instead we use our estimator in B2 we get that the implied σ is 94bps pre-clearing and 65bps afterwards, which is a reduction of 29bps . Thus our estimator in B2 is only approximately 1bp off without having to estimate μ before and after as we would need to in B1.

To build an intuition for when it is reasonable to use the approximation in B2 instead of B1 we start by taking the partial derivative with respect to μ and σ in B1. Defining $\hat{\mu} \equiv \frac{\mu}{\sigma}$ we get that:

$$\frac{\partial E[Y]}{\partial \mu} = -\hat{\mu} \sqrt{\frac{2}{\pi}} e^{-\frac{1}{2}\hat{\mu}^2} + 1 + 2\hat{\mu}\phi(-\hat{\mu}) - 2\Phi(-\hat{\mu}) \quad (\text{B3})$$

and

$$\frac{\partial E[Y]}{\partial \sigma} = \sqrt{\frac{2}{\pi}} e^{-\frac{1}{2}\hat{\mu}^2} (1 + \hat{\mu}^2) - 2\hat{\mu}^2\phi(-\hat{\mu}) \quad (\text{B4})$$

From equations B3 and B4 we can see that the ratio of the mean of X to the standard deviation is a sufficient statistic for the partial derivative with respect to each of them. Since in our paper σ tends to be larger than μ in figure B1 we consider the value of those derivatives for a range of values for the ratio of σ divided by μ from 0 to 10. As you can see in equations B3 and B4 above and in figure B1 as σ gets

large relative to μ the partial derivative with respect σ asymptotes to $\sqrt{\frac{2}{\pi}}$ while the partial derivative with respect to μ shrinks continuously so that the ratio of the partials increases linearly and the mean has less effect on the expectation of the absolute value. The intuition behind this result is that in the limit where $\mu \ll \sigma$ the expectation of a folded normal distribution becomes $E[Y] \approx \sigma \sqrt{\frac{2}{\pi}}$ so that the absolute value is just proportional to σ .

In our sample we have a σ 5 to 10 times larger than μ so the effect of changes in μ are minimal. In particular, in the example provided previously, if σ remains unchanged at 73bps the change in μ from -9bps to 15bps results in a change in the $E[Y]$ of only 4/5ths of a basis point. The effect is so small because the symmetry of the normal distribution means the change from -9bps to 15bps is the same as effect of a change from 9bps to 15bps, or only 6bps. Also, since σ is about 7 times larger than μ the partial derivative is around 0.12. Thus, taking these together $6bps \times 0.12 \approx 0.7bps$ which is approximately the result we arrived at previously.

Table 1. Summary Statistics

A. Dow Jones Stocks Monthly

This table reports the sample statistics for the trading data for stocks on the NYSE or CSE. Security market data were hand collected at a monthly frequency from the *New York Times* and *Commercial and Financial Chronicle* from September 1886 – December 1925 for all stocks in the Dow Jones Indices. All data is winsorized at the 1st and 99th percentile. To be included in the first level of summary analysis a security must trade at least 1 share on both exchanges on a given date, while for the second, which is the one used in our primary econometric specifications, we require at least 200 shares (2 standard contracts).

| | NYSE Closing Price | NYSE Trading Volume (# Shares) | CSE Trading Volume (#Shares) | NYSE Trading Volume (\$000s) | CSE Trading Volume (\$000s) | NYSE Bid- Ask Spread (bps) |
|---|--------------------------|--------------------------------------|------------------------------------|------------------------------------|-----------------------------------|----------------------------------|
| <i>With Minimum 1 Shares Traded (n = 9,373)</i> | | | | | | |
| Mean | 84.4 | 13,726 | 3,241 | 1,352 | 322 | 52 |
| Median | 81.4 | 4,400 | 410 | 324 | 29 | 32 |
| Standard Dev. | 42.4 | 29,340 | 8,710 | 3,304 | 965 | 66 |
| Minimum | 4 | 5 | 5 | 0.2 | 0.04 | 7 |
| Maximum | 323 | 489,444 | 291,870 | 52,300 | 24,100 | 1,818 |
| <i>With Minimum 200 Shares Traded (n = 6,065)</i> | | | | | | |
| Mean | 85.5 | 19,911 | 4,958 | 1,972 | 493 | 41 |
| Median | 81.0 | 8,425 | 1,150 | 644 | 88 | 26 |
| Standard Dev. | 41.1 | 34,912 | 10,432 | 3,966 | 1,164 | 52 |
| Minimum | 4.7 | 200 | 200 | 3.6 | 1.4 | 7 |
| Maximum | 319.5 | 489,444 | 291,870 | 52,300 | 24,100 | 1,481 |

B. All NYSE/CSE Stocks Daily

This table reports sample statistics for the trading data for stocks on the NYSE or CSE. Security market data were hand collected at a daily frequency from the *New York Times* from January 1892 – Dec 1901 for all stocks on the NYSE or CSE. All data is winsorized at the 1st and 99th percentile. To be included in the first level of summary analysis a security must trade at least 1 share on both exchanges on a given date, while for the second, which is the one used in our primary econometric specifications, we require at least 200 shares (2 standard contracts) and 20 observations before and after the introduction of clearing.

| | NYSE Closing Price | NYSE Trading Volume (#Shares) | CSE Trading Volume (#Shares) | NYSE Trading Volume (\$000s) | CSE Trading Volume (\$000s) | NYSE Bid- Ask Spread (bps) | CSE Bid-Ask Spread (bps) |
|--|--------------------------|-------------------------------------|------------------------------------|---------------------------------|-----------------------------------|----------------------------------|-----------------------------|
| <i>With Minimum 1 Shares Traded (n = 62,959)</i> | | | | | | | |
| Mean | 56.3 | 10,122 | 3,055 | 743 | 252 | 68 | 120 |
| Median | 47.4 | 3,750 | 320 | 167 | 14 | 37 | 41 |
| Standard Dev. | 38.5 | 19,930 | 7,613 | 1,873 | 773 | 92 | 241 |
| Minimum | 0.8 | 1 | 2 | 0.004 | 0.009 | 9 | 9 |
| Maximum | 259 | 957,955 | 262,250 | 75,200 | 30,800 | 625 | 1,667 |
| <i>With Minimum 200 Shares Traded and 20 Observations before and after Clearing (n = 28,161)</i> | | | | | | | |
| Mean | 64.6 | 15,820 | 5,789 | 1,255 | 496 | 44 | 49 |
| Median | 58.4 | 8,310 | 1,880 | 456 | 96 | 28 | 28 |
| Standard Dev. | 37.4 | 24,633 | 10,022 | 2,509 | 1,070 | 53 | 87 |
| Minimum | 0.8 | 200 | 200 | 0.6 | 0.4 | 9 | 9 |
| Maximum | 230 | 957,955 | 262,250 | 75,200 | 30,800 | 625 | 1,667 |

C. Call Loan Rate and Exchange Seat Prices

This table reports the sample statistics for the average overnight collateralized borrowing rate, the *Call Loan Rate*, and seat prices for membership on the New York and Consolidated Stock Exchanges over four periods from September 1886- December 1925. Seat price data were hand collected at a monthly frequency from the *Commercial and Financial Chronicle*.

| | Full Sample 1886-1925 | Pre-Clearinghouse 1886-1893 | Clearinghouse 1894-1925 | Clearinghouse Subsample 1894-1908 |
|--|--------------------------|--------------------------------|----------------------------|---|
| <i>Call Loan Rate (%)</i> | | | | |
| Mean | 4.0 | 4.7 | 3.8 | 3.6 |
| Median | 3.2 | 4.0 | 3.0 | 2.5 |
| Standard Dev. | 3.6 | 3.7 | 3.6 | 4.8 |
| Minimum | 0.9 | 1.1 | 0.9 | 0.9 |
| Maximum | 40.0 | 22.0 | 40.0 | 40.0 |
| <i>New York Stock Exchange Seat Price (\$000s)</i> | | | | |
| Mean | 56.9 | 20.0 | 63.9 | 50.6 |
| Median | 63.0 | 20.0 | 68.5 | 54.5 |
| Standard Dev. | 29.1 | 1.8 | 26.5 | 26.3 |
| Minimum | 14.3 | 16.5 | 14.3 | 14.3 |
| Maximum | 150.0 | 24.0 | 150.0 | 95.0 |
| <i>Consolidated Stock Exchange Seat Price (\$000s)</i> | | | | |
| Mean | 1.1 | 0.4 | 1.3 | 0.8 |
| Median | 0.7 | 0.3 | 0.8 | 0.7 |
| Standard Dev. | 1.3 | 0.3 | 1.5 | 0.7 |
| Minimum | 0.1 | 0.1 | 0.1 | 0.1 |
| Maximum | 6.0 | 1.0 | 6.0 | 2.5 |

Table 2. Average Counterparty Risk Premium

Following econometric specifications (9) and (10), in this table we show the estimated effect of the introduction of multilateral net settlement through a centralized clearing party on the closing price of a stock on the New York Stock Exchange relative to the closing price on the Consolidated Stock Exchange for the same security on the same day. Security market data were hand collected at a monthly frequency from the *New York Times* and *Commercial and Financial Chronicle* from September 1886 – December 1925 for all stocks in the Dow Jones Indices. To be included in the analysis a security must trade at least 200 shares on both exchanges on a given date. All data is winsorized at the 1st and 99th percentile. In column 1, *NYSE-CSE/Close* is the price on the NYSE minus the CSE normalized by the average closing price on both exchanges. *Clearinghouse* is a stock-specific dummy variable which equals 1 if a stock is cleared on the NYSE. In column 2, *NYSE-Con/NYSE Bid-Ask* is the LHS variable and is the price on the NYSE minus the CSE normalized by the bid-ask spread on the NYSE. Column 3 shows the results including stock-specific time-varying market liquidity controls on the NYSE and CSE. These include the bid-ask spread on the NYSE, the dollar trading volume on the NYSE, and the dollar trading volume on the CSE. Column 4 shows the results after including *Call Loan Rate (%)*, the overnight collateralized borrowing rate. Column 5 includes an interaction term between the *Clearinghouse* dummy variable and the *Call Loan Rate (%)* as described in specification (10). Column 6 repeats the analysis in column 4, but restricting the sample to only stocks already clearing. All specifications are run with security-level fixed effects and errors are clustered at the security-level. P-Values: * 10%; ** 5%; ***1%.

| | (1) | (2) | (3) | (4) | (5) | (6) |
|-----------------------------------|---------------------|-------------------------|---------------------|-----------------------|------------------------|----------------------|
| Dependent Variable: | NYSE-CSE /Close (%) | NYSE-CSE / NYSE Bid-Ask | NYSE-CSE /Close (%) | NYSE-CSE /Close (%) | NYSE-CSE /Close (%) | NYSE-CSE /Close (%) |
| Clearinghouse | 0.237*** (0.062) | 0.733*** (0.126) | 0.234*** (0.061) | 0.230*** (0.061) | 0.122* (0.068) | |
| Call Loan Rate | | | | -0.00294 (0.00191) | -0.0217*** (0.0055) | 0.00220 (0.00169) |
| Call Loan Rate x Clearinghouse | | | | | 0.0247*** (0.0058) | |
| Constant | -0.094** (0.040) | -0.295*** (0.082) | -0.107** (0.045) | -0.093** (0.048) | -0.0008 (0.0055) | -0.0062 (0.023) |
| Security Fixed Effects | Y | Y | Y | Y | Y | Y |
| Stock Liquidity Controls | N | N | Y | Y | Y | Y |
| Only Clearinghouse | N | N | N | N | N | Y |
| # Clusters | 90 | 90 | 90 | 90 | 90 | 51 |
| # Observations | 5,997 | 5,984 | 5,994 | 5,994 | 5,994 | 3,904 |
| Adjusted R-squared | 0.0086 | 0.0056 | 0.0104 | 0.0105 | 0.0138 | 0.0326 |

Table 3. Counterparty Risk

Following econometric specifications (9), (10) and (11), in this table we show the estimated effect of the introduction of multilateral net settlement through a centralized clearing party on the *volatility* of the closing price of a stock on the New York Stock Exchange relative to the closing price on the Consolidated Stock Exchange for the same security on the same day by looking at the absolute value of the relative price differences. Security market data were hand collected at a monthly frequency from the *New York Times* and *Commercial and Financial Chronicle* from Sept 1886 – Dec 1925 for all stocks in the Dow Jones Indices. To be included in the analysis a security must trade at least 200 shares on both exchanges on a given date. All data is winsorized at the 1st and 99th percentile. In column 1, $|NYSE-CSE|/Close$ absolute value of the price on the NYSE relative to the CSE, normalized by the average closing price on both exchanges in percent. *Clearinghouse* is a stock-specific dummy variable which equals 1 if a stock is cleared on the NYSE. In column 2, $|NYSE-CSE|/NYSE Bid-Ask$ is the volatility of the price on the NYSE minus the CSE normalized by the bid-ask spread on the NYSE. Column 3 shows the results with stock-specific time-varying market liquidity controls on the NYSE and CSE including the stock's bid-ask spread on the NYSE and dollar trading volume on NYSE, and CSE. Column 4 shows results after including *Call Loan Rate (%)*, the overnight collateralized borrowing rate, and an interaction term between the *Clearinghouse* dummy variable and the *Call Loan Rate (%)* as described in specification (10). Column 5 repeats the analysis in column 4, but restricting the sample to only stocks already clearing. Column 6 includes a dummy, *Post 1893*, which is equal to 1 for all securities clearing after 1893 and zero prior to May 1892. All specifications are run with security-level fixed effects and errors are clustered at the security-level. P-Values: * 10%; ** 5%; *** 1%.

| Dependent Variable: | (1) $ NYSE-CSE /Close$ (%) | (2) $ NYSE-CSE /NYSE Bid-Ask$ | (3) $ NYSE-CSE /Close$ (%) | (4) $ NYSE-CSE /Close$ (%) | (5) $ NYSE-CSE /Close$ (%) | (6) $ NYSE-CSE /Close$ (%) |
|-----------------------------------|-------------------------------|----------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|
| Clearinghouse | -0.204** (0.105) | -0.929*** (0.323) | -0.207*** (0.082) | -0.174** (0.089) | | |
| Post 1893 | | | | | | -0.399*** (0.077) |
| Call Loan Rate | | | | 0.0081* (0.0046) | 0.0009 (0.0015) | |
| Call Loan Rate x Clearinghouse | | | | -0.0067 (0.0049) | | |
| Constant | 0.544*** (0.069) | 1.840*** (0.210) | 0.397*** (0.055) | 0.360*** (0.064) | 0.174*** (0.016) | 0.557*** (0.0068) |
| Security Fixed Effects | Y | Y | Y | Y | Y | Y |
| Stock Liquidity Controls | N | N | Y | Y | Y | Y |
| Only Clearinghouse | N | N | N | N | Y | N |
| # Clusters | 90 | 90 | 90 | 90 | 51 | 54 |
| # Observations | 5,997 | 5,984 | 5,994 | 5,994 | 3,904 | 4,314 |
| Adjusted R-squared | 0.223 | 0.165 | 0.293 | 0.293 | 0.157 | 0.171 |

Table 4. Contagion (Indirect Counterparty) Risk

Following econometric specifications (12), in this table we show the estimated effect of the introduction of multilateral net settlement through a centralized clearing party on the closing price of a stock on the New York Stock Exchange relative to the closing price on the Consolidated Stock Exchange for the same security on the same day broken out by contagion risk and direct counterparty risk. Security market data were hand collected at a monthly frequency from the *New York Times* and *Commercial and Financial Chronicle* from Sept 1886 – Dec 1925 for all stocks in the Dow Jones Indices. To be included in the analysis a security must trade at least 200 shares on both exchanges on a given date. All data is winsorized at the 1st and 99th percentile. In Column 1, $|NYSE-CSE|/NYSE\ Bid-Ask$ is an estimate of monthly volatility of the price on the NYSE relative to the CSE, normalized by the bid-ask spread on the NYSE. *Clearinghouse* is a stock-specific dummy variable which equals 1 if a stock is cleared on the NYSE. This column includes date fixed effects. Column 2 is the same as Column 1, but $|NYSE-Con|/NYSE\ Close$ is the volatility of the price on the NYSE minus the CSE normalized by the average closing price on both exchanges in percent. Column 3 includes the effects of spillovers by including, *% of Dow Clearing*, which is the percent of NYSE stocks in a Dow Jones Index currently clearing in addition to the *Clearinghouse* dummy. Column 4 restricts the sample to only stocks not clearing to show spillover effects and contagion risk. This regression includes variable, *High Trading Volume*, which is 1 if the \$ trading volume is higher than the median for all stocks over the period. This variable is then interacted with *% of Dow Clearing*. Column 5 is the same as Column 4 but looks at $|NYSE-CSE|/NYSE\ Close$. All specifications are run with security-level fixed effects and errors are clustered at the security-level. P-Values: * 10%; ** 5%; *** 1%.

| | (1) | (2) | (3) | (4) | (5) |
|--|------------------------------|----------------------------|---------------------------------|------------------------------|----------------------------|
| Dependent Variable: | $ NYSE-CSE / NYSE\ Bid-Ask$ | $ NYSE-CSE / Close\ (\%)$ | $ NYSE-CSE / NYSE\ Bid-Ask$ | $ NYSE-CSE / NYSE\ Bid-Ask$ | $ NYSE-CSE / Close\ (\%)$ |
| % of Dow Clearing | | | -0.508* | 0.328 | 0.020 |
| Clearinghouse | -0.370 (0.269) | -0.156* (0.088) | (0.295) -0.558*** (0.108) | (0.278) | (0.16) |
| High Volume Dummy x % of Dow Clearing | | | | -0.772** (0.308) | -0.300** (0.137) |
| High Volume Dummy | | | | 0.538** (0.203) | 0.201** (0.096) |
| Constant | 1.830** (0.119) | 0.582*** (0.038) | 2.091*** (0.210) | 1.199*** (0.193) | 0.329*** (0.098) |
| Security Fixed Effects | Y | Y | Y | Y | Y |
| Date Fixed Effects | Y | Y | N | N | N |
| Stock Liquidity Controls | Y | Y | Y | Y | Y |
| Only Pre-Clearing Stocks | N | N | N | Y | Y |
| # Clusters | 90 | 90 | 90 | 50 | 50 |
| # Observations | 5,983 | 5,994 | 5,983 | 2,086 | 2,090 |
| Adjusted R-squared | 0.236 | 0.326 | 0.186 | 0.332 | 0.398 |

Table 5.**Monthly Data Robustness Tests for Changes in Microstructure Noise or Market Liquidity**

In this table, we show that the introduction of clearing on the NYSE is not associated with a change in the relative trading on the NYSE vs. the CSE and that the introduction of multilateral net settlement through a centralized clearing party reduced the premium and volatility of the closing price of a stock on the New York Stock Exchange relative to the closing price on the Consolidated Stock Exchange for the same security on the same day. Security market data were hand collected at a monthly frequency from the *New York Times* and *Commercial and Financial Chronicle* from Sept 1886 – Dec 1925 for all stocks in the Dow Jones Indices. To be included in the analysis a security must trade at least 200 shares on both exchanges on a given date. All data is winsorized at the 1st and 99th percentile. In column 1, $\$ Volume (NYSE-CSE)$, is the difference in the dollar volume of trading for a stock on the NYSE minus the volume on the CSE on the same day. *Clearinghouse* is a stock-specific dummy variable which equals 1 if a stock is cleared on the NYSE. Column 2 shows the same as column 1, but now the looking at $Volume (\% CSE)$, which is the dollar trading volume on the CSE divided by the sum of the trading volume on the NYSE and CSE for a given security on a given day. Column 3 is the same specification as Column 2, but the left-hand side variable is the Amihud illiquidity measure, $(|NYSE Ret_t|/NYSE Sales_t)/(|CSE Ret_t|/CSE Sales_t)$. In specifications in columns 4-5 securities are restricted to those with at least 500 contracts trading on the NYSE and CSE on a given day. In column 4, $|NYSE-Con|/Close$ is an estimate of monthly volatility of the price on the NYSE relative to the CSE by looking at the absolute price deviation, normalized by the average closing price on both exchanges in percent. In Column 5, $NYSE-CSE/Close$ is the price on the NYSE minus the CSE normalized by the average closing price on both exchanges. Column 6 is the same as column 5 but only restricts to at least 200 shares traded on both exchanges and includes relative stock-specific time-varying market liquidity controls. These include $\$ Volume (NYSE-CSE)$, $Volume (\% CSE)$, the Amihud illiquidity measures on both exchanges and their ratio, seat prices on the NYSE and CSE and their ratio, and natural logs of $\$ volume$ on both the NYSE and CSE. Column 7 repeats the baseline results in Table 2 column 1, but only for the period prior to passage of the Aldrich-Vreeland Act in 1909. All specifications are run with security-level fixed effects and errors are clustered at the security-level. P-Values: *10%; **5%; ***1%.

| Dependent Variable: | (1) \$ Volume (NYSE-CSE) | (2) Volume (% CSE) | (3) Amihud Illiquidity (NYSE/Con) | (4) NYSE-Con /Close (%) | (5) NYSE-CSE /Close (%) | (6) NYSE-CSE /Close (%) | (7) NYSE-CSE /Close (%) |
|--------------------------------------|--|------------------------------|--|---------------------------------|---------------------------------|-------------------------------|---------------------------------|
| Clearinghouse | 251,209 | -3.45 | -0.103 | -0.226** | 0.289*** | 0.224*** | 0.238*** |
| Constant | (354,478) 1,310,949*** (230,860) | (2.49) 20.96*** (1.62) | (0.067) 0.363*** (0.044) | (0.101) 0.386*** (0.0697) | (0.077) -0.147*** (0.059) | (0.079) -0.245 (0.203) | (0.059) -0.152*** (0.055) |
| Security Fixed Effects | Y | Y | Y | Y | Y | Y | Y |
| Stock Liquidity Controls | N | N | N | Y | Y | Y | Y |
| NYSE/CSE Stock Liquidity Controls | N | N | N | N | N | Y | N |
| Period | 1886-1925 | 1886-1925 | 1886-1925 | 1886-1925 | 1886-1925 | 1888-1925 | 1886-1908 |
| Min Traded Shares | 200 | 200 | 200 | 500 | 500 | 200 | 200 |
| Data Frequency | Monthly | Monthly | Monthly | Monthly | Monthly | Monthly | Monthly |
| Price Used | Close | Close | Close | Close | Close | Close | Close |
| # Clusters | 90 | 90 | 89 | 85 | 85 | 88 | 62 |
| # Observations | 5,996 | 5,996 | 5,623 | 4,272 | 4,272 | 5,504 | 2,983 |
| Adjusted R-squared | 0.213 | 0.280 | 0.185 | 0.306 | 0.019 | 0.020 | 0.010 |

Table 6.

Daily Data Robustness Tests for Changes in Microstructure Noise or Market Liquidity

In this table we show that the introduction of clearing on the NYSE is not associated with a change in the relative trading on the NYSE vs. the CSE and that the introduction of multilateral net settlement through a centralized clearing party reduced the premium and volatility of the closing price of a stock on the New York Stock Exchange relative to the closing price on the Consolidated Stock Exchange for the same security on the same day. Security market data were hand collected at a daily frequency from the *New York Times* from January 1892 – Dec 1901 for all stocks on the NYSE or CSE. To be included in the analysis a security must trade at least 200 shares on both exchanges on a given date. All data is winsorized at the 1st and 99th percentile. In Column 1, $|NYSE-Con|/Close$ is an estimate of monthly volatility of the price on the NYSE relative to the CSE, normalized by the average closing price on both exchanges in percent. *Post 1893*, which is equal to 1 for all securities clearing after 1893 and zero prior. In Column 2, $|NYSE-CSE|/NYSE Bid-Ask$ is the volatility of the price on the NYSE minus the CSE normalized by the bid-ask spread on the NYSE. Column 3 shows results if we only include stocks with at least 20 daily observations before and after the introduction of clearing. Column 4 shows results with stock-specific time-varying market liquidity controls. In addition to the estimated bid-ask spread on the NYSE, the dollar trading volume on the NYSE, and the dollar trading volume on the CSE. *CSE Bid-Ask Control*, indicates that it also includes the estimated bid-ask spread on the CSE. Column 5 shows results using opening instead of closing transaction prices. In Column 6, *Bid-Ask (%) NYSE-CSE*, is the NYSE minus CSE percent bid-ask spreads (normalized by price) on each exchange. In Column 7 *(Hi-Lo)/Open CSE/NYSE* is the high minus low value normalized by the opening price on the CSE divided by the same on the NYSE. All specifications are run with security-level fixed effects and errors are clustered at the security-level. P-Values: * 10%; ** 5%; *** 1%.

| Dependent Variable: | (1) $ NYSE-CSE /Close$ (%) | (2) $ NYSE-CSE /NYSE Bid-Ask$ | (3) $ NYSE-CSE /Close$ (%) | (4) $ NYSE-CSE /Close$ (%) | (5) $ NYSE-CSE /Open$ (%) | (6) Bid-Ask (%) NYSE-CSE | (7) Hi-Lo/Open CSE/NYSE |
|--------------------------|-------------------------------|----------------------------------|-------------------------------|-------------------------------|------------------------------|-----------------------------|----------------------------|
| Post-1893 | -0.141*** (0.051) | -0.393*** (0.062) | -0.194*** (0.055) | -0.193*** (0.034) | -0.225*** (0.055) | -0.056 (0.074) | 0.038** (0.016) |
| Constant | 0.745*** (0.038) | 1.742*** (0.046) | 0.692*** (0.040) | 0.386*** (0.036) | 0.600*** (0.063) | -0.314*** (0.055) | 0.957*** (0.012) |
| Security Fixed Effects | Y | Y | Y | Y | Y | Y | Y |
| Stock Liquidity Controls | N | N | N | Y | Y | N | Y |
| CSE Bid-Ask Control | N | N | N | Y | Y | N | Y |
| Period | 1892-1901 | 1892-1901 | 1892-1901 | 1892-1901 | 1892-1901 | 1892-1901 | 1892-1901 |
| Min Traded Shares | 200 | 200 | 200 | 200 | 200 | N/A | 200 |
| Min Pre & Post Obs | N/A | N/A | 20 | 20 | 20 | 20 | 20 |
| Data Frequency | Daily | Daily | Daily | Daily | Daily | Daily | Daily |
| Price Used | Close | Close | Close | Close | Open | Close | Open |
| # Clusters | 188 | 188 | 48 | 48 | 48 | 48 | 48 |
| # Observations | 37,682 | 37,666 | 28,165 | 28,100 | 28,097 | 43,271 | 27,183 |
| Adjusted R-squared | 0.164 | 0.078 | 0.049 | 0.101 | 0.052 | 0.097 | 0.061 |

Table 7.
Effect of the Introduction of Novation

In this table we show that the introduction of novation (mutualization of risk through a centralized counterparty) on the NYSE in April 1920 does not appear to significantly affect the counterparty risk premium between the NYSE and CSE. Security market data were hand collected and are analyzed at a monthly frequency from the *New York Times* and *Commercial and Financial Chronicle* from Sept 1886 – January 1922 for all stocks in the Dow Jones Indices. The period February 1922-December 1925 is excluded from this analysis because of accusations of fraud on the CSE, which eventually led to its downfall, beginning with the failure of MacMasters & Co. in February of 1922. To be included in the analysis a security must trade at least 200 shares on both exchanges on a given date. All data is winsorized at the 1st and 99th percentile. In column 1, *NYSE-CSE/Close* is the price on the NYSE minus the CSE normalized by the average closing price on both exchanges and *Novation* is a dummy variable equal to 1 if the date is after April 1920. Column 2 is the same as column 1 but includes relative stock-specific time-varying market liquidity controls. These include $\$ Volume$ (*NYSE-CSE*), $Volume$ ($\% CSE$), the Amihud illiquidity measures on both exchanges and their ratio, seat prices on the NYSE and CSE and their ratio, and natural logs of $\$ volume$ on both the NYSE and CSE. In column 3, *NYSE-Con/NYSE Bid-Ask* is the LHS variable and is the price on the NYSE minus the CSE normalized by the bid-ask spread on the NYSE. In column 4, $|NYSE-Con|/Close$ is an estimate of monthly volatility of the price on the NYSE relative to the CSE by looking at the absolute price deviation, normalized by the average closing price on both exchanges in percent. All specifications are run with security-level fixed effects and errors are clustered at the security-level. P-Values: * 10%; ** 5%; *** 1%.

| Dependent Variable: | (1) NYSE-CSE / Close (%) | (2) NYSE-CSE / Close (%) | (3) NYSE-CSE /NYSE Bid-Ask | (4) NYSE-CSE /NYSE Bid-Ask |
|--------------------------------------|--------------------------------|--------------------------------|----------------------------------|------------------------------------|
| Novation | -0.0462 (0.0434) | -0.1198 (0.0762) | -0.1391 (0.1240) | 0.0912 (0.1011) |
| Constant | 0.0548*** (0.0028) | -0.326 (0.212) | 0.1828*** (0.0079) | 1.064*** (0.0065) |
| Security Fixed Effects | Y | Y | Y | Y |
| Stock Liquidity Controls | N | Y | N | N |
| NYSE/CSE Stock Liquidity Controls | N | Y | N | N |
| Period | Sep 1886 – Jan 1922 | Sep 1886 – Jan 1922 | Sep 1886 – Jan 1922 | Sep 1886 – Jan 1922 |
| Only Post-clearing Stocks | Y | Y | Y | Y |
| # Clusters | 51 | 50 | 51 | 51 |
| # Observations | 3,487 | 3,313 | 3,479 | 3,479 |
| Adjusted R-squared | 0.019 | 0.046 | 0.012 | 0.017 |

Figure 1

Timeline of Introduction of Clearing on New York and Consolidated Stock Exchanges

This timeline shows the introduction of a clearinghouse on the Consolidated Stock Exchange in June 1886 and the introduction in stages on the New York Stock Exchange beginning in May 1892. Data on trading volumes are taken from Sobel (2000).

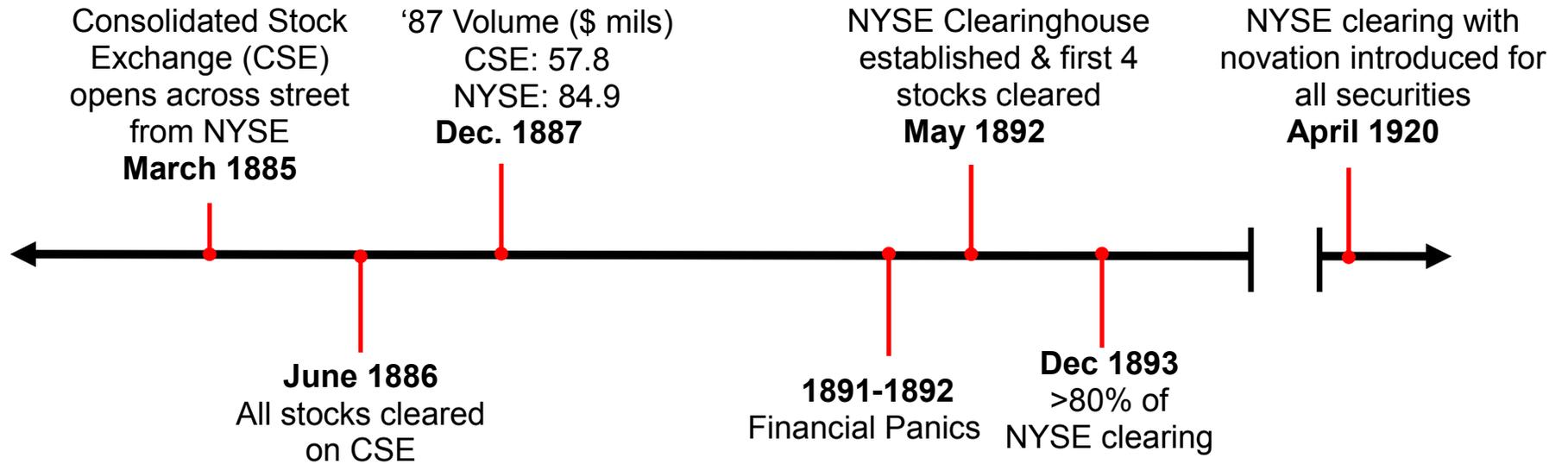


Figure 2

Counterparty Risk Premium and Introduction of Clearing on NYSE (1886-1925)

In this figure we show the estimated effect of the introduction of multilateral net settlement through a centralized clearing party on the closing price of a stock on the New York Stock Exchange relative to the closing price on the Consolidated Stock Exchange for the same security on the same day. Security market data were hand collected at a monthly frequency from the *New York Times* and *Commercial and Financial Chronicle* from September 1886 – December 1925 for all stocks in the Dow Jones Indices. To be included in the analysis a security must trade at least 200 shares on both exchanges on a given date. All data is winsorized at the 1st and 99th percentile. *NYSE-Con/NYSE Bid-Ask* is the price on the NYSE minus the CSE normalized by the bid-ask spread on the NYSE and *Call Loan Rate* is the overnight collateralized broker borrowing rate. The period prior to the establishment of the NYSE clearinghouse May 17th, 1892 is highlighted in red.

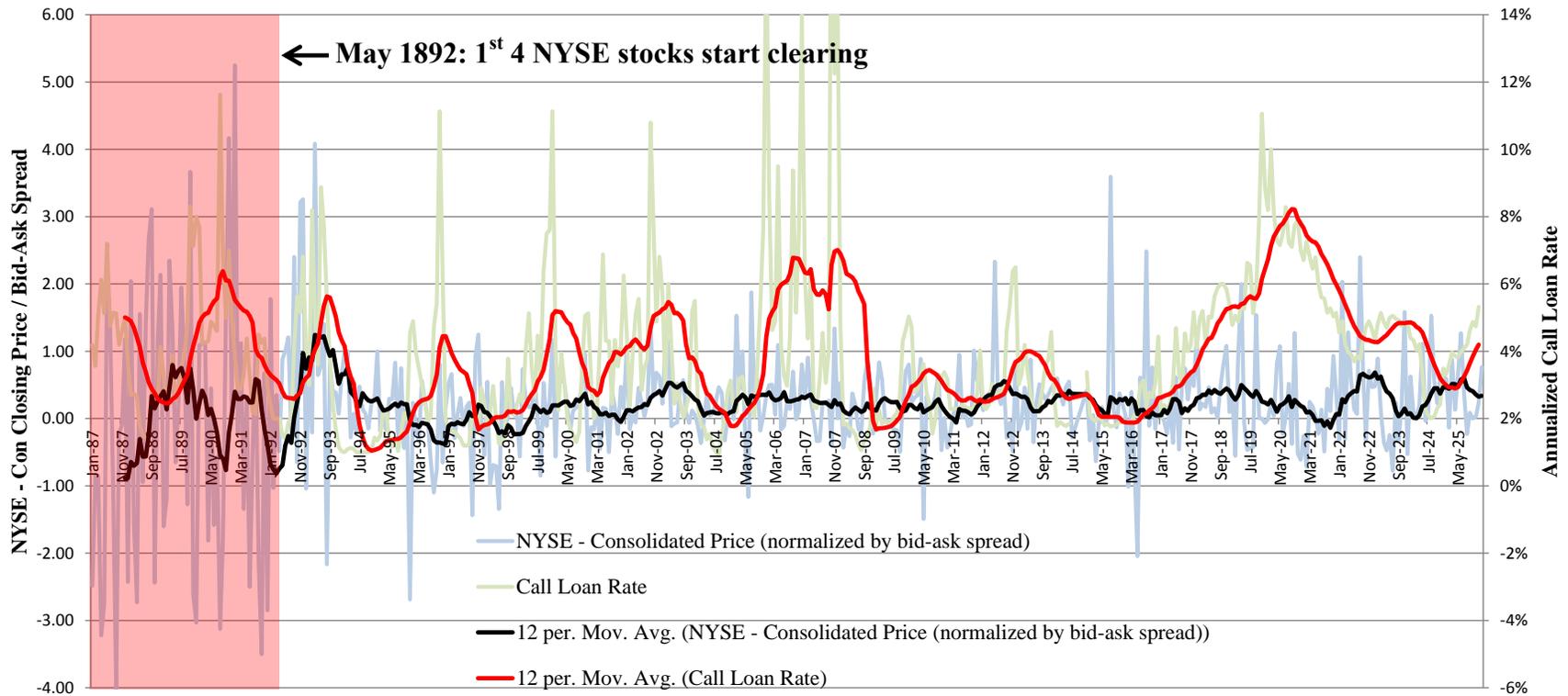


Figure 3

Rolling Standard Deviation of Price Deviations NYSE-CSE and Introduction of Clearing on NYSE (1886-1925)

In this figure we show the estimated effect of the introduction of multilateral net settlement through a centralized clearing party on the rolling 12-month standard deviation of closing price of a stock on the New York Stock Exchange relative to the closing price on the Consolidated Stock Exchange for the same security on the same day. Security market data were hand collected at a monthly frequency from the *New York Times* and *Commercial and Financial Chronicle* from September 1886 – December 1925 for all stocks in the Dow Jones Indices. To be included in the analysis a security must trade at least 200 shares on both exchanges on a given date. All data is winsorized at the 1st and 99th percentile. *NYSE-Con/NYSE Bid-Ask* is the price on the NYSE minus the CSE normalized by the bid-ask spread on the NYSE. The period prior to the establishment of the NYSE clearinghouse May 17th, 1892 is highlighted in red.

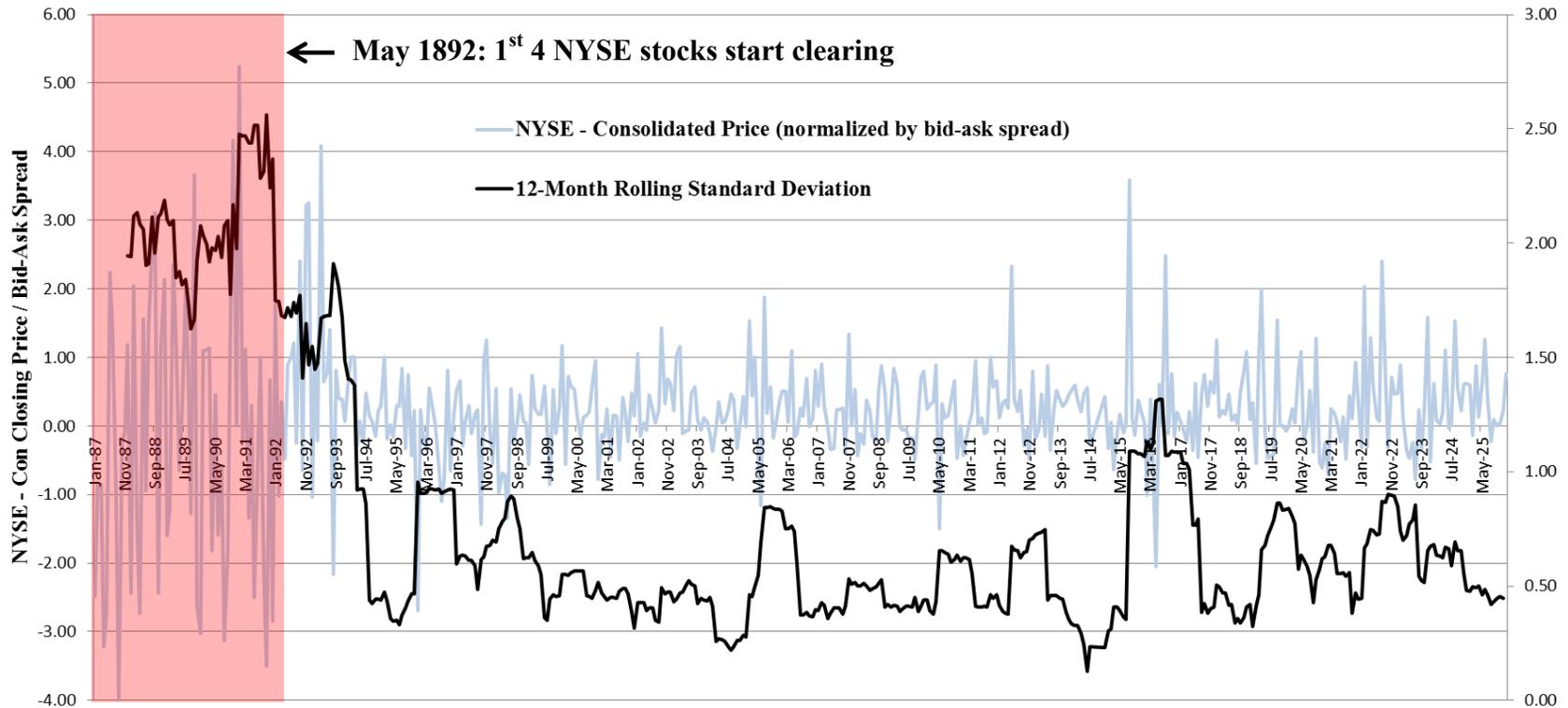


Figure 4

Mean Absolute Value of NYSE-CSE Normalized by NYSE Bid-Ask Spread and Introduction of Clearing on NYSE (1886-1925)

In this figure we show the estimated effect of the introduction of multilateral net settlement through a centralized clearing party on average absolute value of the price difference of the closing price of a stock on the New York Stock Exchange relative to the closing price on the Consolidated Stock Exchange for the same security on the same day. Security market data were hand collected at a monthly frequency from the *New York Times* and *Commercial and Financial Chronicle* from September 1886 – December 1925 for all stocks in the Dow Jones Indices. To be included in the analysis, a security must trade at least 200 shares on both exchanges on a given date. All data is winsorized at the 1st and 99th percentile. The blue plot is the $|NYSE-CSE|/NYSE\ Bid-Ask$ which is the price on the NYSE minus the CSE normalized by the bid-ask spread on the NYSE and the change is driven by a reduction in volatility on the NYSE. The red dash lines indicate the average before and after the end of 1893.

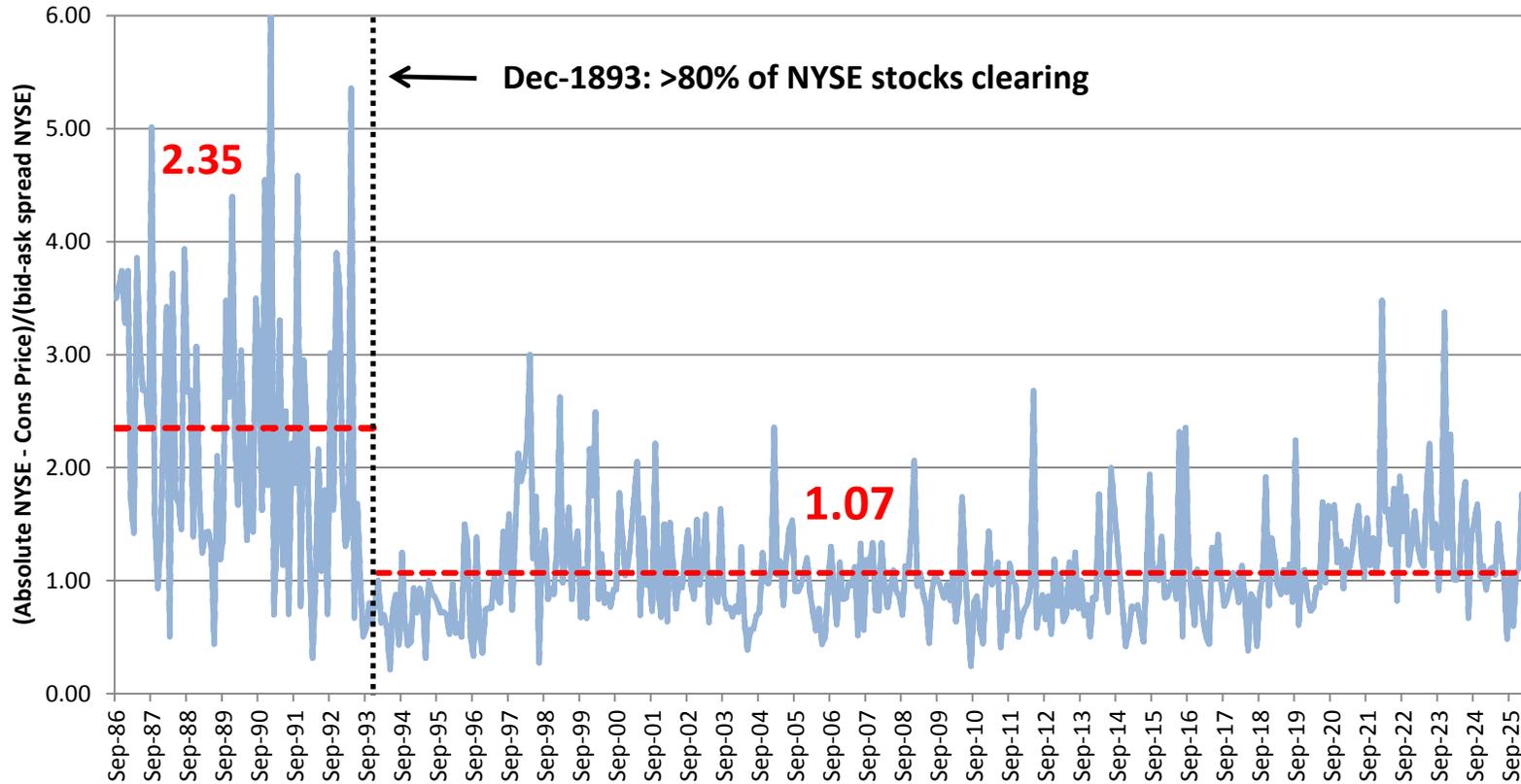


Figure 5

Daily Volumes for Dow Jones Stocks on NYSE and CSE 1886-1900

In this figure we show that the introduction of clearing on the NYSE is not associated with a change in the relative trading on the NYSE vs. the CSE. Security market data were hand collected at a monthly frequency from the *New York Times* and *Commercial and Financial Chronicle* from September 1886 – December 1925 for all stocks in the Dow Jones Indices. To be included in the analysis a security must trade at least 200 shares on both exchanges on a given date. The green dashed line indicates the establishment of the NYSE clearinghouse May 17th, 1892. All data is winsorized at the 1st and 99th percentile.

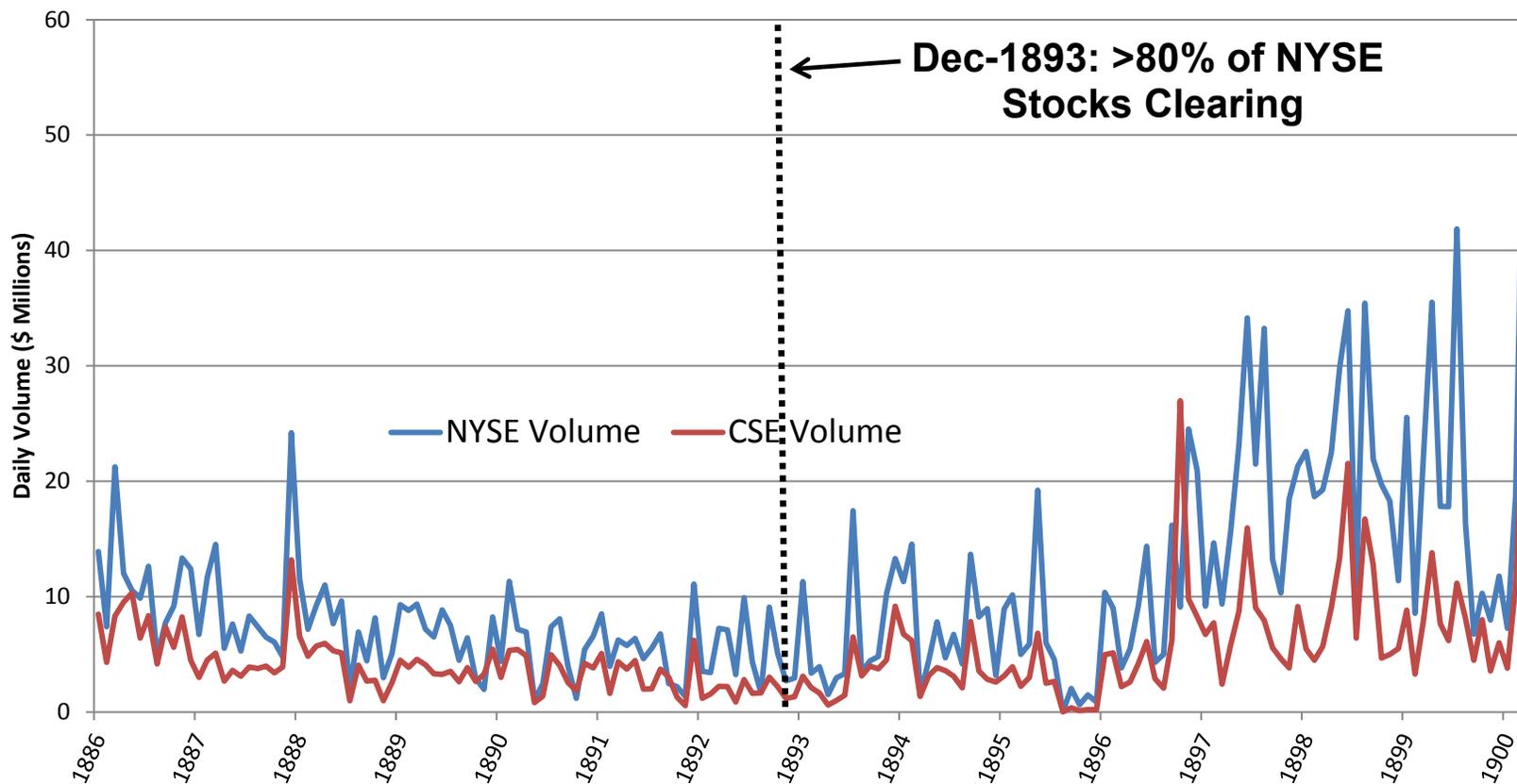


Figure 6

CSE/NYSE Bid-Ask Spreads 1892-1901

In this figure we show that the introduction of clearing on the NYSE is not associated with a change in the relative bid-ask spread on the NYSE vs. the CSE. Security market data were hand collected at a daily frequency from the *New York Times* from January 1892 – Dec 1901 for all stocks on the NYSE or CSE. To be included in the analysis a security must trade at least 200 shares on both exchanges on a given date. All data is winsorized at the 1st and 99th percentile. For a description of the estimation of the bid-ask spreads see appendix A.

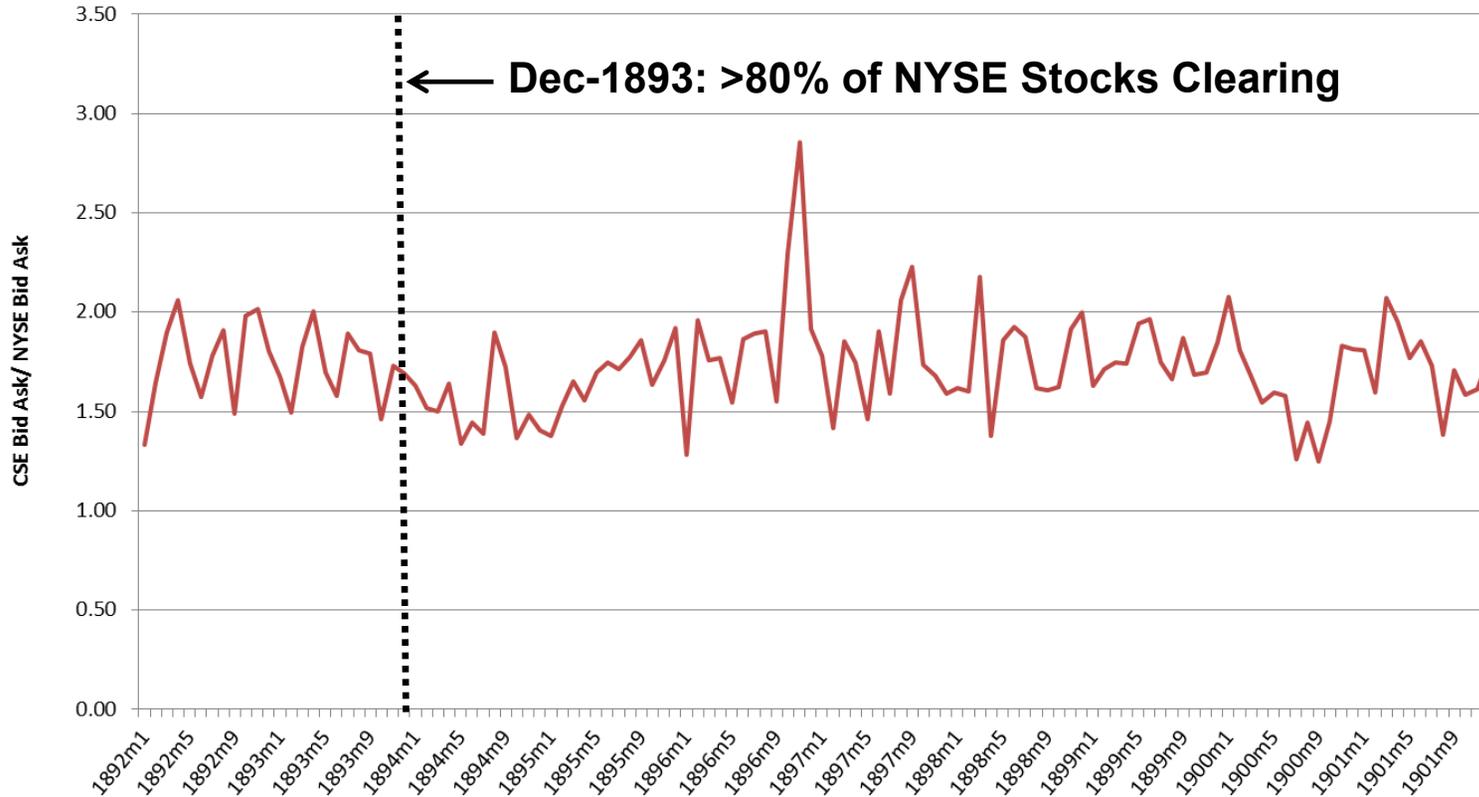


Figure 7

Call Loan Interest Rates 1886-1925 (Overnight Collateralized Borrowing Rate)

In this figure we show that the introduction of clearing on the NYSE is not associated with a change in macro-economic risk. Closing monthly broker call loan rates are taken from NBER macro-history database for the entire period.

