Central Banking, Liquidity, and Financial Crises

Asaf Bernstein  Eric Hughson  Marc Weidenmier

February, 2011

Abstract

We use the nineteenth and early twentieth century as a randomized historical experiment to examine the effect of funding liquidity on financial markets from 1815-1925. US markets were often illiquid and prone to crises in September and October because of financial stress from the harvest. We find that in periods without a financial institution acting as a central bank market volatility is substantially higher during the harvest than during the rest of the year. However, during periods with financial institutions such as the Second Bank of the US (1816-1836) and the Federal Reserve (1915-1925) seasonal fluctuations disappear. Additionally, we find that shocks to funding liquidity precede market declines and decreases in market liquidity. Through this relationship the founding of the Federal Reserve is associated with a drop in stock liquidity betas and hence illiquidity premiums. These results suggest that the founding of the Fed was a watershed event for improving the liquidity of financial markets.

Sloan School of Management-MIT; E-mail: asafb@mit.edu  Claremont McKenna College; E-mail: Eric.Hughson@claremontmckenna.edu  Claremont McKenna College and National Beareau of Economic Research Associate; 500 East Ninth Street, Claremont, CA 91711. E-mail: mweidenmier@cmc.edu; Phone: (909)607-8497

The authors would like to thank Vishnu Narasimhan for excellent research assistance, participants at the 2010 Western Economic Association Meetings, Ron Masulis, and seminar participants at the Australian National University, The Massachusetts Institute of Technology, Monash University, the University of New South Wales, and the University of Sydney for helpful comments. We also wish to thank the Lowe Institute of Political Economy and the Financial Economics Institute at Claremont McKenna College for financial support.
The recent financial crisis raises serious concerns about the origins and effects of funding liquidity (the ease with which a trader can obtain funding) on financial markets. The argument has been made that the lack of funding liquidity can have serious negative consequences. For example, the inability of borrower to obtain funding for home mortgages can cause home prices to fall (Brunnermeier, 2009). Further, the inability of firms to sell commercial paper to finance continued operations can cause their stock prices to decline, as funding concerns cause them to abandon positive net present value projects. The Federal Reserve clearly believes that the consequences of funding illiquidity are negative because it has reacted strongly to inject liquidity into financial markets. Recent examples include the Fed’s decision to purchase unsecured 90-day commercial paper directly from corporations in late October 2008 and the recently-completed $1.25 trillion home mortgage bond purchase program. These actions are perhaps unsurprising given that Fed Chairman Bernanke is an expert in how shocks to funding liquidity can cause asset prices to decline through the balance sheet channel (Bernanke and Gertler 1990, 2000).

New research has identified other important effects of changes in funding liquidity on financial markets. Brunnermeier and Pederson (2009), for example, explore the relationship between funding liquidity and market liquidity – the ability to and the price at which one can buy or sell an asset. They argue that funding liquidity is an important determinant of market liquidity, market volatility, and market risk premiums. In particular, a decrease in funding liquidity (i.e. due to a change in traders’ wealth or a change in margin interest rates) can reduce market liquidity. Their analysis suggests that purchased commercial paper valued at $145.7 billion.  

1 By Oct 29, the Federal Reserve
market liquidity is likely to be low (meaning low trading volume and high bid-ask spreads) when funding liquidity is low – i.e. when margin costs are high. Hence, a negative shock to funding liquidity can also cause prices for risky assets to fall. Brunnermeier and Pedersen (2009) point to the 1987 Stock Market Crash, collapse of Long-Term Capital Management (LTCM), and the recent sub-prime mortgage crisis as examples where funding constraints have played an important role in the onset and spread of a financial crisis.

Given the Federal Reserve's concerns about funding liquidity, an important question is whether central bank intervention is likely to have a positive impact. It is difficult, however, to identify the effect of a shock to funding liquidity on market liquidity because funding and market liquidity are often jointly determined both in theoretical models and in the marketplace (Brunnermeier and Pedersen, 2009). Fortunately, history provides a natural experiment to identify both the impact of an exogenous change in funding liquidity on financial markets and the importance of central and quasi-central banks for reducing funding constraints. During the nineteenth and early twentieth centuries, financial crises often occurred in September and October, including the major panics of 1819, 1857, 1873, 1890, and 1907. Financial markets were often illiquid during the fall because farmers borrowed then to finance the production and marketing of crops. Although the increased amount of uncertainty during the fall was forecastable, the realization of the funding shock was not. Hence, it was more likely that

---

2 Brunnermeier and Pedersen (2009) analyze a shock to speculator capital - something which is hard to identify. 3 Most financial panics of the nineteenth century occurred just after asset values had fallen from business cycle peaks. See Calomiris and Gorton (1991) or Bernstein, Hughson, and Weidenmier (2010) for details. Davis et. al (2009) provide evidence that business cycles from 1880 until the outbreak of World War I were caused by fluctuations in the size of the cotton harvest.
during the fall, banks would not have sufficient funds on hand to lend, and when they did not, given the US was on the gold standard, interest rates would spike – an exogenous funding shock which not only affected the rate at which farmers could borrow, but also that at which brokers could borrow in New York..

Our proxy for these exogenous funding shocks is the call loan rate, the rate at which investors could buy on margin. Prior to the Great Depression, this forward-looking was set by market forces. Using today’s margin rate to measure funding liquidity is problematic because it is not a market rate today - the Fed sets it. Therefore, many modern studies rely instead on the interest rate differential between LIBOR and Treasury bills to calculate a measure of funding liquidity.4

First, we investigate the effect of funding shocks on asset volatility. In particular, we compare the volatility of monthly stock returns and interest rates in September and October with the rest of the year over the period 1815-1925. We find that interest rate volatility in September and October was more than 50 percent higher in the fall than during the rest of the year. Stock volatility was more than 70 percent higher. However, market volatility in September and October was not significantly higher than the rest of the year during the two periods when there were financial institutions, the Second Bank of the United States (SBUS) (1816-1836) and the Federal Reserve (1915-1925), which could reduce liquidity risk. The results highlight the importance of funding liquidity as well as the role of financial institutions in preventing liquidity spirals and financial crises. Further, this identification strategy is immune to the criticisms that (1) the agricultural sector was of decreasing importance throughout the period because the agricultural sector 4 The creation of the SEC in the 1930s granted the Federal Reserve the right to set margin rates in financial markets.
was largest during the time of the SBUS, and stock return volatility during the fall was actually lower than during the rest of the year and (2) World War I and the closure of the New York financial markets also affected the stochastic behavior of interest rates, so that a time series analysis was likely to be problematic.

Next, we examine the effect of funding and market liquidity on stock returns by analyzing the dynamic relationship between the call loan rate, bid-ask spreads, and stock returns from 1894 to 1925. We find that increases in the call loan rate Granger-cause stock returns at the five-percent level of significance. Impulse response analysis reveals that a one standard deviation positive shock to the call loan rate reduces stock returns by 1.9 percent after 36 months, while a one-standard deviation negative shock to stock returns actually decreases the call loan rate. Both shocks up in call loan rates and down in stock returns decrease market liquidity, as indicated by an increase in the average bid-ask spread. The presence of a central bank appears to have significantly relaxed funding constraints which lead to a natural decline in stock market panics through this identified liquidity and asset price dynamics.

Finally, we investigate how the changes in market liquidity affect expected asset returns. In particular, we investigate whether the founding of the Federal Reserve affects stock market liquidity through (1) reduced bid-ask spreads and (2) through a change in liquidity risk (see Acharya and Pedersen (2005)) – that is, the risk that bid-ask spreads widen when a stock must be sold. We further examine whether there is a flight to quality
– when liquidity premiums are high, the differential between liquidity premiums on illiquid and liquid stocks is also high. There are many reasons to explore the liquidity implications of this particular monetary regime change, first and most important, our
earlier results suggest that the Fed smoothed out funding liquidity shocks through the link between funding and market liquidity, suggesting that market liquidity itself might improve. Second, one can examine cleanly the effect of a central bank on liquidity. Third, stock markets in the United States were far less liquid than they are now, so the creation of the Federal Reserve could have had a massive effect. Last, Brunnermeier and Pedersen’s (2009) flight to quality hypothesis suggests that liquidity risk is likely to be a far greater problem then than now since the relative illiquidity risk of illiquid stocks is likely to be very high and could be substantially reduced by the Fed.

To analyze the change in liquidity risk we collect monthly bid-ask data on every stock on the NYSE from 1894 until 1925. We then sort stocks into four liquidity portfolios and estimate liquidity premiums for each along the lines suggested by Acharya and Pedersen (2005) both before and after the monetary regime change. Compared with Acharya and Pedersen’s liquidity beta estimates, the ones we compute for this time period are enormous: the net liquidity beta estimated for Acharya and Pedersen’s most liquid quintile of stocks is about 1.13, and it is 5.25 for their least liquid quintile. In contrast, after the founding of the Fed, our most and least liquid quartiles of stocks have liquidity betas of 10.64 and 31.88, and they are 13.03 and 36.19 in the pre-Fed period, about an order of magnitude higher than those in Acharya and Pedersen5.

Although the level of bid-ask spreads is unaffected by the monetary regime change, liquidity betas decline after the Fed’s founding, as seen above, so that illiquidity premiums fall across the board, falling 43 basis points even for the most liquid stocks. In addition, we find strong evidence for the flight-to-quality posited in Brunnermeier and 5 In keeping with the convention of Archarya and Pedersen all betas have been multiplied by 100 when reported for ease of reading.
Pedersen (2009). Before the founding of the Fed, when markets were less liquid, the liquidity premium differential between high and low liquidity stocks is 35 basis points higher than afterward. Although some of the effect could be due to increasing liquidity over time in the stock market, it is unlikely to be the primary driver of these results. Hence, the founding of the Federal Reserve appears to have had profound effects on liquidity.

The analysis begins with a brief history of early US financial markets. We then discuss the implications of the Brunnermeier and Petersen (2009) model of funding and market liquidity for early US financial markets. In the next subsection, we examine the relationship between changes in interest rates, stock returns, and bid-ask spreads. Finally, we analyze changes in liquidity during financial crises and estimate the liquidity premium using a version of Acharya and Pedersen’s (2005) liquidity-adjusted CAPM. We conclude with a discussion of the implications of the results for future studies of the importance of funding liquidity for financial markets.

I. US Financial Markets, 1815-1925

A. Overview

That banking institutions in the United States did not evolve continuously over the nineteenth and early twentieth century makes analyzing the effect of central banking on financial markets considerably easier. In particular, before 1836, the United States had, two quasi-central banks, initially the First Bank of the United States and then, after a small gap, the Second. From 1837 until at least 1908, there was no institution that performed any central banking function. After 1908, a period of study began which...
culminated in the founding of the Federal Reserve in 1913. Hence, one can attribute changes in volatility and liquidity more easily to changes in banking institutions, rather than to secular trends, such as increasing liquidity and the decreasing size of the agricultural sector over time.

B. Antebellum Period

Established in 1791, the First Bank of the United States (FBUS) was chartered for 20 years and served as the banker of the US government. The FBUS was a semi-public national bank where foreigners held a large non-voting stake in the institution. Although the FBUS did not have the explicit ability to print money, it performed many traditional central banking functions. It served as a depository for government revenues. It attempted to regulate state banks that had over-issued bank notes and tried to coordinate credit policies across the different branches of the FBUS (Cowen, 2000, 2008). The bank closed in 1811 after Congress failed to renew its charter in 1808.

After the War of 1812, the United States government established a successor to the FBUS that performed many of the same functions. Nicholas Biddle, President of the SBUS from (1823-1836), brought several important institutional changes to the operation of the bank that reduced frictions in credit markets even though the SBUS also did not have the legal authority to print money. He established a series of branch banks and national payment system for government revenue. The SBUS had some ability to control the money supply in the United States with determined by the amount of specie. During almost the entire nineteenth century, argues that the FBUS triggered a financial panic in 1792 by initially discounting too many bills thereby adding excessive liquidity to the economy. The FBUS abruptly changed course by reducing the supply of credit which initiated a panic in American financial markets. Secretary Hamilton purchased securities on the open market to curtail the financial crisis (Sylla et. al, 2009).
the money supply by altering the length of time that they held onto bank notes before presenting them for redemption (Bodenhorn, 2000). There is some evidence that the bank was successful in its attempts to provide liquidity and reduce volatility. Knodell (1998) finds that centralized management by the bank of domestic exchanges reduced domestic exchange rate volatility in the Midwest. Hilt (2009) provides evidence that because of its relatively conservative lending policy, the SBUS was able to provide funding liquidity in the form of short-term loans to financial institutions during Wall Street’s first corporate governance crisis in 1826.

Unfortunately for the Second Bank, Andrew Jackson vetoed legislation in 1833 that would have renewed its charter. Rather than depositing government assets with the Second Bank, Jackson then established a series of “pet” banks that served as depositories for revenue collected from land sales by the Federal government. This policy effectively rendered the SBUS powerless as the financial institution no longer had federal funds to support short-term credit operations and could not limit money creation (Atack and Passell, 1994).

Shortly after the SBUS ceased operations, the United States experienced the Panic of 1837. The Panic and accompanying recession is widely regarded as one of the most severe in American history, with the money supply falling by 34 percent between 1838 and 1842 and prices decreasing 33 percent from 1839 to 1843. It is a matter of some debate as to whether the demise of the SBUS caused the Panic.8

8 Some scholars point to the elimination of the SBUS as playing an important role in the financial crisis. The SBUS checked rapid expansion of the money supply by wildcat banks in the west by presenting notes for redemption (Highfield, O’Hara, and Smith, 1996; Knodell, 2006). Rousseau (2002) argues that a series of interbank transfers and a western
land boom that required payment in specie as a result of the Specie Circular (1836) drained New York City banks of coin and triggered a financial panic. Temin points instead
The remainder of the antebellum period is often characterized as the “Free Banking Era.” This regime had some deficiencies. First, the nation had no unified currency. State banks issued their own bank notes as currency against their own deposits of specie with reserve requirements that varied across states. Hence, it was difficult to determine relative values of state bank notes. Second, for obvious reasons, the money supply and the price level were highly unstable, adding additional asset market volatility. Third, because of unit banking there were frequent bank runs that resulted in substantial depositor losses.

Many banking innovations did occur during this time, however. Savings banks, insurance companies and the short-term credit market developed. An active market for commercial paper began to develop in the 1830s as a short-term method of finance for corporations (Myers, 1944). The call loan market also became an important short-term debt instrument. In this market, banks from around the United States would send funds to New York that brokers and banks would lend to stock speculators to purchase stock on margin.⁹

A. Post-Bellum Period

Although the Civil War brought many changes to the banking system, it is not clear whether on balance, those changes were helpful. The US Congress passed the National to contractionary monetary policy by the Bank of England in response to a gold drain as the most important factor in triggering the Panic of 1837. The central bank raised interest rates in 1836 that caused a specie outflow from the United States. Investors were generally required to provide collateral that amounted to 80 to 90 percent of the value of the stock loan. Collateral usually took the form of government bonds or high grade railroad bonds. In the event of a stock market crash, the bank or broker could sell the collateral
on the open market to minimize their losses.
Banking Acts of 1863, 1864, and 1865 that established a uniform currency, raised funds to fight the Civil War, and standardized the banking system. The legislation required banks to maintain a certain level of capital and purchase government bonds that were held by the US Treasury. In turn, banks could issue notes up to 90 percent of the par value of its bonds.

Unfortunately, the National Banking Act established a three-tiered reserve system. The first tier consisted central reserve cities such as Chicago and New York City.

The second consisted of reserve city banks and the third tier was comprised of country banks. Reserve city banks could hold half of their reserves as deposits in central reserve cities. Country banks, on the other hand, could hold as much as 60 percent of their reserves as deposits in New York City.

This created incentives for banks to deposit funds in New York City and other central reserve cities where they could earn two percent interest (reserves held in second tier and third-tier banks did not pay interest). This incentive led to the “pyramiding of reserves” problem where funds in central reserve city banks were counted as reserves not only by the central reserve city banks but also by second- and third-tier banks. Central reserve city bankers then often used these to issue call loans to investors who used the fund to purchase stock on margin. The short-term debt instrument was callable on demand by the broker and banker that issued the obligation. Unexpected demand from depositors at second or third tier banks could create serious problems for investors because it could force the central reserve city banks to call in their stock loans, raise interest rates substantially, or both. Any of these actions could trigger a liquidity spiral.
and lead to a financial crisis.
US financial markets were particularly vulnerable to a financial crisis during the fall harvest season. Indeed, some of the largest financial crises of the nineteenth and early twentieth century occurred during the fall, including the Panics of 1873, 1890, and 1907 (Kemmerer, 1911; Sprague, 1910). Uncertainty associated with loan and currency demand increased as farmers used credit to harvest and market their crops. An unexpected increase in the demand for funds led to a rise in interest rates because the US was on the gold standard and did not have a central bank to provide additional short-term liquidity. This means that a large withdrawal was more likely to lead banks or financial institutions to call in their stock loans. This could trigger a bank run if depositors were unsure about bank solvency. Because of depositor uncertainty bank asset values, this could create a domino effect and could spread throughout the financial system and lead to a panic. Further, monetary stringency in the fall harvest season could be exacerbated if the US economy had already experienced a business cycle turning point earlier in the year that led to a decline in bank asset values (Calomiris and Gorton, 1991).

The frequent occurrence of financial crises during the National Banking Period ultimately led to reform of the financial system. Following the Panic of 1907 in which JP Morgan and a small group of bankers provided liquidity to the New York financial market to shore up financial markets and avert a larger crisis, in May 1909, Congress passed the Aldrich-Vreeland Act that granted certain banks the authority to issue emergency currency during a financial crisis. The Aldrich-Vreeland Act also created the National Monetary Commission to investigate the possibility of creating a central bank.  

\footnote{The Aldrich-Vreeland Act was only used once before the establishment of the Federal Reserve. Secretary of Treasury William McAdoo invoked the act in July 1914 and issued emergency currency to prevent a financial crisis in the United States following the}
outbreak of World War One (Silber, 2005, 2007a, 2007b).
for the United States. The Federal Reserve Act was passed in 1913 and the central bank began using open market operations in January 1915. As was noted by Wheelock (1992) and can be seen in figure 1 the seasonal provision of credit and currency by the Federal Reserve System highlighted the pre-Federal Reserve seasonal market demand for money and helped to alleviate its inelastic supply during the harvest months.

II. Funding Liquidity and Historical Financial Markets

The seasonal nature of nineteenth and early twentieth century financial markets provides a laboratory to examine the impact of an exogenous change to funding liquidity. Our proxy for funding liquidity is the call loan interest rate, the rate at which investors could buy and sell on margin. Investors could typically borrow 80 percent against the value of their collateral that usually took the form of US government bonds. Unlike today, when margin rates are determined by the Federal Reserve, the call loan rate was determined by the supply and demand for excess reserves in the New York market. During 1815-1925, the amount of excess reserves was largely determined by agricultural shocks. Hence, the call loan rate could be very volatile during the harvest season because unexpected loan demand could be high and there was no institution to increase the money supply or provide additional funding liquidity.

We use the call loan rate as a direct measure of funding liquidity to test the
predictions of the Brunnermeier and Pedersen (2009). One testable implication is that without a lender of last resort, stock return and interest rate volatility should be higher in September and October because of agricultural shocks to funding liquidity. We therefore
compare the volatility of stock returns and the call loan rate in the fall with the rest of the year. Then we investigate how a change in funding constraints affects financial markets for the period 1815-1925. The pre-1925 period is unique in American history because the U.S. had two financial institutions that performed central banking functions to varying degrees: (1) the Second Bank of the United States and (2) the Federal Reserve.

The existence of a quasi or fully functional central bank means that liquidity crises should be less likely to occur because the central bank can either lend more generously or create money to lend to prevent large increases in the call loan rate which could otherwise lead to liquidity crises. Furthermore, the demise of the SBUS provides a rare opportunity to analyze the impact of dismantling a financial institution that had some control over monetary and credit policy.

Second, to the extent that speculators are long and their positions are financed by buying on margin, stock prices should fall with an increase in the call loan rate. The fall could be either temporary or longer lasting depending on the availability of credit and the importance of the balance sheet channel (Bernanke and Gertler 1990). Third, if speculators also provide liquidity in the stock market, market liquidity would decline with an increase in the call loan rate as shown by a rise in bid-ask spreads.

Brunnermeier and Pedersen’s (2009) model also predicts that a shock to funding liquidity should affect all asset prices – there is commonality in liquidity. This follows because a change in the call loan rate should affect all securities and traders in the marketplace. The effects could also be non-linear because a large increase in the call loan rate could result in a credit freeze, forcing leveraged investors and market makers to
Bernstein, Hughson and Weidenmier (2010) show that volatility in the commercial paper rate should also increase.
liquidate their positions. A large decrease need not have the opposite effect. For speculators who were not financially constrained, however, it is unlikely that changes in the call loan rate would have much of an effect on their margin accounts.

The testable implications can be summarized as follows:

1. Stock and short-term interest rate\textsuperscript{12} volatility should be higher during the fall as long as there is not a financial institution that can increase funding liquidity.

2. Call loan rates should Granger-cause (1) low stock returns and (2) higher bid-ask spreads.

3. There should be commonality in funding liquidity so that bid-ask spreads are correlated across stocks.

4. Funding liquidity should be significantly lower in September and October when there is not a financial institution that can increase funding liquidity in the event of a crisis.

We now turn to the empirical analysis to analyze the effect of funding constraints on financial markets over the period 1815-1925.

II. Empirical Analysis

A. Data

To analyze the impact of funding liquidity on market liquidity, we use financial data from several different sources. For short-term interest rates, we use call loan money rates (1857-1925) from the NBER macro-history database and the commercial paper rate (1835-1925) from Global Financial Data (GFD).\textsuperscript{13} For the stock market, we use

\textsuperscript{12} Short-term interest rate proxies include the commercial paper and call loan rates. The commercial paper rates from GFD are taken from the \textit{Commercial and Financial Chronicle} and the \textit{Financial Review}. The call loan rates are taken from Macaulay (1938).

\textsuperscript{13}
Goetzmann, Ibbotson, and Peng's, (2001) hereafter GIP, comprehensive monthly stock market indexes of the pre-CRSP era for the period 1815-1925. End-of-month bid-ask data are taken from the *New York Times*. The GIP data is the broadest index publicly available for the pre-CRSP period and covers more than 600 securities during our sample period. Month-end prices were obtained by searching for the last transaction price for each stock in a given month from the *New York Times* and other financial newspapers. When a closing price was not available, the most recent bid and ask prices were averaged, in keeping with the methodology employed by CRSP. The GIP index significantly improves on the Cowles Index and the Dow Jones Industrial Average, the other two widely employed indexes from this period.\(^{15}\)

As a test of the informational content of our indices we consider the relationship between them and the new comprehensive annual industrial production index for 1790-1915 collected by Davis (2004). As noted first by Fama (1990) for 1953-1987 and then by Schwert (1990) from 1889-1988 future production growth rates explain a large fraction of the variation in stock returns for monthly, quarterly, and annual holding periods. So, if the GIP index was collected accurately, the index is fairly comprehensive, and financial markets throughout the 19 and 20th century contained informational content we would expect stock returns to explain future growth rates during our period of

---

\(^{14}\) Trading volume taken from the NYSE website and the *New York Times* were also considered as a possible market liquidity proxy, but overall market volume may actually increase when market liquidity declines as traders flood the market with sell orders. To construct liquidity proxies with volume of the kind proposed in Amihud (2002) a more comprehensive collection of firm-specific time series of volumes and price movement would be necessary than are currently available. \(^{15}\) The Cowles Index is value weighted over the period from 1872-1925, causing a large-cap bias in computed index returns. Prices are also calculated by averaging monthly high and low prices which induces serial correlation in the Cowles Index of monthly returns. As shown in Bernstein, Hughson and Weidenmier (2010), the first-order autocorrelation coefficient for the Cowles Index is 26 percent versus six percent for the price-weighted GIP index.
interest as well. We find that from 1815 to 1915 there is a 52% correlation between annual stock returns and next year changes in log production and using 30-year rolling calculations there is no period where the correlation is lower than 43% over the entire sample. This provides a good justification for the use of the GIP index over this period as a comprehensive stock market index and predictor of future real economic activity.

**B. Volatility Tests**

**Stock Market Volatility**

To investigate the importance of funding liquidity, we first examine its effect on stock volatility over the period 1815-1925. We expect a strong link between funding liquidity shocks and stock returns in periods where the US did not have a quasi-central banks (Sibus) or a lender of last resort (Fed/AV), (1837-1908). In particular, high call loan rates should be associated with lower stock returns for four reasons: 1) the balance sheet channel identified by Bernanke and Gertler (1990), 2) equity demand falls when funding liquidity is tight and interest rates are rising and 3) expected gross equity returns must be higher during periods of market illiquidity because of the increased costs of market making, 4) as noted by Benmelech et al (2010) usury laws in effect during the 19th century were binding at times when short-term market rates spiked, restricting borrowing.

16 Similar results hold when instead a vector auto-regression is used with deviations from the log IP series based on a Hodrick-Prescott filter and a conventional smoothing parameter of 100. There is also some evidence to suggest that annual average call loan rates were inversely related to shocks to the next year’s industrial production when stock returns are omitted from the regression. Details available from authors upon request.
and lending among smaller borrowers effecting financial markets and subsequently real economic activity.

We therefore compare stock return volatility using data from only the months of September and October with volatility using data drawn only from the rest of the year. This strategy is motivated by the observation that funding liquidity for asset purchases could dry up during the harvest season because farmers either unexpectedly withdrew funds or took out unexpectedly large loans to finance the production and marketing of crops. This is supported by the evidence in figures 2 and 3 that New York City banks’ reserve ratios were lower and withdrawals higher during September and October. We compute average stock return volatility for each calendar month and then compare average variances in September and October with those the rest of the year. We exclude the Civil War years to minimize the effect of the conflict on the empirical results. Over 1815-1925, the monthly standard deviation of stock index returns is 5.16 percent. It is 5.76 percent during the months of September and October compared with 5.04 percent for the rest of the year, a difference that is significant at the one percent level.

Although the baseline results suggest that stock volatility is higher during the harvest, we divide the sample into several sub-periods to test the robustness of the results. The baseline empirical results could be driven by the antebellum period when the agricultural sector was a much larger fraction of the US economy. As shown in Table 1, the baseline results are not driven by agriculture’s greater share of economic activity in months which may have different interest rate volatilities due to the harvest cycle. Historical estimates of US GNP suggest that agriculture accounted for about 80 percent of American economic activity in 1840 and 1850 and nearly 40 percent in 1870. Agriculture’s share of GNP averaged approximately 35 percent in the 1870s, 22.5 percent around the turn of the century, 17 percent in 1908, 16 percent by 1916 and 11.6 percent in 1925 (US Bureau of the Census, 1976).
the antebellum period. Stock volatility in the post-bellum period (5.94 percent) is actually higher than in the antebellum period (7.12 percent). One possible explanation for this result is that the National Banking Act of 1863 created an additional incentive for country banks to deposits their funds in New York City and other reserve center banks because they received interest on the deposits. In turn, financial institutions expanded the supply of call loans that increased funding and liquidity risk in the presence of a large withdrawal or agricultural shock in the fall.

As noted earlier, we expect stock return volatility to be higher only in the absence of a lender of last resort, that is, in the absence of either the SBUS or the Federal Reserve.

Table 1 reveals that during the operation of the SBUS (1816-1836), even though agriculture accounted for about 80 percent of American economic activity, volatility across the months of September and October averaged 2.44 percent – actually lower than the 2.76 percent found during the rest of the year. Following the demise of the SBUS, for 1837-1860, stock volatility increased to 6.45 percent in September and October, which is statistically significantly higher than the 5.18 percent during the rest of the year.

We re-estimated stock volatility from 1870 (the post-Civil War period) until 1925 to investigate the impact of the Federal Reserve. Stock return volatility averaged 7.07 percent in September and October prior to the founding of the Fed versus 5.94 percent for the rest of the year. The effect is statistically significant at the one percent level. This effect is not qualitatively altered if either (1) the Civil War period is included or the Panic of 1873 (where interest rates jumped briefly to over 60 percent) is omitted from the analysis. After the founding of a central bank, however, average monthly volatilities are again lower during the harvest months (3.92 percent) than during the rest of the year.
(4.78 percent). The results for the post-bellum period are consistent with the findings of Bernstein, Hughson, and Weidenmier (2010). Overall, the results suggest that the presence of the Second Bank of the United States and the Federal Reserve significantly reduced stock volatility in financial markets.

**Interest Rate Volatility**

We next examine interest rate volatility, using as proxies both the call loan rate and the commercial paper rate, with which it is highly correlated. We again divided the sample period into several sub-periods to test the robustness of the results and examine the effects of the establishment of a lender-of-last resort on financial markets—the creation of the Fed in 1913.

The empirical results are presented in Table 2A. The analysis shows that interest rate volatility was (statistically) twice as high in the fall than during the rest of the year prior to the passage of the Aldrich-Vreeland Act. As shown in Table 2A, this large difference is true regardless of whether we use 1857 (the start of the sample period), 1863 (start of National Banking Period), or 1870 (post-Civil War period) as the starting point for the empirical analysis. The volatility of short-term interest rates declined by more than 70 percent in the months of September and October following the passage of the

---

19 The creation of the Fed took place in two steps: 1) the Passage of the Aldrich-Vreeland Act in 1908 that allowed certain banks to issue emergency currency during a financial crisis and 2) the Federal Reserve Act of 1913 that authorized the establishment of a central bank that began open market operations in January 1915. Bernstein, Hughson, and Weidenmier (2010) show that there is no similar effect during the spring planting season. Volatility in the spring is indistinguishable from that during the rest of the year. 21 The results are also robust to excluding the panic of 1873 and starting the empirical analysis in 1880.
Aldrich-Vreeland Act in 1908 – from 4.05 percent from 1870 until the passage of the Aldrich-Vreeland Act, interest rate volatility in September and October is no longer significantly different from interest rate volatility in the rest of the year (1.81 percent during the harvest months and 1.85 percent during the rest of the year). The results are consistent with the stock volatility analysis: the establishment of a lender of last resort increased funding and market liquidity.

We next analyze the commercial paper rate from 1835-1925. Even though it is not a direct measure of funding liquidity for investors, it is for firms, and an advantage of this series is its additional length. As shown in Table 2B, we find that volatility in the commercial paper rate was more than 60 percent higher in September and October than the rest of the year in the pre-Aldrich Vreeland period (before 1908). The result is statistically significant at the one percent level. The basic tenor of the results remains unchanged if the Civil War is dropped from the analysis and we restrict the analysis to the National Bank Period before the passage of Aldrich-Vreeland. Again we also find that after the passage of the monetary reform legislation, the volatility of the commercial paper rate declined more than 50 percent over the entire sample period and interest rate volatility in the fall is not statistically different from that the rest of the year.

C. Funding Liquidity, Market Liquidity, and Stock Returns

Many models in more recent history have examined not only the coincident behavior, but also the casual relation between interest rate spikes and stock returns.
Bernanke and Gertler (1990) argue that funding constraints can reduce the ability of firms to borrow. If this inability to borrow persists, it can lead to lower stock prices and a financial crisis. Brunnermeier and Pedersen (2009) suggest that funding liquidity, market liquidity, and asset price declines can be mutually reinforcing, leading to a liquidity spiral and a financial crisis. If there is a strong connection between interest rate shocks and stock market crashes a central bank’s ability to smooth fluctuations in short-term funding rates should also have an effect on turbulence in asset prices and market liquidity. Therefore, we explicitly examine the relationship between funding liquidity, market liquidity, and stock returns to see if the change in stock return volatility differential can be explained by the central bank’s ability to smooth interest rates and what effect this smoothing had on market liquidity.

Because we have a much longer history of interest rates and stock returns than bid-asks spreads in our sample we begin by examining only the relationship between funding liquidity, as proxied by the call loan rate, and stock market returns and later show that this relationship remains if market liquidity is included over the shorter history of available bid-ask data. To motivate our analysis we begin by observing that large decreases in funding liquidity are associated with a decline in the stock market. Figures 4a, 4b, and 4c and Table 3 show average and cumulative average returns for the GIP index in the six-month window during periods when there is a spike in the call loan rate. A spike in the call loan rate is defined as a period when the call loan rate is greater than two standard deviations (11.72%) above its mean and the change in call loan rate MoM is greater than one standard deviation (3.65%). The two figures suggest that stock returns fall not only coincident with reductions in funding liquidity (as measured by spikes up in 21
the call loan rate), but also in the month following the spike as well suggesting that funding liquidity declines precede market declines.

To more formally understand the relationship between funding liquidity and asset prices we run a two-variable vector autoregression (VAR) that includes the call loan rate and stock market returns. A lag length of one is chosen for the analysis on the basis of the Schwarz Information Criteria (SIC) and we estimate impulse response functions. We employ a Choleski decomposition using the ordering call loan rates and then stock returns. This causal ordering is selected for two reasons: (1) the call loan rate is Granger prior to stock returns and (2) the Brunnermeier and Pedersen model (2008) predicts that an increase in funding constraints reduces stock prices. Figure 5 shows over the full history available that a one-standard deviation shock to the call loan rate reduces stock returns by 1.93% after 36 months. On the other hand, a one-standard deviation shock in stock returns does not have a statistically significant effect on the call loan rate. These results suggest that panics were set-off by sharp increases in short-term funding constraints causing a decline in stock returns. After a stock market crash, call loan rates actually stabilized and returned to normal levels within a couple of months. This evidence is supportive of funding liquidity shocks as the proximate cause of crises.

---

22 For stock market returns the equally weighted GIP index is used. To avoid issues arising from missing months of data gaps are filled first using the estimates from a regression based on an index constructed from the average of the bid-ask data collected over the period from 1894-1925 and second using linear interpolation consistent with the price-weighted index used by Goetzmann, Ibbotson, and Peng. Results throughout are robust to alternative methods of filling gaps and using the original price-weighted series. 23 The impulse response functions for the effect of innovations in stock returns on the call loan rate and the call loan rate squared are available from the authors by request. 24 Throughout the analysis in this paper we include funding liquidity shocks first in the Choleski decomposition consistent with the interpretation of funding shocks as
the proximate cause of financial panics which is focus of our analysis. Inclusion of stock returns as first in the ordering does not alter the expected sign of the effects of shocks on interest rates and stock returns, supporting the interpretation that liquidity shocks preempted shocks in the stock market.
We also perform the same analysis for the National Banking (1863-1913) and Federal Reserve periods (1915-1925) to see if there is a substantial change in this relationship. As shown in figures 6 and 7 a one standard deviation shock to call loan rates is associated with a decline of 2.1% in the stock market in the National Banking Period after 36 months and a 2.9% decline after 12 months in the Federal Reserve Period which are both significant at the 5% level. The effect is no longer significant in the Federal Reserve Period after 36 months, but given the limited sample size (11 years) this does not offer compelling evidence that the relationship changed significantly following the establishment of the Federal Reserve. As another test of robustness we rerun this analysis using commercial paper rates instead of call loan rates. In figure 8 we see that a one-standard deviation shock to the commercial paper rate is associated with a 1.1% decline in the stock market which is consistent with our previous results.

Commercial paper rates extend back to 1835 which also allow us to test the relationship during the Free Banking Period (1837-1863). Again we find that even during the free banking period shocks to commercial paper rates were associated with a decline in the stock market. As shown in figure 9 a one-standard deviation shock to commercial paper rates is associated with a 2.1% decline in the stock market over the next 36 months.

The empirical results are consistent with the interpretation that the Second Bank of the United States and the Federal Reserve may have diminished stock market crashes by decreasing funding liquidity risk. During the panic of 1907, for example, the size of the shock to the call loan rate was nearly 17 percentage points (or approximately 5.5%). The period from 1914-1915 is omitted to avoid noise and missing data points associated with the outbreak of WWI and closing of the U.S. stock markets. Inclusion of these additional years does not have
a substantive effect on any of the results. For commercial paper rates we use a lag of two based on the SIC.
standard deviations). This means that the shock to funding liquidity coincided with a 10.5% drop in the stock market during a financial panic. The weakened results, depicted in figure 10, when high call loan rates are omitted from the sample suggest that these effects were especially strong during market panics. This would be consistent with model proposed by Brunnermeier and Pedersen, where funding constraints have limited effect until they become binding.

Given this robust connection between liquidity shocks and asset prices the model in Brunnermeier and Pedersen (2009) would suggest a natural inclusion of a market liquidity factor in an empirical analysis of the market dynamics. Since we only have bid-ask spreads starting in 1894 we restrict our analysis to the period from 1894-1925. We consider relative bid-ask spread as the difference between the bid and ask prices normalized by the mid-point. As we did in the two variable case we include a lag of one based on the SIC and include funding liquidity shocks first in the Choleski decomposition. Figure 11 shows that including mean bid-ask spread in the regression does not qualitatively alter the relationship between funding liquidity and asset prices. A one-standard deviation shock up in call loan rates predicts a 1.5% decline in stock returns over the next 36 months which is statistically significant at the 5% level. Figures 12 and 13 also show that shocks in the bid-ask spread are not associated with statistically significant effects on either the call loan rate or stock returns. Consistent with what we would expect Figure 14 shows that a one-standard deviation shock in the call loan rate is associated with a 150 bp higher average market bid-ask spread after 36 months and figure 15 shows that a one-standard deviation shock to stock returns is associated with a 250 bp

\[27\] We present results with stock returns 2nd
and bid-ask spreads $3_{rd}$ in the Choleski decomposition, but results are not substantially altered by switching the order of these two variables.
rise in average bid-ask spread after 36 months. These are consistent with the interpretation that shocks to funding liquidity and asset prices effect market liquidity.

Bid-ask spreads during this period for high price stocks can be difficult to analyze since the minimum spread of 1/8 could create unusual asymmetric behavior. Low price stocks could also be problematic since they tended to be less liquid and listed prices could represent stale prices resulting from a lack of trading in the security. To address these concerns we also construct quartiles of portfolios of bid-ask spreads which are rebalanced monthly based on the rolling 12-month average stock price. Residuals from an AR2 model of monthly changes in these average bid-ask quartiles are then used as proxies for market liquidity shocks. Figure 16 shows that a one-standard deviation shock upward in the call loan rate is associated with a 21bps increase in the bid-ask spread innovation of the 2 smallest quartile that is significant at the 5% level after 36 months. Though the direction is what we would expect the results for the 2nd largest quartile are not statistically significant at the 5% level for large stocks. The relationship is more pronounced for stock market declines preceding increases in bid-ask spread innovation (increased market illiquidity). From figures 18 and 19 we see that a one-standard deviation decline in stock returns predicts an increase in bid-ask spread innovation for the 2nd smallest and 2nd largest quartiles of 28bps and 27bps respectively which are significant at the 5% level over 36 months. Overall these results are consistent with the results from using the mean market bid-ask spread. This suggests that market panics which raised interest rates and caused the stock market to crash also decreased market liquidity. In particular, at the same time that agents needed to sell securities because of funding constraints and a stock market crash, the market liquidity needed evaporated and
et programmatic implementation of these findings.

D. Mark Liqidity

Market

Liquidity

We
et li q ui di ty a n d th e in fl u e n c e of th e p a pp a s s a g e of Al dric h-Vr ee a n d th e Fe der al R es
where the percentage liquidity cost, \( C_i \), is the liquidity cost of security \( i \) in dollars, \( P_{1M} \) is the previous period's price for security \( i \), \( M \) is the risk-free rate, and \( r_i \) is the individual security return, \( r \) is the market return, \( r \)

conditional market risk premium with transaction costs.

From these assumptions Acharya and Pedersen (2005 proposition 1) show that

\[
(r - \rho)^{(var)}_{\mid \mid m} = \frac{1}{\sqrt{\sum \frac{\text{cov}(\text{var})}{\text{cov}(\text{cov})} \cdot (\text{cov}(\text{cov}))}} \cdot (\text{cov}(\text{cov}))
\]
That is, expected excess return is equal to the sum of

1. the expected illiquidity cost

2. (\text{a standard CAPM beta, adjusted for transaction costs}) \cdot \text{t}

3. (\text{a procyclical liquidity term which says that required returns must be higher if asset liquidity has a positive covariance with market liquidity}) \cdot \text{t}

4. (\text{a term that says that required returns are larger if an asset has higher returns in times of market illiquidity}) \cdot \text{t} \cdot (\text{-1})

5. (\text{a term that says that required returns are larger if an asset has lower liquidity costs when market returns are low – i.e. in a down market}) \cdot \text{t} \cdot (\text{-1})

To estimate an unconditional version of this relation, with unconditional liquidity betas, we follow Acharya and Pedersen and assume constant conditional covariances between illiquidity innovations and returns which yields the following result:

\[ cEcrE \quad %\text{term (2) above} \]

\[ rErr \quad %\text{term (3) above} \]

\[ rEcEri \quad %\text{term (4) above} \]

\[ rErcEc \quad %\text{term (5) above} \]

\[ rcrE \quad %\text{final result} \]
For our empirical analysis we use the price-weighted GIP stock return index as our market return proxy and innovations in bid-ask spread as our estimate for stock specific market liquidity. Individual innovations in market liquidity are determined by applying the coefficients of an AR(2) on an equal weighted average of all bid-ask spreads to each individual stock bid-ask, when lagged values are available. For market returns we use the mean monthly price-weighted GIP returns. We then compute liquidity betas for a high liquidity portfolio and a low liquidity portfolio, where each portfolio is equally-weighted and is formed each month based on the average price over the past 12 months. The price estimate is used as a proxy for firm size and liquidity. These liquidity betas are estimated on a rolling basis with 60-month windows for two sub-periods: the pre-Federal Reserve Period from 1894-1913 and the Federal Reserve Period from 1915-1925. In the liquidity beta computations in the sub-periods, the denominator is the variance of the net market return in the period over which the betas are computed.

In table 4 we can see our choice of illiquidity proxy in portfolios appears to be well chosen. During both periods as portfolio illiquidity increases the level of bid-ask spreads increases, the volatility of the bid-ask spreads increases, and the volatility of the portfolio stock return increases. Note that the average bid-ask spreads throughout our sample period are quite high, ranging from 3% for the most liquid portfolio in the pre-Federal Reserve period to 8.2% for the most liquid portfolio in the Federal Reserve period. The bid-ask spread for each of the four portfolios is essentially the same in the

28 As Acharya and Pedersen do, we cap the
maximum illiquidity at 30 percent to prevent noisy outliers from driving the results. Brown et al (2008) find a strong correlation between firm size and stock price during the early 20 century.
pre-Fed and Fed periods. This is surprising, given the substantial increase in trading activity on the stock market that began during World War I.

In tables 5 and 6 we can also see that the portfolio beta with the market is increasing in illiquidity which is to be expected since smaller stocks tend to move more sensitive to market movements. Table 5 also reveals that in the pre-Federal Reserve period, every one of the liquidity betas is increasing as illiquidity increases leading to a net liquidity beta differential (the combination of all the betas except the market beta term) of 0.235 between the least and most liquid portfolios. Based on Acharya and Pedersen’s assumptions of an unconditional net equity market premium of 1.5% monthly and monthly turnover of 3.5% the liquidity premium differential, which equals \( \text{(bid-ask spread differential) x (average turnover)} + \text{(net beta) x (lambda)} \) x 12, between the most and least liquid portfolios is 6.06% per year. Of this, amount, 4.20% is due to the liquidity beta term. That the expected return differential is so high is due in part to the assumption that 1.5% per month. Assuming smaller values for reduce the liquidity beta effect proportionally. For example, if the equity premium net of transaction costs were assumed to be 3% per year, the effect of liquidity betas would be reduced by a factor of six, to slightly less than 1% per year. This effect, although smaller, comports with intuition about how much liquidity ought to matter.

As can be seen in table 6 during the Federal Reserve period the results change significantly. Perhaps most illuminating is the change in net liquidity beta, which declines for each of our four portfolios after the founding of the Federal Reserve. The illiquidity

---

This unconditional expected premium estimate (lambda) and average monthly turnover are taken from estimates in Acharya and Pedersen. Estimates of the risk-free rate during this period can be problematic so rather than relying and the estimates provided seem quite conservative which is why we feel comfortable using the same values.
premium due to bid-ask spread is essentially unchanged by the monetary regime change.

Because relatively less-liquid stocks have less sensitivity in liquidity to market movements after the monetary regime change than more-liquid stocks have before it, it is hard to argue that the decreases in liquidity sensitivity arise solely from increases in stock market activity during and after World War I. The net effects are summarized more clearly in table 7. Both the liquidity premium and liquidity beta differentials decrease after the establishment of the Federal Reserve. For example, there is a decline in 0.02 in the liquidity beta differential between the least and most liquid portfolio and a subsequent decline of 28 basis points in the liquidity premium differential.

In sum, we find that (1) for all liquidity portfolios, net liquidity betas fall for all portfolios after the founding of the Federal Reserve leading to a decline in the liquidity premiums due to liquidity beta; (2) the liquidity premium differential between the most- and least-liquid stock portfolios falls by 28 basis points, from 6.06% to 5.79%; These results suggest that the creation of the Fed was a watershed event for improving the liquidity of financial markets.

III. Conclusion

How do funding constraints impact financial markets? This question has recently received a considerable amount of attention by financial economists. We provide a historical perspective on this question by examine the impact of an exogenous change in margin/capital requirements on market volatility, market liquidity, and stock returns. The
pre-World War I period is a unique period in American financial history where the
market’s funding constraint was largely determined by agricultural shocks. For much of the nineteenth and early twentieth centuries, country banks deposited reserves with financial institutions in New York City and other reserve center cities. The New York City banks often used these funds to extend credit in the form of call loans to speculators. In the event of a large withdrawal from country banks, the New York City banks might call in their loans to increase their reserve position. This might lead to a bank run followed by a liquidity spiral and financial crisis.

We analyze the impact of this exogenous shock to the market’s funding constraint using the new GIP Index of stock prices from 1815-1925 and the call loan rate, a direct measure of funding liquidity. The empirical analysis suggests that market volatility was more than 50 percent higher during September and October. Large negative stock returns and the frequency of liquidity spirals were also significantly greater during the fall harvest season. We find that market liquidity, market volatility, or the frequency of large negative stock returns are significantly larger in September and October during the periods when the Second Bank of the United States and the Federal Reserve were in operation. The SBUS and the Federal Reserve were able to provide seasonal funds to reduce liquidity risk during the fall. Overall, we interpret our results as consistent with Brunnermeier and Pederson’s theory that funding constraints can be an important driver of market liquidity and market risk premiums.

Finally, we note that the existence of a lender of last resort, even if it is only a quasi-central bank plays a crucial role in determining market reaction to financial shocks. The ability of the Fed to smooth interest rate shocks decreases the propensity for stock market panics which we observe over and over during the nineteenth century, when prices.
central bank did not exist. We take this as evidence that market participants felt that a lender of last resort was likely to head off prolonged periods of tight money which could affect the ability of firms to obtain funding, as the Fed has recently done, both in the mortgage and commercial paper markets. This lead to a decline of 3.1% in the liquidity premium required by investors between the most and least liquid quartiles of stocks after the establishment of the Federal Reserve.

References


Silber, W. L. 2007b. The great financial crisis of 1914: What can we learn from
Table 1

Monthly Stock Return Volatility during Varying U.S. Banking Regimes

The equality of variance for stock returns was tested over various sample periods from 1815-1925. The critical values for the equality of variance tests were found using an F-test.

<table>
<thead>
<tr>
<th>U.S. Banking Regime</th>
<th>Sample Period</th>
<th>Rest of the Year Sept. &amp; Oct. Test</th>
<th>Second Bank of the U.S. 1816-1836</th>
<th>0.76% 2.44</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antebellum Period</td>
<td>1837-1860</td>
<td>5.18% 6.45% 0.04 Pre-Aldrich-Vreeland-National Banking System (Ex-Civil War)</td>
<td>1870-May</td>
<td>1908 Pre-Aldrich-Vreeland &amp; Federal Reserve Period June</td>
</tr>
<tr>
<td>Pre-Aldrich-Vreeland &amp; Federal Reserve Period June</td>
<td>1908-1925</td>
<td>4.78% 3.92% 0.18</td>
<td>Rest of the Year Sept. &amp; Oct. Test</td>
<td>1925-1928</td>
</tr>
</tbody>
</table>

Average Monthly Standard Deviations

<table>
<thead>
<tr>
<th>Period</th>
<th>Average Monthly Standard Deviation</th>
<th>%</th>
<th>%</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1816-1836</td>
<td>2.76%</td>
<td>2.44%</td>
<td>0.35</td>
<td></td>
</tr>
<tr>
<td>1837-1860</td>
<td>5.18%</td>
<td>6.45%</td>
<td>0.04</td>
<td></td>
</tr>
<tr>
<td>Pre-Aldrich-Vreeland &amp; Federal Reserve Period June</td>
<td>1908-1925</td>
<td>4.78%</td>
<td>3.92%</td>
<td>0.18</td>
</tr>
<tr>
<td>Rest of the Year Sept. &amp; Oct. Test</td>
<td>1925-1928</td>
<td>4.78%</td>
<td>3.92%</td>
<td>0.18</td>
</tr>
</tbody>
</table>
# Table 2 Monthly Interest Rate Volatility A: Call Loan Rate Volatility during Varying U.S. Banking Regimes

<table>
<thead>
<tr>
<th>U.S. Banking Regime</th>
<th>Sample Period</th>
<th>Rest of the Year Sept. &amp; Oct.</th>
<th>F-Test Pre Aldrich-Vreeland Period</th>
<th>1857- May 1908</th>
<th>2.99%</th>
<th>6.67%</th>
<th>0.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre Aldrich-Vreeland National Banking System Feb 1863 - May 1908</td>
<td>3.12%</td>
<td>6.91%</td>
<td>0.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre Aldrich-Vreeland &amp; Federal Reserve Period June 1908 - June 1915</td>
<td>1.86%</td>
<td>1.80%</td>
<td>0.84%</td>
<td>Federal Reserve Period 1915 - 1925</td>
<td>1.92%</td>
<td>1.81%</td>
<td>0.79</td>
</tr>
<tr>
<td>Aldrich-Vreeland National Banking System (Ex Civil War) June 1908 - 1925</td>
<td>1.86%</td>
<td>1.80%</td>
<td>0.84%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| | | | | | | | |
| | | | | | | | |

![Bar Chart]

1857 - May 1908 Pre Aldrich-Vreeland Period
8%
7%
6%
5%

Rest of the Year Sept. & Oct.
## B: Commercial Paper Rate Volatility during Varying U.S. Banking Regimes

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>National Banking System</td>
<td>Feb 1863 - May 1908 Pre</td>
<td>1.93% 5.46 % 0.00 Pre</td>
<td>Pre Aldrich-Vreeland National Banking System (Ex Civil War) 1870 - May 1908</td>
</tr>
<tr>
<td>National Bank Period</td>
<td>1870 - May 1908 Pre</td>
<td>1.86% 5.92 % 0.00 Pre</td>
<td>Pre Aldrich-Vreeland National Banking System (Ex Civil War) 1870 - May 1908</td>
</tr>
<tr>
<td>Federal Reserve Period</td>
<td>June 1908 - 1925</td>
<td>1.23% 1.27 % 0.78 Pre</td>
<td>Pre Aldrich-Vreeland National Banking System (Ex Civil War) 1870 - May 1908</td>
</tr>
</tbody>
</table>
Table 3 Call loan rate spikes are defined as periods when call loan rate is above 11.72% (2 sigma above mean) and the change in call loan rate MoM is greater than 3.65% (1 sigma).

<table>
<thead>
<tr>
<th>Call Loan Rate Spike Month Offset Average</th>
<th>Cumulative Return Average</th>
<th>Monthly Return Stdv</th>
<th>Number Points</th>
<th>Standard Error</th>
<th>T-Stat</th>
</tr>
</thead>
<tbody>
<tr>
<td>1857-1925 (no event occurs after 1907)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1873 removed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

39
Table 4 Portfolio Descriptive Statistics  This table reports properties of liquidity portfolios for high and low-priced stocks during the pre-fed (1894-1913) and fed periods (1915-1925), including average bid-ask spread, volatility of bid-ask spread, and volatility of monthly stock returns.

<table>
<thead>
<tr>
<th></th>
<th>AvgBidAsk</th>
<th>VolBidAsk*</th>
<th>VolMoRet</th>
<th>AvgBidAsk</th>
<th>VolBidAsk*</th>
<th>VolMoRet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Fed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Port1</td>
<td>7.6%</td>
<td>0.032%</td>
<td>1.58%</td>
<td>8.2%</td>
<td>0.028%</td>
<td>1.12%</td>
</tr>
<tr>
<td>Port2</td>
<td>4.3%</td>
<td>0.015%</td>
<td>0.86%</td>
<td>4.2%</td>
<td>0.011%</td>
<td>0.47%</td>
</tr>
<tr>
<td>Port3</td>
<td>3.1%</td>
<td>0.008%</td>
<td>0.36%</td>
<td>3.4%</td>
<td>0.005%</td>
<td>0.23%</td>
</tr>
<tr>
<td>Port4</td>
<td>3.0%</td>
<td>0.007%</td>
<td>0.68%</td>
<td>3.5%</td>
<td>0.005%</td>
<td>0.16%</td>
</tr>
<tr>
<td>Full Port</td>
<td>4.5%</td>
<td>0.008%</td>
<td>0.22%</td>
<td>4.8%</td>
<td>0.008%</td>
<td>0.23%</td>
</tr>
</tbody>
</table>

*Refers to innovations in bid-ask

40
Table 5 Pre-Federal Reserve Liquidity Betas and Premium

This table reports properties of liquidity portfolios for high and low-priced stocks during the pre-federal reserve period (1894-1913). Consistent with notation in Acharya and Pedersen (2005) we show each of the betas x100 as well as the net liquidity beta (B2B3-B4) and the total illiquidity premium based on the assumption of a lambda of 1.512% and a monthly turnover of 3.4%. The liquidity betas and premium differential between the smallest (low price) and highest (high price) stocks are also summarized. T-statistics are shown under each estimate in parentheses. Price portfolios are rebalanced monthly based on the lagged 12 average price of all securities with prices in the associated month. Beta1 is sensitivity of the individual portfolio return to the market return. Beta2 is the sensitivity of the individual relative bid-ask spread to innovations in the market relative bid-ask spread. Beta3 is the sensitivity of individual portfolio returns to innovations in the market relative bid-ask spreads. Beta4 is the sensitivity of individual bid-ask spread innovations to changes in market returns. These betas are computed on a rolling basis with a 60-month window and standard errors are computed based on a simple t-test accounting for heteroskedasticity of the error terms.

<table>
<thead>
<tr>
<th></th>
<th>Pre - Fed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(x 100 for all coefs) (ri,rm) (ci,cm)</td>
</tr>
<tr>
<td></td>
<td>B2-B3</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Port1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Port2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Port3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Port4</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

41
Table 6 Federal Reserve Liquidity Betas and Premium  
This table reports properties of liquidity portfolios for high and low-priced stocks during the federal reserve period (1915-1925). Consistent with notation in Acharya and Pedersen (2005) we show each of the betas x100 as well as the net liquidity beta (B2-B3B4) and the total illiquidity premium based on the assumption of a lambda of 1.512% and a monthly turnover of 3.4%. The liquidity betas and premium differential between the smallest (low price) and highest (high price) stocks are also summarized. T-statistics are shown under each estimate in parentheses. Price portfolios are rebalanced monthly based on the lagged 12 average price of all securities with prices in the associated month. Beta1 is sensitivity of the individual portfolio return to the market return. Beta2 is the sensitivity of the individual relative bid-ask spread to innovations in the market relative bid-ask spread. Beta3 is the sensitivity of individual portfolio returns to innovations in the market relative bid-ask spreads. Beta4 is the sensitivity of individual bid-ask spread innovations to changes in market returns. These betas are computed on a rolling basis with a 60-month window and standard errors are computed based on a simple t-test accounting for heteroskedasticity of the error terms.

Fe d (x100 for all co e f s ) ( r i , r m ) ( ci , cm ) ( r i , cm ) ( ci , r m ) B 2 - B 3 - B 4 To t al Du e to Be t a Pri ce  
Portfolios Be t a 1 Be t a 2 - Be t a 3 - Be t a 4 Ne t Be t a I ll iq Prem** I ll iq Pre m*** Smallest Port1 117.77 3.38 14.24 14.26 31.88 9.14 5.78 14. 26 31. 88 9. 14 5. 78  
(1.1 ) (0.2) (0.5 ) (0.9 ) (2.2 ) (0.4) (0.4 )  
Port2 87.54 1.67 9.22 5.77 16.66 4.73 3.02  
(2.6 ) (0.2) (0.3 ) (1.7 ) (1.8 ) (0.3) (0.3 )  
Port3 53.55 1.29 5.15 5.06 11.51 3.46 2.09  
(4.7 ) (0.1) (0.4 ) (0.5 ) (0.3 ) (0.1) (0.0 )  
Largest Port4 40.46 1.42 3.99 5.24 10.64 3.35 1.93  
(1.2 ) (0.1) (0.2) (0.5 ) (0.1) (0.1 ) (0.1 )  
Port1- Port4 77.31 1.19 10.25 9.02 21.24 5.79 3.85  
(1.9 ) (0.1) (0.4 ) (1.2) (2.4 ) (0.4) (0.4 )  
*Re fers to i n nov at ions in bi d - a sk ** Lam bda is a ss u med to be 1.512% a nd tu r no v e r is 3.4% mo nth ly as in A - P. I ll iq P re m = (AvgBidAsk * Tu r no v e r + lambda*netbet a) *12 *** Lam b da is a ss u med to be 1.512 % a s in A - P. I ll iq P re m Du e to Ne t Be t a = (lambda*netbeta)*12  

42
Table 7 Change in Liquidity Betas and Premium with Introduction of the Fed

This table reports differences between of liquidity portfolio betas and premiums for high and low-priced stocks during the pre-federal reserve (1894-1913) and federal reserve period (1915-1925). Consistent with notation in Acharya and Pedersen (2005) we show each of the betas x100 as well as the net liquidity beta (B2-B3-B4) and the total illiquidity premium based on the assumption of a lambda of 1.512% and a monthly turnover of 3.4%. The liquidity betas and premium differential between the smallest (low price) and highest (high price) stocks are also summarized. T-statistics are shown under each estimate in parentheses. Price portfolios are rebalanced monthly based on the lagged 12 average price of all securities with prices in the associated month. Beta1 is sensitivity of the individual portfolio return to the market return. Beta2 is the sensitivity of the individual relative bid-ask spread to innovations in the market relative bid-ask spread. Beta3 is the sensitivity of individual portfolio returns to innovations in the market relative bid-ask spreads. Beta4 is the sensitivity of individual bid-ask spread innovations to changes in market returns. These betas are computed on a rolling basis with a 60-month window and standard errors are computed based on a simple t-test accounting for heteroskedasticity of the error terms.

<table>
<thead>
<tr>
<th></th>
<th>Fed-Pre Fed</th>
<th>(x100 for all coefs)</th>
<th>( (r_i, r_m) )</th>
<th>( (c_i, c_m) )</th>
<th>Total Due to Beta Price Portfolios</th>
<th>Smallest Port1</th>
<th>19.12</th>
<th>-1.59</th>
<th>-3.59</th>
<th>0.86</th>
<th>-4.31</th>
<th>-0.51</th>
<th>-0.78</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Beta1</td>
<td>Beta2</td>
<td>Beta3</td>
<td>Beta4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Portfolios</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smallest</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.59 (1.3)</td>
<td>1.6 (1.8)</td>
<td>0.7  (0.7)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Largest</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.39 (1.2)</td>
<td>0.6 (0.7)</td>
<td>0.2  (0.5)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Refers to innovations in bid-ask **lambda is assumed to be 1.512% and turnover is 3.4% monthly as in A-P. Illiq Prem = (AvgBidAsk * Turnover + lambda * netbeta) *12 *** lambda is assumed to be 1.512% as in A-P. Illiq Prem Due to Net Beta = (lambda * netbeta) *12

43
Figure 1. Monthly averages of daily millions of dollars of Federal Reserve credit and money in circulation. Source is the Board of Governors of the Federal Reserve System (1943, 369-371).
Figure 2. Average weekly reserve ratios for New York City Banks from 1890-1908. Source is Andrew (1910, 79-117).
Figure 3. Average net inflows of funds from interior to New York City Banks (million $) from 1899-1906. Taken from Calomiris and Gorton (1991) with original source Kemmerer (1910, 358-59).
Figure 4a. Call loan rate spikes are defined as periods when call loan rate is above 11.72% (2 sigma above mean) and the change in call loan rate MoM is greater than 3.65% (1 sigma). Graphs are based on full 1857-1925 sample.
Figure 4b. Call loan rate spikes are defined as periods when call loan rate is above 11.72% (2 sigma above mean) and the change in call loan rate MoM is greater than 3.65% (1 sigma). Graphs are based on full 1857-1925 sample.
Figure 4c. Call loan rate spikes are defined as periods when call loan rate is above 11.72% (2 sigma above mean) and the change in call loan rate MoM is greater than 3.65% (1 sigma). Graphs are based on full 1857-1925 sample.
Figure 5. Cumulative Impulse Response of equally weighted stock market returns to One Standard Deviation Shock to the Call Loan Rate over all available history (1857-1925). Market liquidity is not included in this VAR which includes one lag.
Figure 6. Cumulative Impulse Response of equally weighted stock market returns to One Standard Deviation Shock to the Call Loan Rate during the National Banking Period (1863-1913). Market liquidity is not included in this VAR which includes one lag.
Figure 7. Cumulative Impulse Response of equally weighted stock market returns to One Standard Deviation Shock to the Call Loan Rate, Federal Reserve Period (1915-1925). Market liquidity is not included in this VAR which includes one lag.
Figure 8. Cumulative Impulse Response of equally weighted stock market returns to One Standard Deviation Shock to the commercial paper rate (1857-1925). Market liquidity is not included in this VAR which includes two lags.
Figure 9. Cumulative Impulse Response of equally weighted stock market returns to One Standard Deviation Shock to the commercial paper rate during the Free Banking Period (1837-1863). Market liquidity is not included in this VAR which includes two lags.
Figure 10. Cumulative Impulse Response of equally weighted stock market returns to One-Standard Deviation Shock to the Call Loan Rate, full history (1857-1925), where any call loan rates larger than two standard deviations from the average have been removed from the sample. Market liquidity is not included in this VAR with a lag of one.
Figure 11. Cumulative Impulse Response of equally weighted stock market returns to One-Standard Deviation Shock to the call loan rate, full history (1894-1925). Average market bid-ask spread is used the market liquidity proxy. A lag of one is used in the three variable VAR.
Figure 12. Cumulative Impulse Response of equally weighted stock market returns to One-Standard Deviation Shock to the average market bid-ask spread, full history (18941925). A lag of one is used in the three variable VAR.
Figure 13. Cumulative Impulse Response of call loan rate to One-Standard Deviation Shock to the average market bid-ask spread, full history (1894-1925). A lag of one is used in the three variable VAR.
Figure 14. Cumulative Impulse Response of average market bid-ask spread to One Standard Deviation Shock to equally weighted stock market returns full history (18941925). A lag of one is used in the three variable VAR.
Figure 15. Cumulative Impulse Response of average market bid-ask spread to OneStandard Deviation Shock to call loan rate for full history (1894-1925). A lag of one is used in the three variable VAR.
Figure 16. Cumulative Impulse Response of innovations in the average bid-ask spread of the 2 smallest quartile portfolio of stocks as proxied by average price level over the previous 12-months to One-Standard Deviation Shock to the call loan rate, full history (1894-1925). Equally-weighted stock returns are also included in the 3-variable VAR.
Figure 17. Cumulative Impulse Response of innovations in the average bid-ask spread of the 2 largest quartile portfolio of stocks as proxied by average price level over the previous 12-months to One-Standard Deviation Shock to the call loan rate, full history (1894-1925). Equally-weighted stock returns are also included in the 3-variable VAR.
Figure 18. Cumulative Impulse Response of innovations in the average bid-ask spread of the 2 smallest quartile portfolio of stocks as proxied by average price level over the previous 12-months to One-Standard Deviation Shock to equally weighted stock returns, full history (1894-1925). Call loan rate is also included in the 3-variable VAR as a proxy for funding liquidity shocks.
Figure 19. Cumulative Impulse Response of innovations in the average bid-ask spread of the 2 largest quartile portfolio of stocks as proxied by average price level over the previous 12-months to One-Standard Deviation Shock to equally weighted stock returns, full history (1894-1925). Call loan rate is also included in the 3-variable VAR as a proxy for funding liquidity shocks.