Can a Lender-of-Last Resort Stabilize Financial Markets?
Lessons from the Founding of the Fed

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Abstract: The sub-prime mortgage crisis raises serious questions about the role of a lender-of-last resort in containing the spread of a financial crisis. We use the founding of the Federal Reserve as a historical experiment to provide some insight into whether a lender-of-last resort can stabilize financial markets. Following the Panic of 1907, Congress passed two measures that established a lender-of-last resort in the United States: (1) the Aldrich-Vreeland Act of 1908 which authorized certain banks to issue emergency currency during a financial crisis and (2) the Federal Reserve Act of 1913 which established a central bank. We employ a new identification strategy to isolate the effects of the introduction of a lender-of-last resort from other macroeconomic shocks such as World War I, the closing of financial markets in 1914, and the abandonment of the gold standard. We compare the standard deviation of stock returns and short-term interest rates over time across the months of September and October, the two months of the year when financial markets were most vulnerable to a crash because of financial stringency from the harvest season, with the rest of the year during the period 1870-1925. Stock volatility in the post-1907 period (June 1908-1925) was more than 40 percent lower in the months of September and October compared to the period (1870- May 1908). We also find that the volatility of the call loan rate declined nearly 70 percent in September and October following the monetary regime change. The introduction of a lender-of-last resort dramatically reduced financial market volatility in the United States.

Volatility of Monthly Stock Returns
Before and After Monetary Policy Change
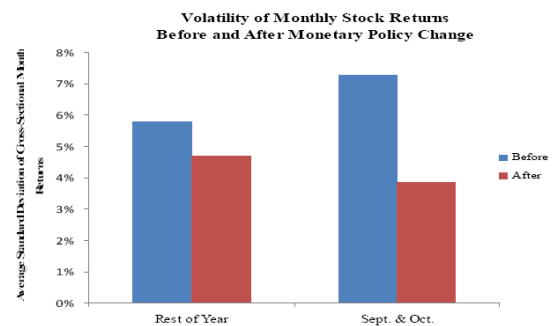
The recent sub-prime mortgage crisis in the United States raises serious questions about the role of monetary policy in a financial crisis. The Federal Reserve has responded to the credit crunch by lowering the Federal Funds Rate from 5.25 percent in September 2007 to 2.0 percent in May 2008. The central bank has followed up interest rate cuts by orchestrating a bail-out of Wall Street Firm Bear Stearns which is heavily invested in sub-prime mortgages. Paul Volcker, former Chairmen of the Federal Reserve, has criticized Chairman Bernanke's rescue of the beleaguered financial institution and accused the central banker of "toeing the "very edge" of the bank's legal authority" (*International Herald Tribune*, April 9, 2008)." Other economists, including former Federal Reserve Vice-Chairwomen Alice Rivlin, have praised recent actions by the Fed for playing the role of a lender-of-last resort and preventing a greater meltdown in world financial markets (*New York Times*, April 11, 2008).

One problem acknowledged by both proponents and opponents of monetary policy, especially in a time of crisis, is that it is very difficult to identify the effect of lender-of-last-resort policies on short-term interest rates and equity markets given the endogeneity problem. Fortunately, history provides an experiment to test the impact of the introduction of a lender-of-last resort on financial markets. Following the Panic of 1907, Congress passed two measures that established a lender-of-last resort in the United States: (1) the Aldrich-Vreeland Act of 1908 which temporarily authorized some banks to issue emergency currency during a financial crisis and (2) the Federal Reserve Act of 1913 that established a public central bank. The legislation was designed to provide a more elastic currency that could meet the seasonal demands of economic activity caused by the agricultural cycle. Several of the most severe financial crises of the National Banking Period (1863-1914) including the Panics of 1873, 1890, 1893, and 1907

occurred in the months of September and October when cash left New York City banks for the interior of the country to help farmers finance the harvesting of crops (Kemmerrer, 1910; Sprague, 1909).

The seasonal nature of financial crises in the National Banking Period motivates the identification strategy employed in this study to isolate the effects of the lender-of-last resort function on interest-rate and stock volatility.[1] We compare the standard deviation of stock returns across the months of September and October over the period 1870-May 1908 with the standard deviation of stock returns in those same months in the post-Aldrich Vreeland (June 1908-1913) and Federal Reserve (1913-1925) period. We employ Goetzmann, Ibbotson, and Peng's (2005) new comprehensive database of pre-CRSP era stock prices, hereafter GIP, from 1870-1925. The new stock price index significantly improves on the widely used Cowles Index by using month-end closing prices rather than the average of monthly highs and lows which introduces a significant autocorrelation problem in stock returns (Schwert, 1989; Working, 1960).

An analysis of the GIP Index shows that stock volatility in September and October declined nearly 50 percent following the passage of the Aldrich-Vreeland Act. Although we find that stock volatility in September and October was significantly greater than the other ten months of the year prior to the passage of Aldrich-Vreeland, this was not true following the monetary regime change.[2] The results are robust to a wide variety of specification tests with the exception that the result does *not* hold if we use the Cowles

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[1] Wohar and Fishe (1990), for example, argue that World War I and the closure of the New York financial markets played an important role in the change in the stochastic behavior of interest rates, in addition to the founding of the Federal Reserve. Given that these events all occurred around the same time, they argue that it is difficult to separate out the effects of these different events on time series properties of interest rates.

[2] Previous studies by Miron (1986) and Mankiw, Miron, and Weil (1988) find that the introduction of the Federal Reserve also reduced the seasonality and level of interest rates. Caporale and Caporale (2003) find that the introduction of the Federal Reserve led to a large reduction in the term premium a six month debt instruments pays over a three-month one.

Index for the empirical analysis. Our findings highlight the potential erroneous conclusions that can be drawn from using the Cowles Index to study financial markets. Future research may want to revisit some questions in financial economics using the new GIP Index.[3] Our analysis supports Friedman and Schwartz' (1963) hypothesis that Aldrich-Vreeland and the creation of the Federal Reserve stabilized financial markets prior to the Great Depression.[4]

We also examine short-term interest rate volatility in the months of September and October before and after the monetary regime change. The volatility of the call loan rate declined by more than 70 percent in the months of September and October following the passage of Aldrich-Vreeland. Consistent with the analysis of the equity market, interest rate volatility in September and October was significantly greater than the rest of the year only in the period before the passage of lender-of-last resort legislation. The analysis also shows that the reduction in interest rate volatility can be attributed to a decrease in the standard deviation of the call loan rate, not to a decline in the level of interest rates.[5] Overall, the results show that the introduction of a lender-of-last resort in the United States dramatically reduced financial market volatility.

We begin the analysis with a brief history of the National Banking Period (1863-1913) in the pre-World War I period. We then discuss the new database on stock prices in

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[3] Some well-known studies that have employed the Cowles Index or Indices from the pre-CRSP era that have the autocorrelation problem include Shapiro (1988), Shiller (1992), and Siegel (2002). Other studies have relied on stock indices such as the Dow which have a very small unber of stocks, but do not have significan autocorrelation problems Schwert (1989a, 1989b).

[4] Obviously, the results would not hold if we included the Great Depression as part of the analysis. As shown by Miron (1986) the seasonality of interest rates reappeared during the Great Depression because the Fed did not accommodate seasonal money demand. Many studies, most notably Friedman and Schwartz (1963), argue that the Federal Reserve exacerbated the severity of the Great Depression because of tight monetary policy (i.e., the Fed failed to play the role of a lender-of-last resort).

[5] Earlier studies by Miron (1986) and Mankiw, Miron, and Weil (1988) found that the introduction of the Federal Reserve reduced the level and seasonality of interest rates. As discussed later, data constraints prevented previous studies from analyzing the effect of the monetary regime change on the stock market.

the pre-CRSP era. This is followed by an empirical analysis of stock and interest rate volatility. We conclude with a discussion of the implications of our results for future studies in financial economics and the role of monetary policy during a financial crisis.

II. The National Banking System (1863-1913)

The National Banking Acts of 1863, 1864, an 1865 were passed to raise revenue to fight the Civil War, create a uniform currency and to standardize the banking system in the United States. Prior to the passage of the monetary legislation, hundreds of different currencies circulated at different exchange rates in the United States during the antebellum period. The Acts required banks to maintain minimum levels of capital, dependent on the local population where the bank was situated, and deposit a minimum quantity of eligible bonds with the U.S. Treasury before commencing business.[6] National bank notes were fully backed by holdings of U.S. government bonds. The amount of notes returned to the issuing bank for a given deposit of bonds was 90 percent or the par of the market value, whichever was lower, of the bonds deposited.[7] A national bank could reduce its notes outstanding by depositing lawful money with the U.S. Treasury. Notes sent to the treasury for redemption would be withdrawn from circulation until the total reduction in notes was complete. Any bank that reduced its circulation could not expand note issue again for a period of six months.

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[6] The primary source for the main features of the National Banking Act is "The National Banking System: A Brief History by Bruce Champ (2007)
[7] The backing requirement was raised to 100 percent in March 1900.

The National Banking Act established a three-tiered reserve system. The top tier consisted of banks in central reserve cities such as New York City.[8] Reserve city banks made up the second tier while the third tier was composed of country banks. Required reserves were held in the form of lawful money, which were gold or silver coin and U.S. notes, though gold and silver certificates were eventually allowed as lawful money. Reserve city banks could hold half of their reserves as deposits in a central reserve city bank, and country banks could hold as much as three-fifths of their reserves as deposits in reserve city banks or central reserve city banks.

The structure of reserve requirements is considered one of the primary shortcomings of the National Banking System. Banks often held the maximum amount of reserves in central city banks since they received two percent interest on their balances. On the other hand, reserves held in their own vaults yielded no return. Called the "pyramiding of reserves" by Sprague (1910), reserves tended to concentrate in central reserve cities such as New York City (and to a lesser extent, other central reserve cities). In turn, central city banks lent (call loans) many of these funds to investors to purchase stock on margin. Outside banks were more inclined to pull their reserves out of New York City (or another center city bank) in a time of monetary stringency or panic which could significantly reduce the reserves of center city banks, precipitate or exacerbate a liquidity or financial crises.

A second problem with the National Banking System was the heavy withdrawals of currency from central reserve cities such as New York City for crop-moving purposes during the early fall months. Country banks needed currency in the late summer and early fall because of costs related to the harvest. The withdrawal of funds by country

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[8] The list of central reserve cities was expanded to include Chicago and St. Louis in 1887.

banks reduced the reserve position of New York City banks as well as the collateral backing of call loans issued off the deposits from outside banks. Champ, Smith, and Williamson (1996) note that withdrawals from New York City banks by outside banks were especially large in the fall and could propagate a liquidity crisis. In August and September 1873, for example, the currency withdrawals were so severe that they caused a contraction of loans that ultimately resulted in the failure of numerous brokerage firms and the closing of the stock exchange for ten days.

The pyramiding of reserves and the heavy withdrawal of funds, especially in the fall harvest season, meant that the money supply tended to contract in those periods when it was need to expand the most. Seasonal money demand and "the perverse elasticity of the money supply" played an important role in propagating the financial crises of the National Banking Era. As noted by Sprague, all of the major panics of the National Banking Period occurred during the fall harvest season --1873, 1884, 1890, 1893, and 1907—when financial markets were illiquid because of the transfer of funds to the interior of the country to finance the harvesting of crops. The Panic of 1907, the last major financial crises of the National Banking Era, led to a reform of the US monetary system after JP Morgan and a group of bankers assembled a rescue package to prevent an even larger meltdown in New York financial markets.

In response to the 1907 crisis, Congress passed the Aldrich-Vreeland Act in May 1908. The Aldrich-Vreeland Act was used only once, at the outbreak of World War I, before the Federal Reserve assumed the role of lender-of-last resort in late 1915. Silber (2006, 2007a, 2007b) argues that the lender-of-last resort legislation was instrumental in preventing a large scale US financial crisis following the outbreak of World War I. He argues further that the Aldrich-Vreeland Act contained provisions that allowed the

private sector to respond much more quickly to a financial crisis than the Federal Reserve. The monetary act allowed a bank to issue notes that did not require the currency to be backed by government bonds. The bank, rather than the central bank, decided the timing and amount of additional currency it needed for liquidity assistance. This means that the money supply increased endogenously to meet a shortage of liquidity (Silber, 2006, p. 6). Friedman and Schwartz argue that "to judge by that one episode, the Aldrich-Vreeland Act provided an effective device for solving a threatened interconvertibility crisis without monetary contraction or widespread bank failures" (Friedman and Schwartz, 1963, p.172). Champ (2007) found that the elasticity of note issuance in the United States increased following the passage of the monetary legislation.

The Aldrich-Vreeland Act also created the National Monetary Commission to investigate the US banking system. As part of the report, E. W. Kemmerer wrote Seasonal Variations in the New York Money Market which points out that panics seemed to occur at the same time as periods of monetary stringency. Professor O.M. Sprague of Harvard University, another contributor to the National Monetary Commission, wrote the *History of Crises Under the National Banking System*. In the monograph, Sprague (1910) examined the major panics of the pre-World War period. He documented (1910, p. 157) that "with few exceptions all our crises, panics, and periods of less severe monetary stringency have occurred in the autumn."

The Federal Reserve Act replaced the Aldrich-Vreeland Act on December 23, 1913. As noted in the preamble of the Federal Reserve Act, the purpose of the measure was to "furnish an elastic currency." The Federal Reserve would accommodate seasonal money demand by increasing the supply of high-powered money as economic activity varied across the year. In the analysis that follows, we use Sprague's observations that

monetary stringency and the severity of financial crises were greatest in the fall harvest season as a new identification strategy to isolate the effect of the introduction of a lender-of-last resort on the American financial markets. If a lender-of-last resort mattered, then its biggest effects on markets should be observed during the fall harvest season.

III. Empirical Analysis

A. Model

To motivate the empirical analysis, we use a model developed by Miron (1986) to examine the effect of a lender-of-last-resort on financial markets. Miron assumes that the supply of bank funds is relatively inelastic, so that seasonal increases in loan demand will systematically increase interest rates and potentially increase the likelihood of panic. In the model, the bank's cost function can be written as:

$$c\left(\frac{R}{D}\right) = \frac{(W - E(W))^2}{2} \frac{d^2(Y - F)^2}{(b(W - E(W))^2 + d^2)^2} \tag{1}$$

where R is the bank's reserves, D is the deposits, and W is the withdrawals. The variance of withdrawals is denoted by $(W - E(W))^2$, d is the demand for deposits, Y is the real demand for credit, F is the amount of increase in a supply of loans in open market purchases, and b is some positive constant. The model predicts that the quantity of loans is high under the following conditions: (1) demand for loans is high; (2) bank deposits are high; or (3) when the variance of withdrawals is low. On the other hand, reserves are higher when loan and deposit demand is higher. The ratio of loans to reserves increases as (1) loan demand increases, (2) deposit demand decreases, and the (3) variance of withdrawals decreases.

Another prediction of the model is that the interest rate, i, is a function of the

same variables. The interest-rate can be written as:

$$\iota = \frac{(Y - F)(W - E(W))^2}{(b(W - E(W))^2 + d^2)^2}$$

(2)

Equation (2) suggests that without a lender of last resort, *F,* the interest rate will be high in seasons where loan demand is high or deposit demand is low. This implies that in the harvest months, when there is generally a higher demand for loans, interest rates should be higher on average than the rest of the year. Loan demand is not only higher during the harvest season, but it is also highly variable *across* harvest seasons. Even if loan uncertainty, denoted by $(W - E(W))^2,$ were constant over the year, interest rates should vary across harvest seasons simply because output fluctuates from year-to-year. Given that we do not have a proxy for loan uncertainty, we treat it as a constant in our empirical analysis. It is probably not unreasonable, however, to assume that withdrawal uncertainty is higher during the harvest months, which would increase the magnitude of the results but leave them qualitatively unaffected otherwise.

Although Miron finds that the founding of the Federal Reserve reduced the seasonality of interest rates, his model has a number of other testable hypotheses. Short-term interest rate volatility should decline in all months if the introduction of a lender-of-last resort increased the elasticity of the money supply. Second, the variability of short-term interest-rate should be highest in the harvest months because money demand was more volatile during this period. The volatility of short-term interest rates should not be statistically different from the rest of the year, however, following the introduction of a lender-of-last resort.

An increase in interest rates also reduces stock values to the extent that a higher cost of funds and liquidity constraints increase the probability of a financial crisis. This implies that prior to the passage of the Aldrich-Vreeland Act: (1) stock market volatility should be higher, (2) short-term interest rates and stock returns during the harvest months should be negatively correlated, and (3) monthly stock return volatility should be highest in the harvest months before the introduction of a lender-of-last resort since interest rate spikes were more likely to occur during the fall harvest season. Monthly stock return volatility in the fall harvest season should not be statistically different from the rest of the year following the passage of the Aldrich-Vreeland Act, however.   Finally, if private banks and the Federal Reserve perform the lender-of-last resort function equally well, stock and bond market volatility should be approximately the same under Aldrich-Vreeland as after the founding of the Federal Reserve.

B. Data

To test the effects of the introduction of a lender-of-last resort on interest rate and stock volatility, we use financial data from several different sources. For short-term interest rates, we use call loan money rates with mixed collateral and New York City prime 60-90 day commercial paper rates as reported on the website for the National Bureau of Economic Research (NBER).[9] Monthly data for both rates are collected and analyzed from 1870-1925.

For the stock market, we rely on Goetzmann, Ibbotson, and Peng's, new comprehensive monthly stock market indices of the pre-CRSP era for the period 1870-1925. The GIP data is the broadest index publicly available for the pre-CRSP period and

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[9] The NBER short-term interest rate data are taken from McCaulay (1856),

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 significantly improves on the Cowles Index and the Dow Jones Industrial Average, the other two widely employed indices from this period. 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, r_t^C. As shown in Table 2 of the Appendix, the first-order autocorrelation coefficient for the Cowles Index is 26 percent while the first-order autocorrelation for the price-weighted GIP index is only 6 percent.[10] The autocorrelation problem, called the "Working Effect" makes problematic an analysis of monthly seasonal effects because the average of monthly high and low stock data "smoothes" returns (Working, 1960). Also, the Dow Jones Industrial Average is computed based on a much smaller number of stocks than the GIP index.

C. Interest Rate Volatility

We analyze short-term interest rate volatility using call loans, the interest rate investors used to purchase stock on margin in the late nineteenth and early twentieth

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[10] Indeed, we construct an equally-weighted index using the third of stocks with the highest prices, r_t^B, the first order serial correlation drops to 2% (see appendix table 3), suggesting that autocorrelation induced by non-trading is a serious problem for low-priced stocks, which are also small stocks (see Weidenmier, Brown and Mulherin, forthcoming).

century. For our core results, we divide the sample period into the National Banking Period from 1870-May 1908 and the post-Aldrich-Vreeland/Federal Reserve period from June 1908-1925. Even though the National Banking Period began in 1863 during the Civil War, we exclude the war years to minimize the effect of the conflict on the empirical results.[11] Table 1 and Figure 2 show that the average call loan rate is higher in September and October. Call loan rates during the months of September and October averaged 5.59 percent from 1870-May 1908 and 4.15 percent from June 1908-1925, a drop of more than 25 percent. A simple t-test shows that September and October call loan rates are significantly different from the other ten months of the year at the one percent level before May 1908, but insignificant after the monetary regime change.[12] Although the call loan rate declined from 4.10 percent to 3.9 percent in the other ten months of the year, the effect is not statistically significant at conventional levels. These results essentially replicate Miron's (1986) analysis, albeit in a slightly different time period.

Figure 1 also suggests that monthly call loan rates appear to be considerably smoother after the passage of Aldrich-Vreeland in 1908. This is consistent with our prediction that interest rate volatility should drop because of the introduction of a lender of last resort. As reported in Table 3, we also find that the variance of interest rates is significantly lower in all months after the monetary reform legislation. The volatility of interest rates in the rest of the year (non-September and October months) declined from 2.63 percent to 1.85 percent, or 30 percent, between 1870-May 1908 and June 1908-1925.

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[11] Including the Civil War years in the analysis does not qualitatively change the results.
[12] The basic tenor of the results remains unchanged if we replace the call loan rate with the commercial paper rate.

We next investigate whether the volatility of interest rates declines most in the fall harvest months, as predicted if change in monetary policy increased the liquidity of financial markets. Miron's model suggests that volatility should decline if monetary policy prevents interest rate spikes during some harvest seasons. To test this, we compute average volatility for each calendar month[13] and then compare average variances before and after the change in monetary policy. For many of our tests, we compute the average of monthly variances, which has a non-standard distribution. Therefore, we bootstrap the standard errors. Details for this procedure are found in the appendix. As an alternative, we also compute the variance of call loan rates by first aggregating over all non-harvest months and then aggregating over all harvest months and perform a series of standard F-tests to determine the effect monetary policy. Although the results are qualitatively similar to those reported in the paper,[14] this aggregation may be problematic, because has Kemmerer notes, there are other, albeit smaller, seasonal effects which may affect interest rates.[15]

Table 2 shows that the volatility of interest rates across the months of September and October averaged 6.84 percent from 1870 until the passage of Aldrich-Vreeland in May 1908. The volatility of call loan rates in September and October declined more than 73 percent to 1.81 percent in 1908-1925 after the introduction of a lender-of-last resort. As shown in Table 3, we can reject the equality of variances of the harvest months with the other 10 months of the year at the one percent level before the passage of the Aldrich-

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[13] We do this to avoid aggregating across months which may have different interest rate volatilities due to the harvest cycle.

[14] These results are available from the authors upon request.

[15] Indeed, using a Levene test for equality of variances, we can reject that September and October call loan rates are equally volatile. With stock return data, we cannot reject that September and October stock returns have the same volatilities, nor can we reject that the other ten calendar months have volatilities that are different from each other. Hence, one can argue that using the standard F-test is reasonable for stock data – although it is less reasonable for call loan data.

Vreeland Act. We are unable, however, to reject the null hypothesis of the equality of variances between the rest of the year and September and October in the period from May 1908-1925.

We test the sensitivity of the empirical results using the period from June 1908-1913 as the period for the change in monetary regime. Some previous studies have argued that World War I, the closure of the New York Stock Exchange, the abandonment of the gold standard, and government controls of the call and time-loan markets played an important role (or explain the change) in the change in the time series properties of interest rates rather than the founding of the Federal Reserve (Fishe and Wohar, 1992; Kool, 1994). To control for this possibility, in Table 4 we compare the volatility of interest rates between 1870-May 1908 with the Aldrich-Vreeland period (June 1908-1913) before the outbreak of World War I. The analysis is similar to work by Caporale and McKiernan (1998) with the exception that we employ our new identification scheme to separate the effect of the lender-of-last resort legislation from other macroeconomic shocks by comparing the fall harvest months with the rest of the year. The results are similar to the baseline analysis reported in Table 3. The volatility of call loan rates declined more than 80 percent, from 6.84 percent to 1.25 percent in the Aldrich-Vreeland period. The variance of call loan rates declined from 2.63 percent to .83 percent in the other ten months of the year. The decrease in the volatility of the call loan rate is statistically significant at the five percent level for the harvest months and the one percent level for the rest of the year. Finally, we find that the volatility of call loan rates is not significantly higher than the other ten months of the years in the period (June 1908-1913) ($p = .13$).

Another possibility is that the results are driven by the Aldrich-Vreeland period when interest rate volatility was lowest in the period 1915-25. To test this hypothesis, we compare the volatility of interest rates after the founding of the Federal Reserve from 1915-25 with the volatility of interest rate in the pre-Fed period (1870-1913).[16] As shown in Table 5, we once again find a dramatic decline in interest-rate volatility that is statistically significant at the one percent level. Interest-rate volatility in the months of September and October are significantly larger than the rest of the year prior to the regime change, but not after the introduction of the lender-of-last resort.

We also performed an additional robustness check to test the sensitivity of the empirical results. We begin the sample period in 1879 (as opposed to 1870) for two reasons: (1) the United States joined the gold standard in 1879 and (2) to exclude the Panic of 1873 from the empirical analysis which may be driving the empirical results given that call loan rates increase to more than 60 percent during the crisis. As shown in Table 6, the basic tenor of the results remains unchanged. Again, we find that interest rate volatility is significantly higher in September and October than the rest of the year prior to the monetary regime change. Interest-rate volatility declined from 3.24 percent from 1879-May 1908 to 1.81 percent in the period June 1908-1925 and 1.25 percent from (June 1908-1913).[17]

One possible shortcoming of the analysis is that the decline in volatility may be due to a decrease in the average level of interest rates which other studies have found to be an important effect of the founding of the Fed (Miron, 1986; Mankiw, Miron, and

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[16] We start the analysis of interest-rate volatility for the founding of the Federal Reserve in 1915 to exclude the closure of financial markets in the last half of 1914 following the outbreak of World War I.
[17] Results still hold if the massive coal loan rates in 1873 (displayed in figure 6) are excluded from the analysis.

Weil, 1987). To test this hypothesis, we decomposed the decline in volatility into the fraction that can be explained by a reduction in the variance of interest rates and the portion that can be explained by a decrease in the level of interest rates. Bootstrapping the sample means and variances, we find that over 98 percent of the decrease in volatility can be explained by a decrease in the variance in interest rates.[18]

D. Stock Return Volatility

We next examine stock volatility before and after the monetary regime change using the equally-weighted GIP Index. Table 7 summarizes the standard deviation of stock returns in September and October as well as the rest of the year for the period 1870-1925. The standard deviation of stock returns averaged 7.30 percent between 1870-May 1908 in the months of September and October and 5.80 percent for the rest of the year. In the lender-of-last resort period (June 1908-1925), stock volatility declined to 3.83 percent in September and October and 4.68 percent in the other ten months. Volatility declined by nearly 50 percent in the fall harvest months and more than 19 percent in the remainder of the year. Table 8 shows that stock volatility was significantly higher in the months of September and October relative to the rest of the year before the passage of the Aldrich-Vreeland and Federal Reserve Acts. After the monetary regime change, we find that volatility in the fall harvest months was no longer statistically different from the rest of the year. Consistent with the interest-rate analysis, we also find that the variance of stock returns significantly declined over the entire year with the biggest decrease occurring in September and October.

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[18] We thank Peter Rousseau for suggesting this analysis.

We also conducted a series of robustness checks to test the sensitivity of the empirical results. Table 9 shows the equality of variance tests for stock returns comparing the period 1870-May 1908 with the Aldrich-Vreeland period (June 1908-1913) before the outbreak of World War I. We find that the variance of stock returns was significantly higher in September and October than the rest of the year before the monetary regime change. The variance of stock returns was also significantly lower in the fall harvest months as well as the remainder of the year in the Aldrich-Vreeland period. The standard deviation of stock returns declined by 59 percent in September and October and more than 35 percent in the rest of the year following the passage of the monetary reform legislation. In the Aldrich-Vreeland period, we are also unable to reject the null hypothesis that the variance of stock returns in September and October was significantly different from the rest of the year.

Finally, as shown in Table 10, we obtain similar results if stock return volatility in the months of September and October is compared to the rest of the year before (1870-1913) and after the founding of the Federal Reserve (1915-1925). Stock return volatility is significantly larger in September and October from the other ten months of the year before the founding of the central banks. After the establishment of the Federal Reserve, however, we find that stock volatility in September and October is no longer statistically different from the rest of the year.

We also analyzed stock volatility beginning in 1879 to control for the large effects of the Panic of 1873 as well as the United States' adoption of the gold standard on financial markets. As shown in Table 11, the basic tenor of the results remains unchanged. Stock volatility is significantly lower following the monetary regime change

and the effect is somewhat more pronounced in the fall harvest months when the financial

markets in New York were most prone to a crisis.[19]

We also tested the sensitivity of our results to the construction and choice of the

underlying stock market indices. First, we replicated the empirical analysis using the

Dow Jones Industrial Average, r_t^D, which began in 1896 using end-of-month data

collected by Brown *et. al.* (2008). We also constructed several other market indices using

the GIP data: an equally-weighted monthly return index, r_t^{Eq}, an index of railroad stocks,

r_t^{RR}, sorting stocks by monthly closing price into the top-third, r_t^B, middle-third, r_t^M, and

lowest-third, r_t^S. This indexing strategy is used as a proxy for both liquidity and market

cap, since historically they have shown a strong correlation[20]. The basic tenor of the

empirical results remains unchanged using the various indices with the exception of the

small firm index. We find that the variability of the small firm index was not statistically

different in the fall harvest season from the other ten months of the year before the

monetary regime change. However, we did find that overall stock volatility for small

firms declined following the monetary policy change.[21] We do not view the empirical

results for the small stock index to be very important, however, given that the small firm

index constitutes less than three percent of the market capitalization of the GIP Index.

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[19] Using the bootstrap, we cannot reject equality of harvest-time variance and variance the rest of the year before the monetary regime change. However, using an F-test, we can reject at the five percent level. Using the F-test here may not be problematic, because using a Levene test, we can neither reject that monthly return variances are different across non-harvest months nor that monthly return variances are different across harvest-season months.

[20] Though numbers are not reported here, analysis by Weidenmier, Brown, and Mulherin (forthcoming) reveal extremely strong correlation between price and market capitalization during this period.

[21] The empirical analysis of small stocks is not surprising for two reasons: (1) as shown in Table 3, the first-order serial correlation of the small stock index, r_t^S, is 11 percent and (2) the annualized volatility of the index is 37 percent, three times higher than the volatility of our index of high-priced stocks. The high volatility for the small firm index means that it is difficult to conduct hypothesis testing because the standard errors for the index are very large. Detailed results are available from the authors upon request.

Finally, we performed the same analysis using the Cowles index, r_t^C. In September and October, stock return volatility across months drops from 3.61 percent prior to Aldrich-Vreeland to 2.91 percent afterward. The difference is not statistically significant at conventional levels, however. Further, stock return volatility in other months actually rises from 3.16 percent prior to Aldrich-Vreeland to 3.23 percent afterward. Stock return volatility in the National Banking period was not statistically significantly higher in the harvest months than in other months. We attribute these results to the high degree of first-order serial correlation present in the Cowles index arising from the use of averaging monthly high and low prices to construct the market benchmark. Our findings highlight the potential erroneous conclusions that can be drawn from using the Cowles Index to study financial markets.

Our empirical results also provide some insight into the macroeconomic effects of the introduction of a lender-of-last resort. The poor quality of pre-World War I macroeconomic indicators such as GDP and industrial production makes it difficult to identify the effect of financial panics on economic activity. Given that stock volatility is a leading indicator of future economic activity, our analysis suggests that the introduction of a lender-of-last resort probably reduced the probability of a financial crisis as well as its attendant economic effects.

IV. Conclusion

Can a lender-of-last resort stabilize financial markets? This question has recently received considerable attention given that implied stock volatility for many broad market

US indices has nearly doubled since the onset of the sub-prime mortgage crisis in 2007. The recent rise in stock volatility has raised the specter of an economic recession and a decline in investment spending. We provide a historical perspective on this question by examining the effects of one of the most important monetary regime changes in American history-- the Aldrich-Vreeland Act in 1908 and the creation of the Federal Reserve in 1913--on stock and interest rate volatility.

We introduce a new identification strategy to isolate the effect of the introduction of a lender-of-last resort on American financial markets from other macroeconomic shocks such as World War I, the shutdown of American financial markets from July-December 1914, and the gold standard. Our identifying strategy is motivated by the observation that many of the largest financial crises of the National Banking Period occurred in the months of September and October when the money and short-term credit markets were relatively illiquid because of the harvest season. We exploit the seasonal variation in equity and credit markets to identify the effect of the Aldrich-Vreeland Act and the creation of the Federal Reserve on financial market volatility.

Using Goetzman, Ibbotson, and Peng's new comprehensive pre-CRSP database, we find that the monetary regime change was associated with a dramatic reduction in financial market volatility. Stock volatility in the months of September and October declined nearly 50 percent in the Aldrich-Vreeland and Federal Reserve period. Interest-rate volatility declined more than 70 percent in September and October following the monetary regime change. Although we find that financial market volatility in September and October was significantly higher in the pre-Aldrich-Vreeland period than the other 10 months in the year, this was not the case after the introduction of a lender-of-last resort.

The results provide strong evidence that the introduction of a lender-of-last resort stabilized American financial markets.

The analysis also provides some evidence on the economic effects of a lender-of-last resort. The poor quality of macroeconomic indicators such as GDP, investment spending, and industrial production in the pre-World War II period makes it difficult to assess the effect of the policy changes on the US economy, although Schwert (1990) finds that during the period 1889-1925, lagged stock returns do forecast the current level of real activity. Another problem is that it is difficult to analyze the linkages between the financial and real sectors given that credit and equity markets are forward looking and economic data are not. By examining financial market volatility, we gain some insight into the effects of the introduction of a lender-of-last resort on the US economy given that stock volatility is a leading indicator of future investment spending and economic activity. We interpret our results as strong evidence that the introduction of a lender-of-last resort significantly reduced the probability of a financial crisis and its potentially negative effects on economic activity, especially in the fall harvest months.

Our results have several implications for future studies of financial markets as well as monetary policy in a time of crisis. First, the findings highlight the potential problems in using the Cowles Index to test hypotheses in financial economics. Future research in financial economics may want to revisit the findings of previous studies that have relied on the Cowles Index to study the behavior of stock returns or stock volatility over a long period of time. Second, from the perspective of policymakers, liquidity assistance from a lender-of-last-resort can be very important in preventing a larger

meltdown in financial markets and reducing the probability of a future financial crisis

that can have real economic effects.

References

Brown, W., Mulherin, J., and Weidenmier, M. (forthcoming). "Competing With the NYSE." *Quarterly Journal of Economics*.

Caporale, B. and T. Caporale. (2003). "Investigating the Effects of Monetary Regime Shifts:The Case of the Federal Reserve and the Shrinking Risk Premium." *Economics Letters* 80(1): 87-91.

Caporale, T and McKiernan, B. (1998). "Interest Rate Uncertainty and the Founding of the Federal Reserve." *Journal of Economic History* 58(4): 1110-17.

Champ, B. (2007). "The National Banking System: A Brief History." *Federal Reserve Bank of Cleveland Working Paper* .

Champ, B. (2007). "The National Banking System: Empirical Observations." *Federal Reserve Bank of Cleveland Working Paper.*

Champ, B. (2007). "The National Banking System: The National Bank Note Puzzle." *Federal Reserve Bank of Cleveland Working Paper.*

Champ, B., and Wallace, N. (2003). "Resolving the National Banking System Note-Issue Puzzle." *Federal Reserve Bank of Cleveland Working Paper.*

Champ, B., Freeman, S., and Weber, W. E. (1999). "Redemption costs and interest rates under the U.S. National Banking System." *Journal of Money, Credit, and Banking* 31(3): 568-595.

Champ, B., Smith, B. D., and Williamson, S. D. (1996). "Currency Elasticity and Banking Panics: Theories and Evidence." *Canadian Journal of Economics* 29(4): 828-864.

Clark, T. (1986). "Interest Rate Seasonals and the Federal Reserve." *The Journal of Political Economy* 94(1): 76-125.

Fishe, R. P., and Wohar, Mark. (1990). "The Adjustment of Expectations to a Change in Regime: Comment." *American Economic Review* 80(4): 531-551.

Friedman, M., & Schwartz, A. J. (1963). *A Monetary History of the United States, 1867-1960.* Princeton: Princeton University Press.

Goetzmann, W. N., Ibbotson, G. R., and Peng, L. (2001). "A New Historical Database for The NYSE 1815 To 1925: Performance and Predictability." *Journal of Financial Markets* 4(1): 1-32.

Goodhart, C. A. (1969). *The New York Money Market and the Finance of Trade, 1900-1913.* Cambridge: Harvard University Press.

Kemmerer, E. W. (1911). "Seasonal Variations in the New York Money Market." *American Economic Review* 1(1): 33-49.

Kool, Clemens (1995). "War Finance and Interest Rate Targeting: Regime Changes in 1914-1918." *Explorations in Economic History* 32(3): 365-82.

Macaulay, F. R. (1938). *Some Theoretical Problems Suggested by the Movement of Interest Rates, Bond Yields and Stock Prices in the United States since 1856.* New York: National Bureau of Economic Research.

Mankiw, N. G., and Miron, A. J. (1985). "The Changing Behavior of the Term Structure of Interest Rates." *NBER Working Paper*.

Miron, A. J., Mankiw, N. G., and Weil, D. N. (1987). "The Adjustment of Expectations to a Change in Regime: A Study of the Founding of the Federal Reserve." *American Economic Review* 77(3): 358-374.

Miron, J. (1986). "Financial Panics, the Seasonality of the Nominal Interest Rate, and the Founding of the Fed." *American Economic Review* 76(1): 125-140.

Piatt, A. A. (1906). "The Influence of Crops Upon Business in America." *Quarterly Journal of Economics* , 323-353.

Schwert, G.W. (1989a). "Business Cycles, Financial Crises and Stock Volatility." *Carnegie-Rochester Conference Series on Public Policy* 31: 83-125.

Schwert, G.W. (1989b). "Why Does Stock Market Volatility Change Over Time?" *Journal of Finance* 44(5): 1115-1153.

Schwert, G.W. (1990). "Stock Returns and Real Activity: A Century of Evidence." *Journal of Finance* 45(4): 1237-1257.

Shapiro, M.D. (1988). "The Stabilization of the US Economy: Evidence from the Stock Market." *American Economic Review* 78(5): 1067-079.

Shiller, R. (1992). *Market Volatility*. Cambridge: MIT Press.

Siegel, J. (2002). *Stocks for the Long R*un*: The Definitive Guide to Financial Market*

Returns and Long-Term Investment Strategies. New York: McGraw Hill.

Silber, W. L. (2005). "What Happened to Liquidity When World War I Shut the NYSE?" *Journal of Financial Economics* 78(3): 685-701.

Silber, W. L. (2007a). *When Washington Shut Down Wall Street: The Great Financial Crisis of 1914 and the Origins of America's Monetary Supremacy*. Princeton: Princeton University Press.

Silber, W. L. (2007b). "The Great Financial Crisis of 1914: What can We Learn from Aldrich-Vreeland Currency?" *American Economic Review Paper and Proceedings,* 97(2): 285-89.

Sprague, O. M. (1910). *A History of Crises under the National Banking System.* Washington: U.S. Government Printing Office.

Weber, W. (2000). *Federal Reserve Bank of Minneapolis - Bruce Champ*. Retrieved April 20, 2008, frohttp://reserach.mpls.frb.fed.us/research/economists/wewproj.html

Working, H. (1960). A Note on the Correlation of First Differences of Averages in a Random Chain. *Econometrica* 28: 916-918.

Table 1
Annualized Mean Monthly Call Loan Rates
(in percent)

Month	1870-May 1908	June 1908-1925
January	4.38	3.77
February	3.59	3.88
March	4.30	3.76
April	4.70	3.69
May	3.52	3.67
June	2.95	3.61
July	2.80	3.63
August	3.22	3.57
September	5.72	3.94
October	5.45	4.35
November	5.04	4.65
December	6.48	4.78
Average	4.35	3.94
Average(non-Sept. & Oct.)	4.10	3.90
Average(Sept. & Oct.)	5.59	4.15

Source: NBER Macro-History Database, Series 13001.

Table 2

Call Loan Interest Rate Volatility
(in percent)

Sample Period	Rest of Year	September & October
1870-May 1908	2.63	6.84
1879-May 1908	2.36	3.24
June 1908-1913	0.83	1.25
June 1908-1925	1.85	1.81

Table 3
Tests for the Equality of Variance for Call Loans
Full Sample Period (1870-1925)

H_0: Null Hypothesis	Empirical P-value
Harvest Months(1870-May 1908) = Rest of Year(1870-May 1908)	0.0004
Harvest Months(1870-May 1908) = Harvest Months(June 1908-1925)	0.0009
Harvest Months(June 1908-1925) = Rest of Year(June 1908-1925)	0.4009
Rest of Year(1870-May 1908) = Rest of Year(June 1908-1925)	0.0001

Table 4
Tests for the Equality of Variance for Call Loans
Sub-Sample Period (1870-1913)

H_0: Null Hypothesis	Empirical P-value
Harvest Months(June 1908-1913) = Rest of Year(June 1908-1913)	0.134
Harvest Months(1870-May 1908) = Harvest Months(June 1908-1913)	0.0479
Rest of Year(1870-May 1908) = Rest of Year(June 1908-1913)	0.0025

Table 5
Tests for the Equality of Variance for Call Loans
Federal Reserve Sub-Sample Period (1870-1913) vs. (1915-1925)

H$_0$: Null Hypothesis	Empirical P-value
Harvest Months(June 1915-1925) = Rest of Year(1915-1925)	0.3389
Harvest Months(1870-1913) = Harvest Months(1915-1925)	0.0113
Rest of Year(1870-1913) = Rest of Year(1915-1925)	0.0074

Table 6
F-Tests for the Equality of Variance for Call Loans
Sub-Sample Period (1879-1925)

H$_0$: Null Hypothesis	Empirical P-value
Harvest Months(1879-May 1908) = Rest of Year(1879-May 1908)	0.05545
Harvest Months(1879-May 1908) = Harvest Months(June 1908-1925)	0.0045
Harvest Months(1879-May 1908) = Harvest Months(June 1908-1913)	0.0488

Table 7
Standard Deviation of Stock Returns Across Months
(in percent)

Sample Period	Rest of Year	September & October
1870-May 1908	5.80	7.30
1879-May 1908	5.91	6.50
June 1908-1913	3.74	2.97
June 1908-1925	4.68	3.83

Table 8
Tests for the Equality of Variance for Stock Returns
Full Sample Period (1870-1925)

H$_0$: Null Hypothesis	Empirical P-value
Harvest Months(1870-May 1908) = Rest of Year(1870-May 1908)	0.0351
Harvest Months(1870-May 1908) = Harvest Months(June 1908-1925)	0.0029
Harvest Months(June 1908-1925) = Rest of Year(June 1908-1925)	0.2211
Rest of Year(1870-May 1908) = Rest of Year(June 1908-1925)	0.0050

Table 9
Tests for the Equality of Variance for Stock Returns
National Banking Period (1870- 1908) vs. Aldrich Vreeland Period (1908-1913)

H$_0$: Null Hypothesis	Empirical P-value
Harvest Months(June 1908-1913) = Rest of Year(June 1908-1913)	0.2610
Harvest Months(1870-May 1908) = Harvest Months(June 1908-1913)	0.0030
Rest of Year(1870-May 1908) = Rest of Year(June 1908-1913)	0.0091

Table 10
Tests for the Equality of Variance for Stock Returns
Federal Reserve Sub-Sample Period (1870- 1913) vs. (1915-1925)

H$_0$: Null Hypothesis	Empirical P-value
Harvest Months(June 1908-1913) = Rest of Year(1915-1925)	0.1652
Harvest Months(1870-1913) = Harvest Months(1915-1925)	0.0401
Rest of Year(1870-1913) = Rest of Year(1915-1925)	0.1137

Table 11
Tests for the Equality of Variance for Stock Returns
Sub-Sample Period (1879-1925)

| H_0: Null Hypothesis	Empirical P-value
Harvest Months(1879-May 1908) = Rest of Year(1879-May 1908)	0.2848
Harvest Months(1879-May 1908) = Harvest Months(June 1908-1925)	0.0058
Harvest Months(1879-May 1908) = Harvest Months(June 1908-1913)	0.0501

Table 12
Tests for the Equality of Variance for Commercial Paper
Full Sample Period (1870-1925)

H_0: Null Hypothesis	Empirical P-value
Harvest Months(1870-May 1908) = Rest of Year(1870-May 1908)	0.0050
Harvest Months(1870-May 1908) = Harvest Months(June 1908-1925)	0.0068
Harvest Months(June 1908-1925) = Rest of Year(June 1908-1925)	0.3590
Rest of Year(1870-May 1908) = Rest of Year(June 1908-1925)	0.0025

Table 13
**Tests for the Equality of Variance for Cowles Index**
Full Sample Period (1870-1925)

H_0: Null Hypothesis	Empirical P-value
Harvest Months(1870-May 1908) = Rest of Year(1870-May 1908)	0.163
Harvest Months(1870-May 1908) = Harvest Months(June 1908-1925)	0.1365
Harvest Months(June 1908-1925) = Rest of Year(June 1908-1925)	0.2990
Rest of Year(1870-May 1908) = Rest of Year(June 1908-1925)	0.6176

Figure 1
Monthly Call Loan Interest Rates, 1870-1925
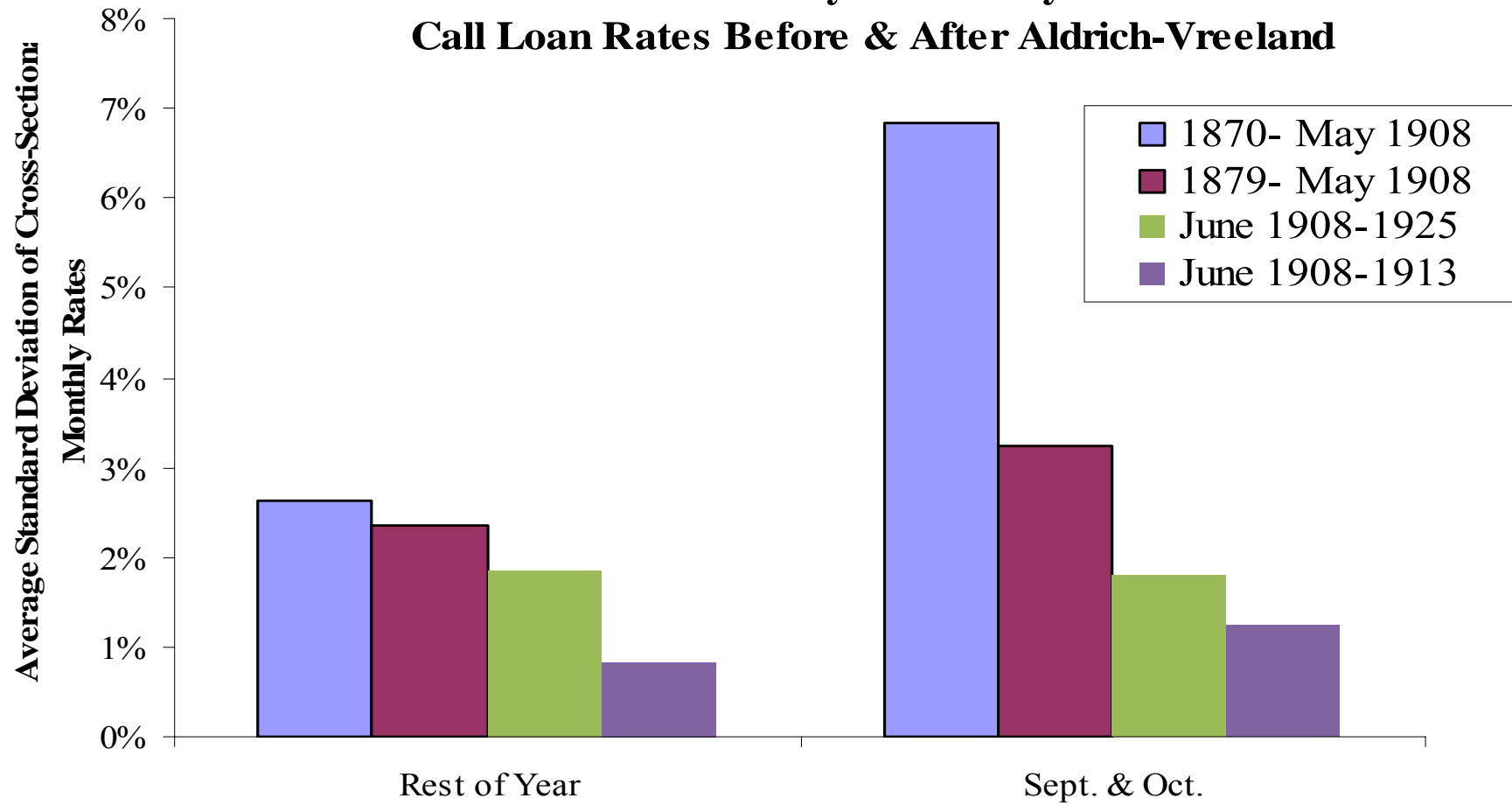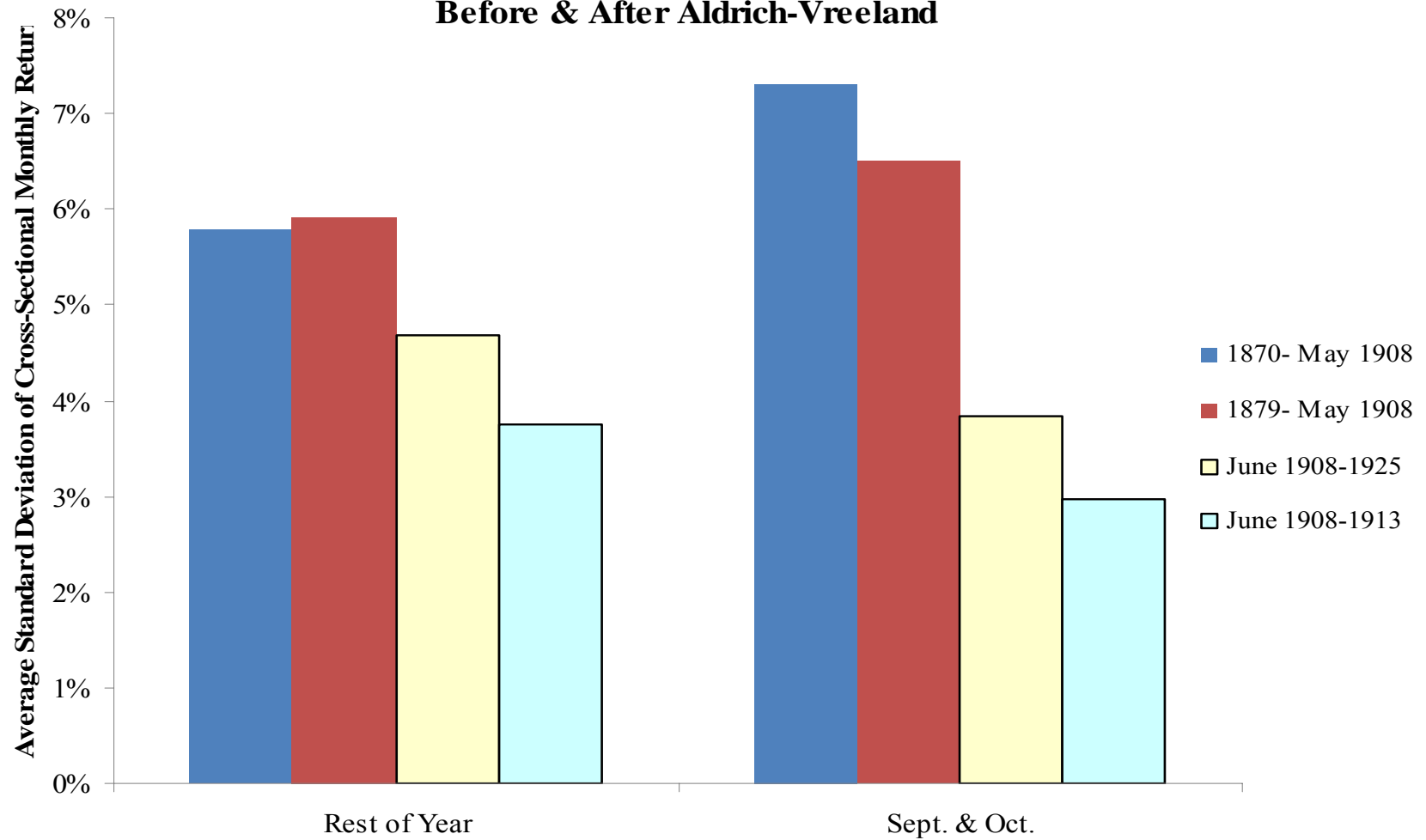**(in percent)**
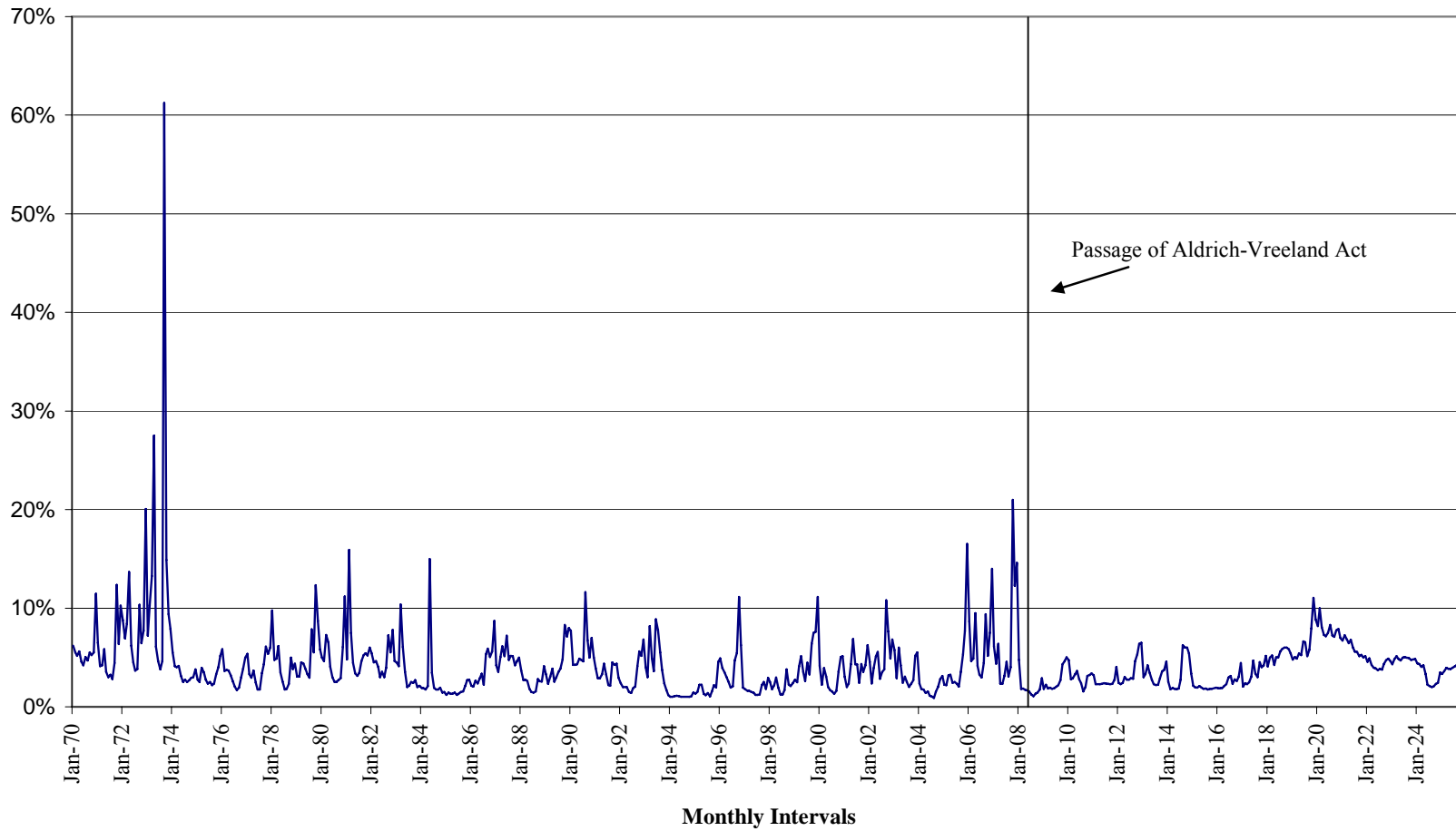
Figure 2
Mean Monthly Call Loan Rates Before and After the Passage of the Aldrich-Vreeland Act
(in percent)
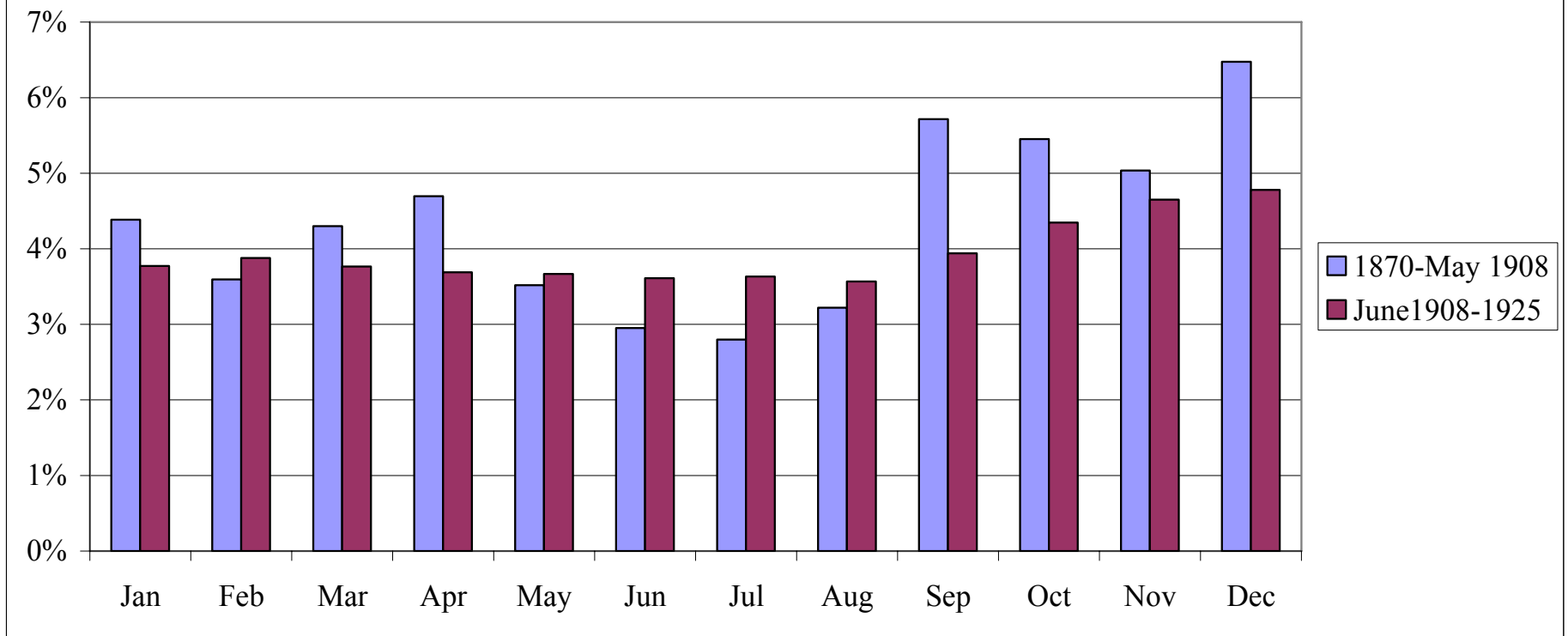
Figure 3
Volatility of Monthly
Call Loan Rates Before & After Aldrich-Vreeland

Figure 4
Volatility of Monthly GIP Index Returns
Before & After Aldrich-Vreeland

Appendix

Table 1
Stock Market Indices

Stock Market Indices	Sample Period	Data Source
r_t^{Wt} = price-weighted index	1870-1925	GIP
r_t^{D} = Dow-Jones Industrial Average	1896-1925	Cowles
r_t^{C} =Cowles Stock Index	1870-1925	GIP
r_t^{B} = equally-weighted index of stocks with prices in the highest third of the index each month	1870-1925	GIP
r_t^{M} = an equally-weighted index of stocks with prices in the middle third of the index each month	1870-1925	GIP
r_t^{S} = an equally-weighted index of stocks with prices in the lowest third of the index each month and finally	1870-1925	GIP
r_t^{Eq} = equally-weighted index	1870-1925	GIP
r_t^{RR} = equally-weighted index of railroads	1870-1925	GIP

Table 2
Correlation of Monthly Returns for Various Stock Market Indices

	r_t^{Wt}	r_t^D	r_t^C	r_t^B	r_t^M	r_t^S	r_t^{Eq}	r_t^{RR}
r_t^{Wt}	1.00							
r_t^D	0.72	1.00						
r_t^C	0.66	0.67	1.00					
r_t^B	0.92	0.71	0.61	1.00				
r_t^M	0.92	0.70	0.60	0.77	1.00			
r_t^S	0.81	0.65	0.59	0.63	0.77	1.00		
r_t^{Eq}	0.94	0.74	0.65	0.81	0.91	0.95	1.00	
r_t^{RR}	0.88	0.64	0.61	0.76	0.86	0.92	0.96	1.00

Table 3
Annualized Volatility and Serial Correlation
of Monthly Index Returns

	r_t^{Wt}	r_t^{D}	r_t^{C}	r_t^{B}	r_t^{M}	r_t^{S}	r_t^{Eq}	r_t^{RR}
σ	0.14	0.20	0.11	0.11	0.20	0.37	0.20	0.23
ρ	0.06	0.06	0.29	0.02	0.06	0.11	0.10	0.08

Notes: σ, is the annualized standard deviation of monthly index returns; ρ is the serial correlation of monthly index returns.

Simulation Details

To test our hypotheses, we therefore compute an average variance for each month,

$$\sigma^m = \frac{1}{T-1}\sum_{t=1}^{T}(r_t^m - \bar{r}_m)^2 \quad \text{where m} = \{\text{January, February, ... December}\} \text{ and T is the}$$

number of months either before (*pre*) or after (*post*) the monetary policy change and $\bar{r}_m$ is

the average call loan rate in a particular month, *m*.

We compute, $\sigma_{pre}^{2h} = \frac{1}{2}\left(\sigma_{pre}^{2Sep.} + \sigma_{pre}^{2Oct}\right)$, the sample average variance before the

policy change and $\sigma_{post}^{2h} = \frac{1}{2}\left(\sigma_{post}^{S2ep.} + \sigma_{post}^{2Oct}\right)$, the sample average variance after the policy

change. Finally, we compute the difference of the two, σ_{diff}^{2h}.

Next, we need to compute the standard error of that difference. But σ_{diff}^{2h}. does not

have a standard sampling distribution. We therefore use a parametric bootstrap to

compute empirical p-values. We first compute the sample means and variances of the

empirical distributions from September and October from 1870-1925. Then, we impose

normality (using distributions with fatter tails had little effect on the results) and create

September (October) call rates, we take random draws from the September (October)

distributions.   Then, we choose the first 38 observations (1870-1907) for both September

and October and compute two monthly variances. We conduct the same procedure for

the 18 observations "after" 1907 and compute the difference between the volatility

measures before and after the monetary regime change. To form the empirical

distribution, we repeat the procedure 10,000 times. We then look to see where σ_{diff}^{2h}.

falls on this empirical distribution to compute p-values.

We use an analogous procedure to test whether the variances of call loan rates are the same during the harvest season as over the rest of the year. To compute the average variance over the rest of the year, we again average over monthly variances for the months other than September and October. Empirical p-values for the average variance are computed using the same bootstrap procedure. We then perform a similar analysis on stock returns using the same methodology.