Droughts, Floods and Financial Markets in the United States

by

John Landon-Lane
Rutgers University

Hugh Rockoff
Rutgers University

Richard H. Steckel
Ohio State University

May 19, 2009

Prepared for the NBER conference on Climate Change: Past and Present, Cambridge, MA May 30-31, 2009

The relationships among the weather, agricultural markets, and financial markets have long been of interest to economic historians, but relatively little empirical work has been done. We push this literature forward by using modern drought indexes, which are available in detail over a wide area and for long periods of time to perform a battery of tests on the relationship between these indexes and sensitive indicators of financial stress.

The drought indexes were devised by climate historians from instrument records and tree rings, and because they are unfamiliar to most economic historians and economists, we briefly describe the methodology. The financial literature in the area can be traced to William Stanley Jevons, who connected his sun spot theory to rainfall patterns. The Dust bowl of the 1930s brought the climate-finance link to the attention of the general public. Here we assemble new evidence to test various hypotheses involving the impact of extreme swings in moisture on financial stress.

Prior Work on Climate and Financial Markets

The idea that climate affects the financial sector and through the financial sector the economy as a whole has a long, if not always persuasive, history among economists. The British economist William Stanley Jevons (1884 [1878]) famously argued that financial crises were produced, ultimately, by sunspots. Financial crises had occurred with a frequency of 10+ years in Jevons's time (1825, 1836, 1847, and 1866). Could it be an accident, Jevons asked, that spots appeared on the surface of the sun at (approximately) the same 10+ year intervals? The connection, Jevons concluded, was through India, where sunspot activity disrupted rainfall and harvests. Low incomes in India depressed imports from Britain. The disruption of British trade with India in turn produced the financial crises. Jevons's son, H. Stanley Jevons (1933), attempted to defend and extend his father's theory. He recognized that the business cycle was the result of several factors. However, he argued that a harvest cycle of 3+ years was part of the business cycle, and that harvest cycle was related to meteorological conditions (shown in part in the tree ring data), and the regular fluctuations in meteorological conditions were partly the result of fluctuations in solar radiation.

Although Jevons's sunspot theory was often ridiculed, one may prefer John Maynard Keynes's (1936, 531) cautious conclusion: "The theory was prejudiced by being stated in too precise and categorical a form. Nevertheless, Jevons notion, that meteorological phenomena play a part in harvest fluctuations and that harvest fluctuations play a part (though more important formerly than to-day) in the trade cycle, is not to be lightly dismissed."

Similarly, the American economist Henry Ludwell Moore (1921) argued that the business cycle was produced by the “transit of Venus.” Every eight years Venus stands between the Earth and the Sun disrupting the Sun’s radiation on its path to the earth. The result, according to Moore, is a regular eight-year rainfall cycle (identifiable in part by evidence from tree rings), a regular eight-year crop cycle, and a regular eight-year business cycle.

Weather driven fluctuations in harvests also play a role in accounts of particular episodes. Indeed the business cycle at the end of the nineteenth century has often been described as a product of climate and agriculture. Friedman and Schwartz (1963, 98) argued that the cyclical expansion from 1879 to 1882 was reinforced by "two successive years of bumper crops in the United States and unusually short crops elsewhere." Katherine Coman (1911, 315) thought that the bumper crop of 1884 had produced the opposite effect because it sold for low prices: "The wheat crop of 1884 was the largest that had ever been harvested, and the price fell to sixty four cents a bushel, half that obtained three years before." As a result there was a rash of bankruptcies in the wheat growing areas and the "inability of the agriculturists to meet their obligations to Eastern capitalists and to purchase the products of Eastern mills and workshops, extended and prolonged the industrial depression." Wesley Claire Mitchell (1941, 2) argued that the recovery from the 1890 financial crisis was partly a harvest driven event: "Unusually large American crops of grain, sold at exceptionally high prices, cut short what was promising to be an extended period of liquidation after the crisis of 1890 and suddenly set the tide of business rising." O.M.W. Sprague (1910, 154) attributed the severity of the depression that followed the crisis of 1893 to low farm prices and high farm mortgages. Ernest Ludlow Bogart (1939, 690) agreed that the farm sector was heavily involved in the depression of the 1890s because of "the ruinous failure of the corn crop in 1894, and the falling off of the European demand for wheat, the price of which fell to less than fifty cents a bushel." The poor corn harvest was the result of drought (*New York Times*; August 4, 1894, p. 1, August 5, 1894, p.8, and subsequent stories). Friedman and Schwartz concluded (1963, 140) that the economic revival after 1896 was reinforced by "another one of those fortuitous combinations of good harvests at home and poor harvests abroad that were so critical from time to time in nineteenth-century American economic history."

A. Piatt Andrew (1906) surveyed many of these individual episodes. He concluded that although corn, cotton, and wheat were the most important U.S. crops, and that all influenced the business cycle, the latter two especially through exports, it was fluctuations in the value of the wheat crop that had the most impact on the business cycle. The reason was that wheat was an international crop and hence the influence of the American harvest could be offset or reinforced by the success or failure of wheat crops abroad. Recent work by Davis, Hanes, and Rhode (2009), has reinforced the view that weather-driven harvest events influenced the macroeconomy in the period between the U.S return to the gold standard after the Civil War and World War I. The channel ran through the balance of payments: Strong cotton exports produced increased imports of gold, expansion of the money supply, and lower interest rates. However, they challenge the claim of earlier writers that wheat and corn harvests mattered, finding little statistical evidence for a relationship running from the wheat or corn to industrial production.

A related literature emphasizes that the restrictions on branch banking in the United States weakened the U.S. banking system, especially when compared with foreign systems that permitted branch banking, such as the Canadian system (Bordo, Rockoff, and Redish 1994; Calomiris 2000, chapter 1; Ramirez 2003). Why might this be so? There are several possibilities. A recent paper by Carlson and Mitchener (2009), for example, argues that branch banking increased stability in the 1930s by increasing competition, and thus forcing more prudent behavior on competing banks and branches. Clearly, however, an obvious potential explanation for the apparent stability of branch banking systems is that branch banking permitted banks to diversify local weather related agricultural shocks. One purpose of this study is to determine the frequency of climate driven banking shocks in American financial history.

Measuring Drought

Today researchers have a vast array of instruments to measure weather conditions around the globe from satellites and weather stations based on land and sea and in the atmosphere. Unfortunately the time-depth of these readings is inadequate for an historical study that reaches back to the era when farming was a dominant source of national income. Understanding the practical limitations of empirical research requires a brief discussion of technology, concepts, private efforts and government action that unfolded since the early 1700s.

<u>Instrument readings</u>. Ideally one would have a geographically dense array of comparable instrument readings that cover various aspects of weather over the past several centuries. Devices for measuring temperature and rainfall, however, were crude until the early eighteenth century,

when Daniel Fahrenheit invented the mercury thermometer (1714) and Reverend Horsely developed the rain gauge (pluviometer) consisting of a funnel placed at the top of a cylinder (1722). In the 1720s Anders Celsius assisted Erik Burman in recording temperatures in Uppsala, and soon thereafter observational sites appeared elsewhere in Sweden.

Although the new technologies solved the problem of consistency, enabling people in distant places to take comparable readings, these early efforts were based on various thermometer scales that had to be converted into a common metric. Recordkeeping efforts were largely private or handled by scientific societies until well into the nineteenth century. Systematic study of weather patterns and their causes, much less climate change and its implications, could not begin effectively until a substantial body of evidence had accumulated. In the United States the Smithsonian Institution took the lead in developing a weather network in 1849 based on 150 voluntary observers. In 1874 the task passed to the U.S. Army Signal Service, whose functions were transferred to the newly created U.S. Weather Bureau in 1891. By 1900 numerous countries had created national meteorological services (http://www.nws.noaa.gov/pa/history/timeline.php).

Concepts. After data collection became routine, researchers suggested ideas for measuring drought (Heim, 2002). In the early 1900s drought was defined by a rule of thumb: 21 or more days with rainfall below one-third of normal. In 1931 Thornthwait proposed the concept of evapotranspiration or the sum of evaporation and plant transpiration, which led to ideas of water balance and alternative time scales. In the 1960s Palmer developed four measures: (a) a hydrological drought index based on measures of groundwater and stream flow with a horizon of 1+ years; (b) a drought severity index with a 9 month horizon; (c) a Z index that measures moisture anomaly in a particular month; and (d) a crop moisture index that monitors weekly conditions.

Soon other measures appeared, such as the standardized precipitation index, a surface water supply index, and the vegetation condition index measured from satellite images.

Here we analyze Palmer's Drought Severity Index (PDSI), which has a time scale useful for assessing the economic consequences of yearly fluctuations or clusters of annual patterns in effective moisture (precipitation minus losses from evapotranspiration). Its water balance equation includes rainfall, runoff, evaporation, transpiration, and soil recharge, which are converted to a scale of -6 (extreme drought) to +6 (extremely wet) relative to normal or average conditions for a locality (Palmer 1965). It ignores stream flow, reservoir levels and snowfall, and is less useful in mountain areas or regions of microclimates (Alley 1984). It is fortunate for our purposes that the PDSI can be reconstructed from tree rings, which provide a chronology over hundreds, or even thousands of years if especially long-lived trees are available (such as bristlecone pines) or preserved logs can be extracted from peat bogs or old buildings.

Dendochronology. Leonardo da Vinci recognized that rings in the branches of trees show annual growth and the thickness of the rings indicate the years that were more or less dry. Andrew Douglas was a pioneer who formulated the scientific basis of the field in the 1920s and 1930s, and importantly the principle of cross dating, whereby overlapping chronologies from different trees could be merged to form long series (Fritts 1976; Nash 1999). He founded the Laboratory of Tree Ring Research at the University of Arizona, where he and co-workers collected a vast number of cores using a tubular boring device.

To understand the meaning of tree rings, growth is decomposed into five parts:[1]

$$R_t = A_t + C_t + \varphi D1_t + \varphi D2_t + E_t \quad (1)$$

---

[1] This section relies on information kindly provided by Henri Grissino-Mayer (http://web.utk.edu/~grissino/my_page.htm#Teach)..

where R denotes ring width; t the year; φ is a presence or absence indicator (taking values of 0 or 1) A is the age trend of tree growth; C indicates climate; D1 represents external disturbance processes such as a fire; D2 represents internal growth disturbance such as a disease; and E is an error term. The goal is to decipher or solve for C given R and information on A, D1 and D2. To reduce the effects of disturbances it is useful to collect large samples in a particular locality.

The Drought Database

Researchers have estimated the Palmer Drought Severity Index from instrument records, which cover the period 1900 to the present, and from tree rings, which go back as much as two thousand years depending upon the locality. Thus there is a break in our data source in 1900, and for this reason it is prudent to divide the analysis into two corresponding parts. We are aware that contrasts in the results across the two periods might be attributable to different data sources or to a structural shift in the relationship between drought and economic activity.

Assembling tree ring chronologies and estimating PDSI is an ongoing process, which is described in The North American Drought Atlas by Cook and Lamont (2004). Here we use PDSI values estimated from 835 tree ring chronologies scattered across North America, which researchers used to estimate PDSI values at 286 grid points (the raw data are available at http://www.ncdc.noaa.gov/paleo/pdsi.html). The points are evenly spaced over a 2.5 degree grid (roughly 175 miles apart), which provides a useful approximation to annual net moisture conditions at the local (state) level.[2]

---

[2] Cook and Lamont used point-by-point regression, which is a sequential, automated fitting of single-point principal component regression models to a grid of climate variables taken from instrument readings. The method assumes that only those tree-ring chronologies close to a given PDSI grid point are good predictors of drought at that location. They used instrument data from 1928-1978 (the calibration period) to develop each regression equation. The remaining data from 1900-1927 (the verification period) of the instrument record were used to test the validity of the PDSI estimates.

In this study we use two sets of drought indexes obtained from the North American Drought Atlas by Cook and Lamont (2004). The first is a set of instrumental PDSI readings for the sample period from 1900 to 2005. The second is a set of reconstructed PDSI readings using tree ring data that can be used to extrapolate the PDSI data far back into the past.

Our Bank "Stress Tests"

There are many variables that could be used to measure the degree of stress placed on a banking system by adverse climatic changes. These include bank failures; changes in various balance sheet items, such as surplus accounts; rates of return on various categories of assets, such as rates of returns on loans; and the rate of return to bank equity.

At first thought, bank failure rates might seem to be a best measure of stress. However, there are several problems with this measure. (1) In many periods there were relatively few National Bank failures. Failures were concentrated among state chartered and private banks, and economic historians, as far as we are aware, have not assembled the data for these sectors. (2) Panics sometimes led to the temporary or permanent closure of many smaller banks because of lack of liquidity, even though these banks were solvent. It is often difficult to determine from existing information whether closures were temporary or permanent, and whether they were the result of insolvency from bad investments or illiquidity from panics that spread from region to region. Obviously, these considerations do not suggest that failure rates contain no information; they merely suggest that using the existing data would be more difficult than it might seem.

Additional details, including a map of the grid points and a discussion of statistical methods, are available at: http://iridl.ldeo.columbia.edu/SOURCES/.LDEO/.TRL/.NADA2004/.pdsi-atlas.html.

Another measure of bank stress would be changes in the surplus account, the account where accountants write down the value of non-performing loans. To test the usefulness of this variable we selected 18 states that we thought to be likely suspects for a significant relationship between drought and banking stress and compiled surplus and other capital accounts for all banks in the state (national, state, and private) for the period 1896 to 1955 from *All Bank Statistics* (Board of Governors of the Federal Reserve 1959). We then performed these variables on drought indexes, but found no systematic relationships.

For this reason we turned to two frequently used rates of return in the hope that they would prove to be more sensitive to climate driven bank distress: (1) bank lending rates, and (2) rates of return to bank equity. The study of regional bank lending rates derived from data on National Banks has a long history including major contributions by Lance Davis (1965), Richard Sylla (1969), Gene Smiley (1975), and John James (1976). The most recent, and in our view, best data now available are the estimates prepared by Scott Redenius (2007a). All of these studies are based on data from National Banks because these banks regularly reported information on their balance sheets and income to the Comptroller of the Currency. If National banks regularly reported their lending rates (i_L) the preparation of estimates of regional interest rates would be relatively straightforward. However, this rate has to be inferred from other information. Beginning in 1869 National Banks reported net earnings (E_N), and beginning in 1888, gross earnings (E_G). To understand the relationships between bank lending rates and rates of return to bank equity, consider the following simplified bank balance sheet.

Assets	Liabilities
Reserves (R)	Deposits (D)
Bonds (B)	Surplus (S)
Loans (L)	Capital (C)

Reserves (R) are the liquid assets of the bank: cash, deposits at other banks and financial institutions, and after 1913, deposits at the Federal Reserve. Bonds (B) are the securities owned by the bank, typically government bonds. Loans (L) includes all types of loans, often short-term loans to local businesses. Deposits (D) includes all sorts of deposits. In much of our period there was a sharp distinction between deposits subject to check and payable on demand, and longer-term savings deposits. The Surplus (S) account records the profits and losses of the bank. The Capital (C) account shows the book value of equity. This is, of course, a highly simplified balance sheet. Each category of liabilities and assets could be broken down into many subcategories, and it omits some categories, such as real estate held by banks, altogether.[3] However, it does give a simplified view of the structure of the banks in our sample, National Banks, over the period we are examining, 1869-1976.

Although we do not know bank lending rates, because they were not reported, we can approximate them after 1888 with the following expression.

$$i_L \approx (E_G - i_B{*}B - i_D{*}D)/L \qquad (2)$$

where i_B is the interest rate earned on bonds, and i_D is the interest rate paid on deposits. The idea is that if we subtract earnings on securities and payments on deposits from gross earnings we will have, approximately, the amount paid by borrowers on loans from the bank. Several elements in this

---

[3] National Banks, the source of most of our data, were not allowed to engage in mortgage lending. Their real estate holdings were limited to real estate taken as result of defaults or real estate necessary for the conduct of business (the bank building).

expression have to be estimated. The description of security holdings is usually too vague for the investigator to be sure exactly what interest (i_B) applies and only sketchy information is available on interest payments on deposits. The expression also makes no allowance for the actual costs of running the bank.

The rate of return to bank equity, which is given by the following expression, is a closely related indicator of bank stress.

$$\text{RoR} \approx (E_N)/(C+S) \quad (3)$$

This variable has several important strengths as a measure of bank stress. (1) It is available from 1869, while most other series are available from a later date. (2) It can be computed from data that were regularly reported to the Comptroller with relatively few judgment calls by the historian. (3) It reflects losses due to late payments and reductions in surplus due to the writing down the value of nonperforming loans. (4) It represents a decision variable for banks, banking authorities, and the public. At some point a bank that earns no income must be closed. Partly for these reasons we have concentrated on this variable. Scott Redenius (2007b) compiled the data we use. Professor Redenius was kind enough to share with us the state level data.[4]

Before proceeding to our empirical tests of the relationship between drought and banking stress, we will look at two cases that are well known to historians: Kansas after the Civil War and Oklahoma in the Great Depression. These examples should give us a better appreciation of the effects we can expect in extreme circumstances.

In God we trusted, in Kansas we busted

Perhaps the clearest examples of climate driven financial distress in U.S. history come from Kansas between the Civil War and 1900. This was period in which Kansas became famous for the

---

[4] Scholars who wish to use this data should contact Professor Redenius at Brandeis University.

motto, emblazoned on the covered wagons of farm families leaving Kansas, "In God we trusted, in Kansas we busted."

Chart 1 shows the reconstructed Palmer Drought Severity Index for Kansas from 1870 to 1900. The periods of drought in the post-Civil War era match up well with the periods of financial distress. The first year of severe drought after the Civil War, 1874, was the year the famous locust swarms devastated plains farmers. A second postbellum drought followed in 1879 – 1881. Four years of good rain from 1882 through 1885 helped create a land boom in western Kansas, but drought struck again in 1886 through 1888.

We have found little discussion about banking in Kansas during the first (Locust) drought. More is available, however, about the second drought. Allan G. Bogue in his classic *Money at Interest* (1955, 103-109) describes the experience of J. B. Watkins and Company a major supplier of mortgage money in western Kansas, and other mortgage bankers. When crops failed during the 1879-1881 drought farmers hoping for loans to tide them over, or to provide the basis after they defaulted for a new start somewhere else, besieged his agents. In those circumstances it was difficult to make safe loans because desperate farmers, and their friends, were willing to attest to any value for a property in order to get some cash. In the end Watkins was stuck with a large number of defaults, and for a time he stopped lending in some of the western counties. This episode, however, failed to prevent a rapid surge of development in the early 1880s when rain became abundant. Drought, however, struck again in 1886. Again Watkins responded by cutting off lending in the affected areas (Bogue 1955, 144-145). Even so, Watkins ended up holding large amounts of land as a result of mortgage foreclosures (Bogue 1955, 167).

The final drought in the nineteenth century lasted four years from 1893 through1896. This was an unusually prolonged drought. One would have to go back to the Civil War Years or forward to the 1950s to find periods in which a four-year average of the Palmer Drought Severity Index was as low as it was in the mid-1890s.[5] It was also a period of international financial distress following the Panic of 1893, and as often the case in such crises, low prices for basic agricultural products. Kansas, in other words, was hit by a perfect storm (perfect lack of storms?): insufficient rain to grow familiar crops, a enormous international financial crisis and depression, and low prices for agricultural products.

The drought and depression of the 1890s was disastrous for the financial system of Kansas. Most of the western mortgage companies, including J. B. Watkins failed (Bogue 1955, 187-192). These companies had been raising capital in the Eastern United States and in Europe, some of it with mortgage-backed securities (Snowden 1995) – not very different from those that underlay today's financial crisis. Therefore, Kansas's financial difficulties spread quickly. Once again farmers left Kansas with the motto "In God We Trusted, in Kansas we Busted" emblazoned on their "prairie schooners." The farmers who used the motto, despite the hardships they had endured, were not always done with pioneering. The *Emporia Daily Gazette*, (Emporia, KS) Monday, August 21, 1893, reported a line of prairie schooners bearing the motto “In God we trusted, in Kansas we busted. So now let ‘er rip for the Cherokee Strip.”

Chart 2, which plots National bank capital in Kansas, measured in 1890 dollars, from 1865 to 1910, shows the booms and busts.[6] Bank capital expands rapidly during the boom of the 1880s, reaches a peak in 1890, and then declines for a decade. Total capital finally surpasses the 1890 level in 1908, but even then the par value of outstanding shares was still below the 1890 level. This

---

[5] It is interesting to note that there was also a sustained drought during 1855 through 1857, the years of "bleeding Kansas."

[6] The chart in nominal terms is similar.

suggests that most of the growth after 1899 was due to reinvestment of bank profits rather than outside investment.

National bank lending rates, however, do not show a strong impact from Kansas's struggles. Chart 3 plots the bank lending rate in the Western Plains less the national average for 1888 (the first year that is available) to 1910. The great drought of the 1890s does not show up as a period of exceptionally high or low rates. There is an uptick in 1897 after the depression began to lift, but this seems to be part of a general increase in regions of new settlement: witness the uptick in rates on the Pacific coast less the national average.

The rate of return to National Bank equity in Kansas, shown in chart 4, tells a somewhat different story. Here we can see clearly the boom of the mid-1880s and then the collapse as the bubble burst, a downturn that seems to precede the national downturn. The drought of 1887 leaves a strong impact on rates of return to equity. But the effect of the drought of the mid1890s is less clear. From 1894 on, Kansas returns follow the national average.

The Comptroller of the Currency in those days assigned a reason for the failure of each national bank. Table 1 shows the 34 National banks that failed in Kansas between 1875 and 1910 and the reasons given by the Comptroller. The 1890s were the hard years. In 1890 alone, the worst year, there were 7 failures. Most of the banks that failed in 1890 and 1891 had been in operation for only a few years, they were creatures of the boom. The exception is the First National Bank of Abilene, which had been in existence for 11 years, but the average was 5 years. In the early 1890s, as in other periods, the Comptroller tended to attribute failures vaguely to injudicious banking, excessive loans to particular stakeholders, or fraud. In 1890 and 1891, however, the Comptroller mentions real estate four times. After that real estate is cited only once more, in 1896. “Stringency” in the money market, on the other hand, is not mentioned before 1893, but is given as a reason in three of the failures that occur in that year. This evidence is consistent with the picture historians have drawn of a sudden real estate boom and bust.

The most important economic reason for failure, taking the period as a whole, was “depreciation of securities,” which was mentioned in 16 cases. The nature of these "securities" is not clear from the information in the Comptroller's *Reports*. It might be possible to learn more in the archives of the Comptroller, where detailed records of the liquidation of closed National banks are available. One possibility is that they were mortgage-backed securities issued by the land companies. Holding these securities was probably not consistent with the provisions of National Banking Act prohibiting lending on real estate, but they might have held them anyway. Our guess, however, is that many of them were railroad and municipal bonds. There had been a huge railroad construction boom in Kansas in the years leading up to the debacle of the 1890s fueled by expectations of rapid expansion of agriculture (Miller 1925, 470-71).

The Dust Bowl

The dust bowl of the 1930s, another classic case of climate-driven economic distress, was most severe in Oklahoma, the Texas Panhandle, and parts of New Mexico during 1930-36. However, as shown in Chart 5, which plots a 3-year moving average of the Instrumental Palmer Drought Severity Index for Oklahoma and Texas for 1900-1975, the drought of the 1930s, although severe, was far from extraordinary. By this measure it was much less severe than the drought that hit in the 1950s. Hansen and Libecap (2004) explain that the severity of the agriculture crisis in the 1930s was due in part to the prevalence of small farms that did not engage sufficiently in practices to limit wind erosion. Nevertheless, the episode should test the extent to which severe drought challenges financial markets.

It appears that bank lending rates were somewhat higher in the dust bowl region in the period 1933-1936 than might have been expected. Rates in this region rose while lending rates in most other regions (and other interest rates generally) fell. This is evident in Chart 6, which shows the difference between the rate in the West Lower South and the national average, and a linear trend. It is clear that the differential rose above trend in the depression years.

This elevation in rates could also reflect a systemic regional risk premium. This premium, if that is the proper interpretation, began to fall in 1937, although it was the end of the decade before the West Lower South premium had returned to trend. In order to test whether the dust bowl elevation in rates was an isolated event, we ran a series of regressions of the West Lower South rate on lagged values of itself, lagged values of the national rate, and the current and lagged values of the Palmer Drought Severity Index. None of our regressions suggested a systematic relationship between the drought severity index and the bank lending rate.

Chart 7 shows rates of return on national bank equity for Oklahoma, Texas, and the United States as a whole, for the years 1920 to 1950. Somewhat surprisingly, neither the Oklahoma nor the Texas systems show a sharp negative impact as a result of the Dust Bowl. For the most part, Texas, followed the national average reflecting its more diversified economy. Oklahoma actually recovered more rapidly than the system as a whole, and posted positive returns in 1933 and 1934. Possibly the development of a regional risk premium in the lending rate served to protect National Bank earnings in Oklahoma. It appears that the banking distress that resulted from the depression and the dust bowl was concentrated among the small state banks and private banks that served rural Oklahoma, and often lost money on livestock loans (Doti and Schweikart 1991, 144), rather than the National Banks. One problem faced by rural banks, in addition to farmers who could not pay their mortgages, was a rash of bank robberies. The most notorious of all the Oklahoma bank robbers was

Charles "Pretty Boy" Floyd who by 1934 had become the FBI's "public enemy number one" (Smallwood 1979, 120-21). Oklahoma and surrounding states would face another severe drought in the 1950s. However, by then economic conditions had changed in Oklahoma. The banks had new fields in which to invest: beef production and, most important, oil (Smallwood 1959, 149-55). There seems, therefore, to have been little imprint of the drought on rates of return to equity in National banks. Nevertheless, long-term time series regressions were more "successful" in generating significant effects running from the drought index to the return on equity, than the experiments using bank loan rates. There results are reported below.

Financial distress may in turn have aggravated the economic distress in the dust bowl. It would have been more difficult, for example, for a farmer who wanted a loan to tide him over the hard times to get one, or for a farmer who wanted to borrow to expand his holdings by purchasing smaller failed farms to get the credit to do so. Conceivably, the Canadian banking system in which banks in rural areas, including drought stricken areas, were branches of large nationwide systems was better able to provide services in these areas. It is plausible that unfavorable weather conditions could place regional financial systems under stress. And possibly, during financial panics, ignite or contribute to a contagion of fear, but as our preliminary look at the dust bowl suggests, the interactions between economic and financial conditions can be complex and difficult to detect.

Econometric Analysis

We would expect there to be two possible effects of drought (or excessive rainfall) on the banking sector: a demand effect and a supply effect. (1) A demand effect would arise because drought affects the income of farmers and businesses related to farming. Low farm incomes would mean that farmers were likely to fall behind on loan repayments, which would directly reduce rates of return to equity. Drought, moreover, would lower aggregate demand in the region affected by the drought, which would lower the demand for new loans, which in turn would reduce interest rates and rates of return to equity. (2) A supply effect could arise if the drought reduced bank capital, reduced the supply of loanable funds, and increased interest rates and rates of return. If the demand effect dominates then we would expect the rate of return to be positively related to the drought index – that is, in periods of drought we would see the rate of return on bank capital declining and in periods of abundant rainfall we would see the rate of return on bank capital increasing. If the supply effect dominates we would expect to see that the rate of return on bank capital be negatively correlated with drought severity. Conceivably, the two effects could offset each other in such a way that we would fail to detect a correlation between drought and the rate of return on equity.

The aim of this analysis is to first determine if there is any relationship between drought and the rate of return on bank capital and if so what the nature of this relationship is. We also want to determine if there are systematic relationships across different regions and across time. To do this we use time series on the drought conditions (PDSI) and on the rate of return on bank capital (RoR), the variable that on the whole seems best calculated to measure the condition of the banking system. This section is broken up into three parts: (1) we first determine the underlying unit root properties of the time series we use in our regressions, (2) we then test for a relationship between the rate of return on bank capital and drought at a regional level and then (3) within each region we test for any idiosyncratic relationship between drought and rate of return on bank capital at the State level.

Unit Root Analysis Tests

Table 2 contains the τ-statistic from an augmented Dickey-Fuller test for a unit root. The null hypothesis for this test is that the time series contains a unit root and the alternative is that the time series is stationary. The number of lags used in the augmented Dickey-Fuller regression was chosen using the Schwarz-Bayesian Information Criterion (SBIC). The results below show that the unit root hypothesis can be rejected for all time series and for all states. In almost all cases the null hypothesis can be rejected at the 1% level with only a few tests resulting in a rejection of the null hypothesis at the 5% level. Given the results of the unit root tests we will treat each time series as a stationary time series so that each series on drought severity and the rate of return on bank capital will enter into our regression equations in levels.

Effects of Drought on Rates of Return at the Regional Level

The first set of regressions that we run are regressions at the regional level. We use regional classifications of Redenius (2000a) which are given in Table 3 below. For each region we estimate an autoregressive distributed lag (ARDL) model with the average rate of return on bank capital as the dependent variable and the drought severity index as the explanatory variable. The ARDL(p,q) model is defined as

$$RoR_t = \beta_0 + \sum_{j=0}^{q} \beta_j PDSI_{t-j} + \sum_{k=1}^{p} \theta_k RoR_{t-k} + \varepsilon_t , \tag{4}$$

where the values of *p* and *q* are determined by minimizing SBIC. Equation (4) is estimated for each version of the drought severity index and for different time periods. Using instrumental PDSI we are constrained to using data from 1900 until 1976 (the last date is due to the limitation of the rate of return to bank capital data). We report results for this period and for two sub-periods: (1) 1900-1945 and (2) 1945-1976 to check whether there are any changes in the impact of drought on rates of return over time. Using the reconstructed PDSI (obtained from tree ring data) we are able to use all of the data that we have on rates of return on bank capital so that our sample period runs from the

1870s until 1976. For the reconstructed PDSI data we break our sample into three time periods: (1) 1870-1910, (2) 1910-1945, and (3) 1945-1976. The results for each version of PDSI and for each time period are shown in tables 4a-4j.

The most striking feature of the results is that for seven of the ten regions there was no systematic relationship between the average rate of return on bank capital and drought severity. The three regions where there are significant relationships are the *Upper South*, the *Old Northwest* and the *Eastern Plains*. The coefficient on the drought severity index for these three regions are significant and positive suggesting that we are picking up the demand effect of drought on the rate of return to bank capital. We also see that the effect of drought is not constant over time. For the *Old Northwest* and the *Eastern Plains* it appears that there was a significant relationship for the first half of the 20th Century.

When we use the reconstructed drought severity index we see similar results in that only in the *Old Northwest* and *Eastern Plains* were there significant effects and again we see that this significant effect appears to be a demand effect and limited to the early part of the 20th Century. Good growing conditions would increase bank earnings in a number of ways: delinquent loans might be brought up to date or liquidated, and the demand for loans to increase working capital might increase. One of the new and highly profitable sources of bank profits in the 1920s through the 1940s was loans for the purchase of consumer durables such as automobiles, washing machines, and so on. It is possible that favorable conditions in agriculture produced an increase in the demand for this sort of loan in the first half of the twentieth century of sufficient magnitude to make an impression on rates of return to equity.

Intra-Regional Differences in Rates of Return using Drought Severity

The regression that was reported in the previous section, when there was indeed an effect, picked up a positive relationship between regional averages of rates of return on bank capital and regional averages of drought severity indexes. In this section we try to detect any evidence that drought had an impact on the rate of return on bank capital (the supply effect) by analyzing the effect that drought severity has on the State's rate of return on bank capital after conditioning for the regional rate of return on bank capital. The model that estimated was

$$(5) \qquad RoR_t = \beta_0 + \alpha_1 RoR\_AV_t + \sum_{j=0}^{q} \beta_j PDSI_{t-j} + \sum_{k=1}^{p} \theta_k RoR_{t-k} + \varepsilon_t ,$$

where *ROR_AV* is the average rate of return on bank capital for the region in which the State is a member. Hopefully, conditioning on regional averages will hold constant macroeconomic trends and shocks. Again the number of lags of the drought severity index and the number of lags of the lagged dependent variable were chosen to minimize the Schwarz Bayesian Information Criterion.

Tables 5a and 5b report the coefficients from (5) for the drought severity indexes for states. If lags of the PDSI are included in the regression then the coefficients for all lags are reported. The results for our two classic examples of climate-driven banking stress – Kansas after the Civil War and Oklahoma in the dustbowl – are interesting. With the reconstructed drought index we can look at the period 1871 to 1910 in Kansas. Here the coefficient is negative and not statistically significant. The size of the coefficient, which indicates an effect of 15 basis points for a one-unit change in the drought index, suggests that the effect was not economically significant. Our intuition is that a movement of at least 25 basis points in response to a one-unit change in the drought index would be needed to count as an economically significant response. Partly, this result for Kansas stems from the inclusion in our sample of a number of years after the turn of the century in which there was a severe drought, but relatively little stress in the Kansas banking system. The coefficient on the instrumental measure of drought in Kansas is negative, but not significant, for the period 1900-1945, and positive, and statistically significant for the period 1945 to 1976. Neither coefficient, however, is economically significant: a one-unit change in the drought index would change the rate of return by less than 10 basis points. Evidently the Kansas troubles, as wrenching as they were, were of limited impact from a longer-term perspective.

A similar story applies to Oklahoma. Here the coefficient for the years 1910-1945 using the instrumental drought index, is negative, and the coefficient is economically significant, 47 basis points for a one-unit change in the drought index. The coefficient for a similar period using the reconstructed drought index is 39 basis points. The negative coefficient is consistent with our qualitative analysis which showed National banks in Oklahoma doing relatively well in terms of rates of return to equity during the era of the dust bowl. The coefficient for the postwar era, a period that includes another bout of severe drought, however, is positive. The coefficient is statistically significant at the ten percent level when the instrumental drought index is used, but not statistically significant when the reconstructed drought index is used. Neither coefficient can be judged economically significant. Again it is clear that the Oklahoma economy and banking system had moved on and was not vulnerable to climatic stress.

Our systematic investigation of the data points to several other cases, for example Wisconsin and Louisiana in the interwar years, and Mississippi in the postwar era, in which the coefficient meets our dual criteria of statistical significance (the 10 percent level) and economic significance (25 basis points). On closer examination these may well turn out to be cases of climate-driven banking stress. However, on the whole, our evidence suggests that climate-driven financial distress was a rare event. Only six states including Oklahoma have coefficients estimated for the interwar period that meets our criteria. And only one state in the postwar era, Mississippi, meets our criteria. The reconstructed drought index allows us to look at the period 1871 to 1910. Here we can identify only four cases that meet our criteria. Evidently, drought could produce distress in the banking system, but required a concatenation of damaging events.

Conclusions and Conjectures

Has drought or excessive rainfall produced distress in the U.S. banking system? In some cases it has. There are some well-known examples that we explored in detail, Kansas after the Civil War and Oklahoma during the dustbowl. Our econometric sifting of the data, moreover, revealed several other cases that have received less attention, which may on closer examination turn out to be cases of climate-driven financial distress. On the whole, however, climatic distress has not left a strong imprint on the banking system. In most states and regions we find no systematic relationship between climatic stress measured by drought indexes and banking stress measured by the rate of return on bank equity. A combination of climatic and macroeconomic disturbances may have staggered a state or regional banking system for a time, but eventually institutions adapted. Farmers began to grow new crops, turned to grazing, or simply moved on to other activities or other places. Bankers learned to finance less vulnerable sectors of the economy.

The few cases in American economic history in which drought seems to have had an impact may have more implications for the future, however, as global warming begins to take a larger toll, than for the past. One implication may be that large branch banking systems are better able to sustain localized drought induced economic stress than smaller systems. This consideration argues against recent calls for breaking up large banks on the grounds that it would be easier to avoid the adverse incentive effects of "too big to fail." The argument is that when banks know they are too big too fail they take excessive risks. However, big banks that branch across regions, as the larger American banks now do, or as the Canadian banks did throughout their history, may be better able to offset temporary regional losses resulting from climate change with surpluses earned in other regions.

The American states, in the period we are examining, resembled small open economies. They were linked by fixed exchange rates and free trade. Capital flowed freely in and out. However, each had its own banking system. An adverse climatic event, if piled on top of a general economic depression, had the potential to create severe stress within the local banking system. The creation of the Federal Reserve, which could produce high-powered money acceptable in all states, ameliorated the problem. Branch banking that linked the banks in vulnerable states to larger national systems also contributed to breaking the relationship between climatic stresses and banking market stress. Perhaps there is a lesson here for small open economies that will become vulnerable to drought as climates change.

Table 1. National Bank Failures in Kansas, 1875-1910

Bank	Failure	Organized	Capital	Reason for Failure
FNB Wichita	1876	1872	50,000	Defalcation of Officers and Fraudulent Management
Merchants NB, Fort Scott	1878	1872	50,000	Investments in Real Estate and Mortgages and Depreciation of Securities
FNB Abilene	1890	1879	50,000	Excessive loans to others, injudicious Banking, and depreciation of securities
State NB, Wellington	1890	1886	50,000	Injudicious banking and failure of large debtors
Kingman NB	1890	1886	75,000	Investments in real estate and mortgages and depreciation of securities
FNB Alma	1890	1887	50,000	Excessive loans to officers and directors and investments in real estate and mortgages
FNB Belleville	1890	1885	50,000	Excessive loans to officers and directors and depreciation of securities
FNB Meade Center	1890	1887	50,000	Injudicious banking and depreciation of securities
American NB, Arkansas City	1890	1889	100,000	Excessive Loans to Officers and directors and depreciation of securities
FNB Ellsworth Kansas	1891	1884	50,000	Excessive loans to others, injudicious Banking, and depreciation of securities
SNB McPherson Kansas	1891	1887	50,000	Fraudulent management and injudicious banking
Pratt County NB	1891	1887	50,000	Excessive Loans to Officers and directors and investments in real estates and mortgages
FNB Kansas City	1891	1887	100,000	Excessive loans to officers and directors and depreciation of securities
FNB, Coldwater Kansas	1891	1887	52,000	Excessive loans to officers and directors and investments in real estates and mortgages
FNB, Downs Kansas	1892	1886	50,000	Injudicious banking and depreciation of securities
Cherryvale NB	1892	1890	50,000	Fraudulent management, excessive loans to officers and directors, and depreciation of securities
FNB, Erie	1892	1889	50,000	Injudicious banking and depreciation of securities
Newton NB	1893	1885	65,000	General stringency of the money market, shrinkage in values, and imprudent methods of banking
FNB, Arkansas City[a]	1893	1885	50,000	Excessive loans to officers and directors and depreciation of securities
FNB, Marion	1893	1883	75,000	General stringency of the money market, shrinkage in values, and imprudent methods of banking
Hutchison NB	1893	1884	50,000	General stringency of the money market, shrinkage in values, and imprudent methods of banking
State NB, Wichita	1894	1886	52,000	Excessive loans to others, injudicious banking, and depreciation of securities
Wichita NB	1894	1882	50,000	Depreciation of securities
FNB Wellington	1895	1883	50,000	Injudicious banking and depreciation of securities
Humbolt FNB	1896	1887	60,000	Injudicious banking and failure of large debtors

Sumner NB, Wellington	1896	1888	75,000	Investments in real estate and mortgages and depreciation of securities
FNB, Larned	1896	1882	50,000	Injudicious banking
FNB Garnett	1896	1883	50,000	General stringency of the money market, shrinkage in values, and imprudent methods of banking
NB of Paola	1898	1887	100,000	Injudicious banking and failure of large debtors
FNB Emporia	1898	1872	50,000	Fraudulent management
Atchison NB	1899	1873	70,000	Excessive loans to others, injudicious banking, and depreciation of securities
FNB McPherson[b]	1899	1886	50,000	Failure of large debtors
FNB Topeka	1905	1882	50,000	Failure of large debtors
FNB Fort Scott	1908	1871	50,000	Fraudulent management and injudicious banking

Notes: FNB stands for First National Bank. The location of the bank is shown when it is not part of the name of the bank.

[a] Temporarily restored to solvency before finally failing in 1899
[b] In voluntary liquidation, prior to failure

Source: *Annual Report Comptroller of the Currency 1910*, Table 44.

Table 2: Unit Root test statistics for Drought and Rate of Return Data

State	PDSI (Instrumental)	PDSI (Tree Ring)	Rate of Return
Alabama	-9.15[a]	-10.64[a]	-3.52[a]
Arkansas	-8.45[a]	-10.08[a]	-3.97[a]
Arizona	-7.45[a]	-5.67[a]	-2.38[b]
California	-3.88[a]	-10.97[a]	-3.39[a]
Colorado	-4.01[a]	-5.56[a]	-4.59[a]
Florida	-9.76[a]	-8.10[a]	-4.68[a]
Georgia	-5.25[a]	-7.82[a]	-4.64[a]
Iowa	-7.35[a]	-8.41[a]	-3.48[a]
Idaho	-5.95[a]	-6.94[a]	-3.24[a]
Illinois	-8.17[a]	-9.71[a]	-5.31[a]
Indiana	-7.97[a]	-10.05[a]	-3.47[a]
Kansas	-4.72[a]	-5.69[a]	-3.53[a]
Kentucky	-8.08[a]	-10.32[a]	-3.11[a]
Louisiana	-8.93[a]	-10.29[a]	-5.15[a]
Massachusetts	-5.87[a]	-9.63[a]	-3.39[a]
Maryland	-4.82[a]	-5.43[a]	-2.60[b]
Maine	-5.75[a]	-9.48[a]	-3.24[a]
Michigan	-7.38[a]	-8.13[a]	-3.81[a]
Minnesota	-4.26[a]	-5.35[a]	-2.91[a]
Missouri	-8.13[a]	-9.21[a]	-4.87[a]
Mississippi	-8.23[a]	-9.97[a]	-3.10[a]
Montana	-4.70[a]	-5.41[a]	-3.70[a]
North Carolina	-4.95[a]	-11.78[a]	-3.68[a]
North Dakota	-4.15[a]	-4.28[a]	-3.02[a]
Nebraska	-4.52[a]	-5.18[a]	-2.94[a]

New Mexico	-7.73 [a]	-5.74[a]	-4.17 [a]
Nevada	-5.94[a]	-7.24[a]	-3.08 [a]
New York	-5.96[a]	-6.41[a]	-4.17 [a]
Ohio	-8.02[a]	-10.04[a]	-3.21 [a]
Oklahoma	-5.12[a]	-7.18[a]	-3.49 [a]
Oregon	-5.82[a]	-7.36[a]	-4.07 [a]
Pennsylvania	-6.40[a]	-10.30[a]	-2.99 [a]
South Carolina	-5.06[a]	-7.81[a]	-4.41 [a]
South Dakota	-4.16[a]	-4.45[a]	-2.79 [a]
Tennessee	-8.29[a]	-9.93[a]	-3.89 [a]
Texas	-6.35[a]	-6.86[a]	-3.98 [a]
Utah	-4.94[a]	-5.82[a]	-6.12 [a]
Virginia	-5.35[a]	-11.37[a]	-3.57 [a]
Vermont	-4.86[a]	-6.36[a]	-3.68 [a]
Washington	-5.98[a]	-7.63[a]	-4.01 [a]
Wisconsin	-7.51[a]	-8.56[a]	-4.52 [a]
Wyoming	-4.41[a]	-5.31[a]	-4.71 [a]

Table 3: Regional Classifications

New England	*Mid-Atlantic*	*E. Lower South*	*Old Northwest*	*Upper South*
Massachusetts	Maryland	Alabama	Illinois	Kentucky
Maine	New York	Florida	Indiana	North Carolina
Vermont	Pennsylvania	Georgia	Michigan	Tennessee
		South Carolina	Ohio	Virginia
			Wisconsin	
East. Plains	*W. Plains*	*W. Lower South*	*Mountain*	*Pacific*
Minnesota	Kansas	Arkansas	Arizona	California
Iowa	Nebraska	Louisiana	Colorado	Oregon
Missouri	North Dakota	Mississippi	Idaho	Washington
	South Dakota	Oklahoma	Montana	
		Texas	New Mexico	
			Nevada	
			Utah	
			Wyoming	

Table 4a: Regional Regression Results: New England

Instrumental PDSI (p=2,q=0)

Coefficient	Full Sample	1900-1945	1945-1976
Constant	1.593	1.503	1.111
	(0.007)	(0.066)	(0.226)
PDSI_average	0.195	0.321	0.056
	(0.455)	(0.523)	(0.744)

Reconstructed PDSI (p=2,q=0)

Coefficient	Full Sample (1872-1976)	1872-1910	1910-1945	1945-1976
Constant	1.526	1.385	1.505	1.590
	(0.000)	(0.018)	(0.076)	(0.095)
PDSI_average	0.149	-0.063	0.382	0.228
	(0.351)	(0.576)	(0.476)	(0.170)

Notes: numbers in parentheses are p-values, coefficients on lagged dependent variables not reported

Table 4b: Regional Regression Results: Mid Atlantic

Instrumental PDSI (p=2,q=0)

Coefficient	Full Sample	1900-1945	1945-1976
Constant	2.030	2.237	1.029
	(0.001)	(0.008)	(0.345)
PDSI_average	0.231	0.383	0.094
	(0.264)	(0.311)	(0.604)

Reconstructed PDSI (p=2,q=0)

Coefficient	Full Sample (1872-1976)	1872-1910	1910-1945	1945-1976
Constant	1.924	2.490	2.142	1.038
	(0.000)	(0.013)	(0.013)	(0.376)
PDSI_average	0.088	-0.050	0.257	0.081
	(0.522)	(0.716)	(0.482)	(0.689)

Notes: numbers in parentheses are p-values, coefficients on lagged dependent variables not reported

Table 4c: Regional Regression Results: Eastern Lower South

Instrumental PDSI (p=1,q=0)

Coefficient	Full Sample	1900-1945	1945-1976
Constant	2.852	2.581	4.001
	(0.002)	(0.048)	(0.006)
PDSI_average	0.523	0.538	0.228
	(0.202)	(0.451)	(0.386)

Reconstructed PDSI (p=1,q=0)

Coefficient	Full Sample (1872-1976)	1872-1910	1910-1945	1945-1976
Constant	2.804	2.527	2.381	4.931
	(0.000)	(0.071)	(0.077)	(0.005)
PDSI_average	0.124	-0.134	0.047	0.232
	(0.663)	(0.682)	(0.951)	(0.361)

Notes: numbers in parentheses are p-values, coefficients on lagged dependent variables not reported

Table 4d: Regional Regression Results: Old Northwest

Instrumental PDSI (p=2,q=0)

Coefficient	Full Sample	1900-1945	1945-1976
Constant	2.497	2.603	2.950
	(0.000)	(0.005)	(0.006)
PDSI_average	**0.479**	**0.705**	0.095
	(0.033)	**(0.048)**	(0.641)

Reconstructed PDSI (p=2,q=0)

Coefficient	Full Sample (1872-1976)	1872-1910	1910-1945	1945-1976
Constant	2.180	2.267	2.441	2.882
	(0.000)	(0.015)	(0.007)	(0.089)
PDSI_average	0.204	-0.094	**0.794**	0.073
	(0.154)	(0.488)	**(0.039)**	(0.703)

Notes: numbers in parentheses are p-values, coefficients on lagged dependent variables not reported

Table 4e: Regional Regression Results: Upper South

Instrumental PDSI (p=2,q=0)

Coefficient	Full Sample	1900-1945	1945-1976
Constant	2.162	2.264	2.690
	(0.001)	(0.013)	(0.035)
PDSI_average	**0.361**	0.472	0.110
	(0.060)	(0.146)	(0.445)

Reconstructed PDSI (p=2,q=0)

Coefficient	Full Sample (1872-1976)	1872-1910	1910-1945	1945-1976
Constant	2.054	2.126	2.222	2.639
	(0.000)	(0.024)	(0.019)	(0.040)
PDSI_average	0.215	0.032	0.467	0.104
	(0.115)	(0.842)	(0.199)	(0.508)

Notes: numbers in parentheses are p-values, coefficients on lagged dependent variables not reported

Table 4f: Regional Regression Results: East Plains

Instrumental PDSI (p=2,q=0)

Coefficient	Full Sample	1900-1945	1945-1976
Constant	3.058	3.324	3.083
	(0.000)	(0.001)	(0.067)
PDSI_average	**0.655**	**0.872**	0.070
	(0.002)	**(0.007)**	(0.700)

Reconstructed PDSI (p=2,q=0)

Coefficient	Full Sample (1872-1976)	1872-1910	1910-1945	1945-1976
Constant	2.502	1.742	2.901	3.511
	(0.000)	(0.053)	(0.006)	(0.038)
PDSI_average	**0.301**	-0.081	**0.833**	0.182
	(0.040)	(0.582)	**(0.034)**	(0.248)

Notes: numbers in parentheses are p-values, coefficients on lagged dependent variables not reported

Table 4g: Regional Regression Results: West Plains

Instrumental PDSI (p=2,q=0)				
Coefficient	Full Sample	1900-1945	1945-1976	
Constant	1.539	1.542	3.815	
	(0.029)	(0.107)	(0.036)	
PDSI_average	0.253	0.451	-0.074	
	(0.209)	(0.168)	(0.568)	
Reconstructed PDSI (p=2,q=0)				
Coefficient	Full Sample (1872-1976)	1872-1910	1910-1945	1945-1976
Constant	1.547	1.640	1.435	4.521
	(0.011)	(0.259)	(0.141)	(0.020)
PDSI_average	0.257	0.291	0.463	0.132
	(0.145)	(0.417)	(0.247)	(0.318)

Notes: numbers in parentheses are p-values, coefficients on lagged dependent variables not reported

Table 4h: Regional Regression Results: Western Lower South

Instrumental PDSI (p=2,q=0)				
Coefficient	Full Sample	1900-1945	1945-1976	
Constant	2.565	2.665	1.804	
	(0.000)	(0.013)	(0.165)	
PDSI_average	0.215	0.267	0.126	
	(0.250)	(0.424)	(0.323)	
Reconstructed PDSI (p=2,q=0)				
Coefficient	Full Sample (1872-1976)	1872-1910	1910-1945	1945-1976
Constant	2.430	2.356	2.502	2.199
	(0.000)	(0.319)	(0.016)	(0.085)
PDSI_average	0.153	-0.130	0.184	**0.184**
	(0.324)	(0.734)	(0.613)	**(0.090)**

Notes: numbers in parentheses are p-values, coefficients on lagged dependent variables not reported

Table 4i: Regional Regression Results: Mountain

Instrumental PDSI (p=2,q=0)				
Coefficient	Full Sample	1900-1945	1945-1976	
Constant	2.407	2.304	6.074	
	(0.005)	(0.021)	(0.025)	
PDSI_average	-0.359	-0.265	-0.343	
	(0.196)	(0.540)	(0.204)	
Reconstructed PDSI (p=2,q=0)				
Coefficient	Full Sample (1872-1976)	1872-1910	1910-1945	1945-1976
Constant	2.300	2.150	2.273	5.455
	(0.002)	(0.181)	(0.029)	(0.048)
PDSI_average	-0.187	0.364	-0.283	-0.321
	(0.372)	(0.311)	(0.541)	(0.169)

Notes: numbers in parentheses are p-values, coefficients on lagged dependent variables not reported

Table 4j: Regional Regression Results: Pacific

Instrumental PDSI (p=2,q=0)				
Coefficient	Full Sample	1900-1945	1945-1976	
Constant	2.961	3.454	3.587	
	(0.001)	(0.009)	(0.010)	
PDSI_average	0.071	0.287	-0.191	
	(0.731)	(0.402)	(0.142)	
Reconstructed PDSI (p=2,q=0)				
Coefficient	Full Sample (1872-1976)	1872-1910	1910-1945	1945-1976
Constant	2.517	1.789	3.776	3.965
	(0.148)	(0.148)	(0.006)	(0.005)
PDSI_average	0.075	-0.270	0.458	-0.134
	(0.640)	(0.373)	(0.169)	(0.268)

Notes: numbers in parentheses are p-values, coefficients on lagged dependent variables not reported

Table 5a: Impact of Drought Severity on State Rates of Return : Instrumental PDSI

State	(p,q)	Full Sample	1900-1945	1945-1976
New England				
Massachusetts	(1,2)	0.01	0.16	-0.18
		0.09	0.16	0.09
		-0.36***	-0.24	-0.24**
Maine	(0,0)	0.12	1.13	0.13
Vermont	(0,0)	0.09	-0.01	0.29**
Mid Atlantic				
Maryland	(1,0)	0.03	0.11	0.16
New York	(0,0)	0.00	0.22	-0.13
Pennsylvania	(1,0)	0.02	0.03	0.03
Upper South				
Kentucky	(1,0)	0.08	0.04	0.02
North Carolina	(0,0)	-0.08	-0.04	-0.06
Tennessee	(0,0)	-0.16	-0.04	-0.30
Virginia	(1,0)	0.01	-0.01	0.05
East Lower South				
Alabama	(2,0)	0.20*	0.25	0.06
Florida	(2,0)	0.42	0.92*	-0.07
Georgia	(0,0)	0.19	0.26	-0.15
South Carolina	(0,0)	-0.19	0.00	0.12
Old North West				
Illinois	(0,0)	0.16	0.26	0.11
Indiana	(2,0)	0.18*	0.17	0.06
Michigan	(2,0)	-0.08	-0.00	-0.22
Ohio	(1,0)	0.07	0.05	0.05
Wisconsin	(1,0)	-0.46***	-0.56**	-0.26
East Plains				
Iowa	(2,2)	-0.03	-0.09	0.02
		-0.12	-0.22	0.16***
		-0.26***	-0.38**	-0.07
Minnesota	(0,0)	0.03	0.08	0.00
Missouri	(0,2)	0.19*	0.24	0.15*
		0.09	0.18	-0.08
		0.38***	0.47***	0.20**
West Plains				
Kansas	(0,0)	-0.02	-0.09	0.08*
North Dakota	(2,0)	-0.05	0.10	-0.19**
Nebraska	(1,0)	-0.10	-0.14*	-0.06
South Dakota	(0,0)	0.04	0.02	0.06
West Lower South				
Arkansas	(1,0)	0.10	0.10	0.04
Louisiana	(0,2)	-0.13	-0.20	-0.07
		-0.03	-0.05	0.10
		-0.45***	-0.63***	-0.20

Mississippi	(1,0)	-0.14	-0.02	-0.33***
Oklahoma	(1,0)	-0.22*	-0.47**	0.10*
Texas	(0,0)	0.01	-0.07	0.10*
Mountain				
Arizona	(0,0)	-0.21	-0.51	-0.14
Colorado	(0,0)	0.18	0.39	-0.15
Idaho	(1,0)	0.28	0.38	0.15
Montana	(1,0)	0.24	0.58**	-0.31
New Mexico	(0,0)	0.11	0.07	0.03
Nevada	(2,0)	-0.43*	-0.62	-0.29
Utah	(0,1)	-0.13	0.06	0.05
		-0.38***	-0.46**	-0.12
Wyoming	(1,0)	-0.10	-0.16	-0.02
Pacific				
California	(1,0)	-0.08	0.05	-0.13
Oregon	(2,1)	-0.10	-0.16	0.03
		0.25**	0.46**	0.14
Washington	(0,0)	-0.10	0.06	-0.09

Notes: * sig at 10% level, ** sig at 5% level, *** sig at 1% level

Table 5b: Impact of Drought Severity on State Rates of Return : Reconstructed PDSI

State	(p,q)	Full Sample	1871-1910	1910-1945	1945-1976
New England					
Massachusetts	(1,0)	-0.04	0.012	0.05	-0.47*
Maine	(0,0)	0.18**	0.01	0.43**	0.05
Vermont	(2,0)	-0.09	0.05	-0.53	0.09
Mid Atlantic					
Maryland	(2,0)	-0.03	-0.05	-0.02	0.20
New York	(1,0)	-0.02	0.24*	-0.23	-0.11
Pennsylvania	(1,0)	-0.02	-0.01	-0.17	0.08
Upper South					
Kentucky	(1,0)	0.04	-0.06	0.02	0.02
North Carolina	(0,0)	-0.02	0.15	-0.01	-0.04
Tennessee	(0,0)	-0.04	0.10	0.01	-0.20
Virginia	(1,0)	-0.03	-0.06	-0.02	0.13
East Lower South					
Alabama	(1,0)	-0.02	-0.69	0.23	0.21
Florida	(1,0)	-0.27	-0.21	-0.65	0.02
Georgia	(1,0)	0.13	0.14	0.23	-0.28*
South Carolina	(0,0)	-0.15	0.26	0.47	-0.13
Old NorthWest					
Illinois	(0,0)	0.13	0.18**	0.13	0.11
Indiana	(2,0)	0.13*	0.01	0.26	0.05
Michigan	(1,0)	-0.20	-0.26***	-0.13	-0.18
Ohio	(1,0)	0.03	-0.08	0.03	0.11
Wisconsin	(2,0)	-0.09	0.14*	-0.39	-0.15
East Plains					
Iowa	(1,0)	0.05	-0.01	0.01	0.07
Minnesota	(1,0)	-0.04	-0.20*	0.38**	-0.06
Missouri	(0,0)	0.01	-0.05	0.05	0.11
West Plains					
Kansas	(1,0)	-0.03	-0.15	-0.06	0.08
North Dakota	(1,0)	0.12	0.42	0.30**	-0.24***
Nebraska	(0,0)	0.13*	0.31*	-0.09	-0.01
South Dakota	(1,1)	0.02	-0.01	0.02	0.07
		-0.19**	-0.36	-0.14	-0.03
West Lower South					
Arkansas	(1,0)	0.03	-0.24	0.19	0.07
Louisiana	(0,0)	0.20	0.43*	0.16	-0.08
Mississippi	(1,0)	-0.16	-0.48*	0.03	-0.15
Oklahoma	(1,0)	-0.18	-0.32	-0.39*	0.06
Texas	(1,0)	0.02	-0.03	0.01	0.04

Mountain					
Arizona	(1,0)	-0.38	0.10	-1.12	-0.16
Colorado	(1,0)	-0.07	-0.18	0.28	-0.24*
Idaho	(0,0)	-0.07	-0.15	0.06	-0.16
Montana	(1,0)	0.42**	0.67*	0.86***	-0.45
New Mexico	(1,0)	0.14	0.10	0.30	0.03
Nevada	(1,0)	-0.40	-1.06	-0.62	-0.09
Utah	(0,0)	-0.23	-0.27	-0.07	0.02
Wyoming	(1,0)	-0.03	-0.08	-0.02	-0.13
Pacific					
California	(1,0)	-0.16**	-0.11	-0.03	-0.17**
Oregon	(1,0)	-0.15	-0.03	-0.17	0.05
Washington	(0,0)	0.00	0.33	-0.01	-0.05

Notes: * sig at 10% level, ** sig at 5% level, *** sig at 1% level

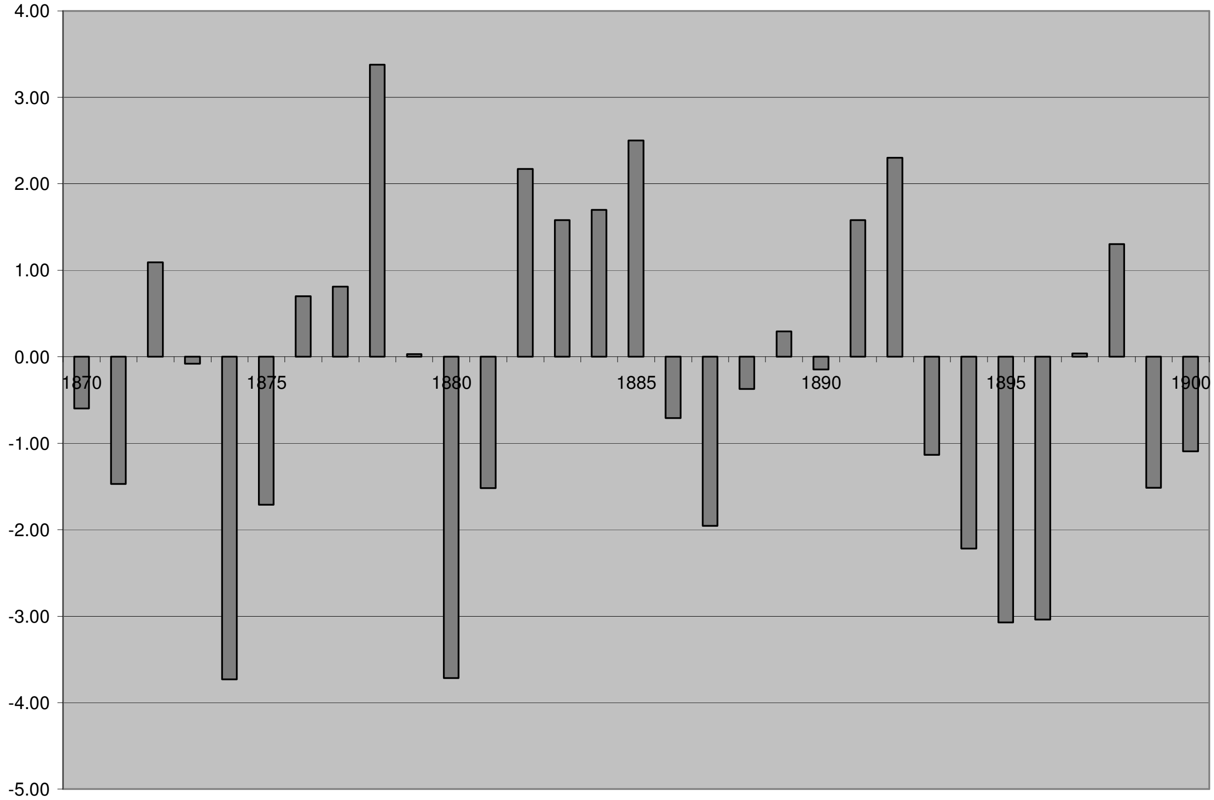

Chart 1. The Reconstructed Drought Severity Index For Kansas, 1870-1900

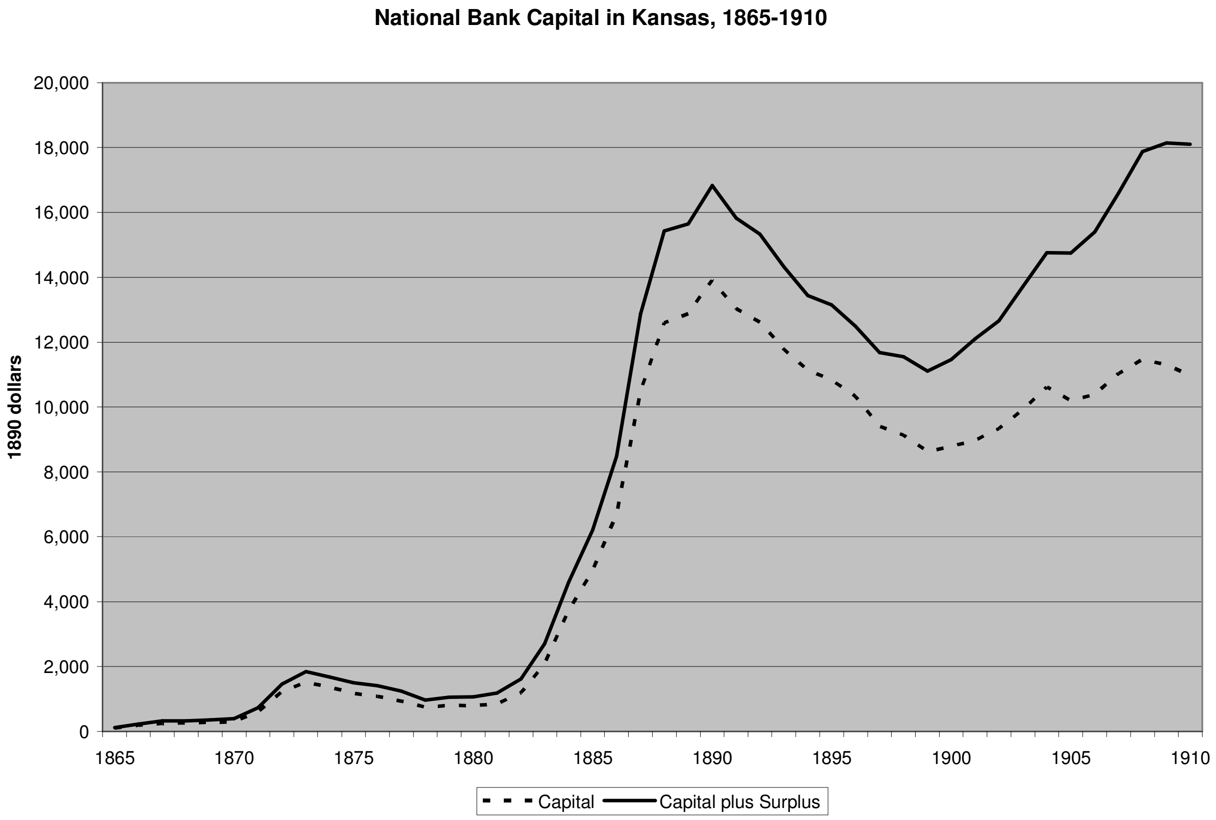

Chart 2. National Bank Capital in Kansas, 1865-1910

Source. Comptroller of the Currency, *Annual Reports*.

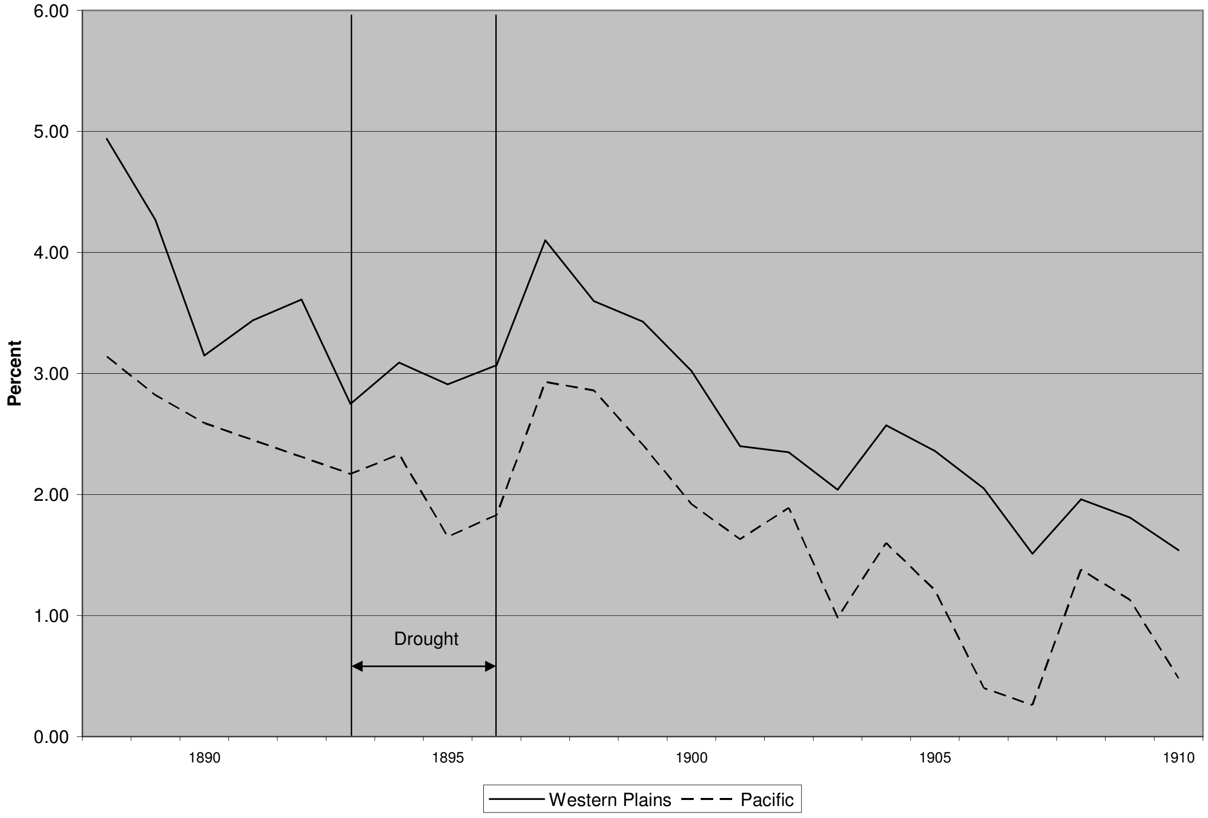

Chart 3. Bank lending rates in excess of the national average, Western plains and the Pacific, 1888-1910.

Source: Redenius (2007a).

Chart 4. The Rate of Return to Equity in National Banks in Kansas, 1869-1910.

Source: Scott Redenius, see text.

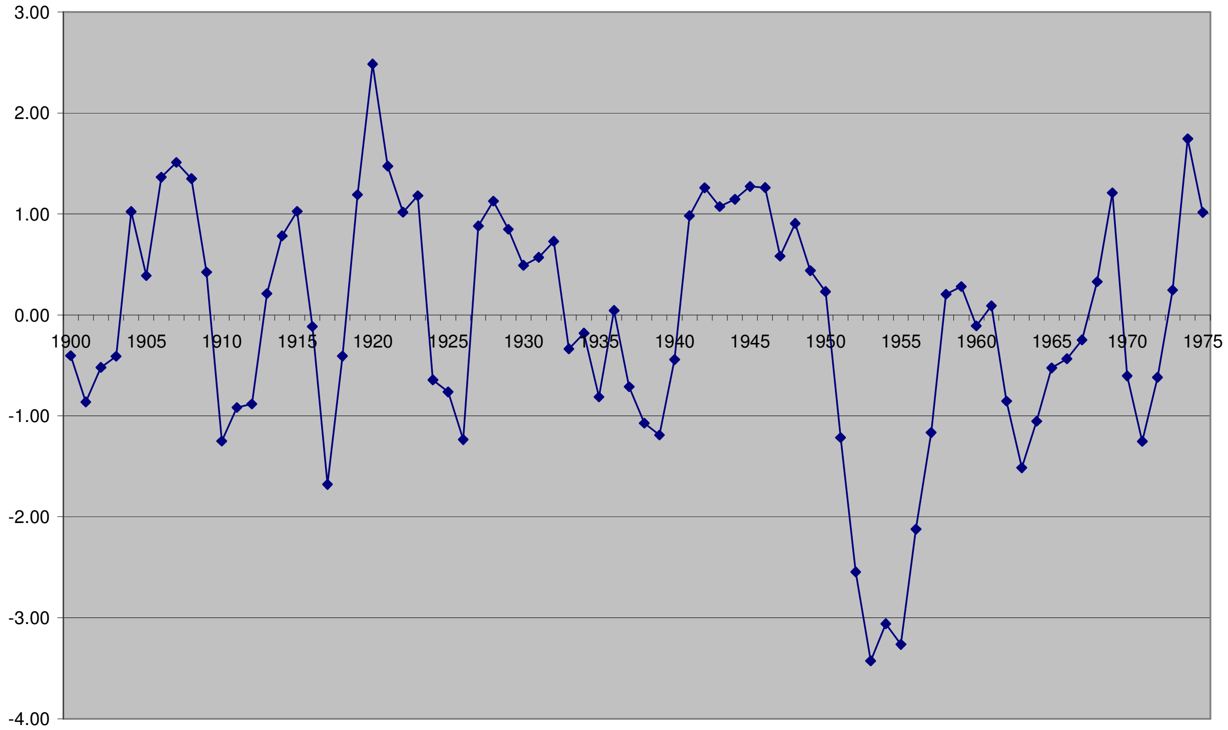

Chart 5. The Palmer Drought Severity Index for Texas and Oklahoma, 3-Year Moving Average, 1900-1975.

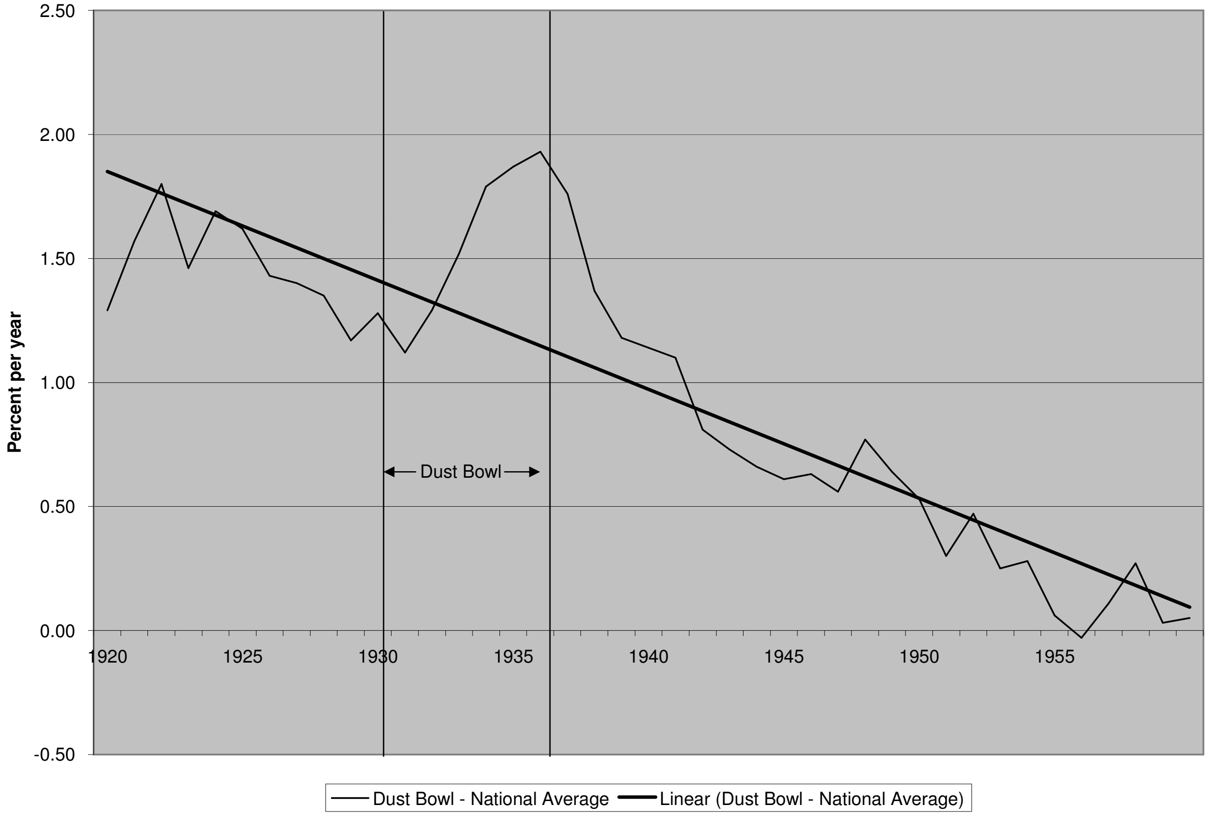

Chart 6. Bank lending rate in excess of the national average, West Lower South (Dust Bowl), 1920-1959.

Source. (Redenius 2007a).

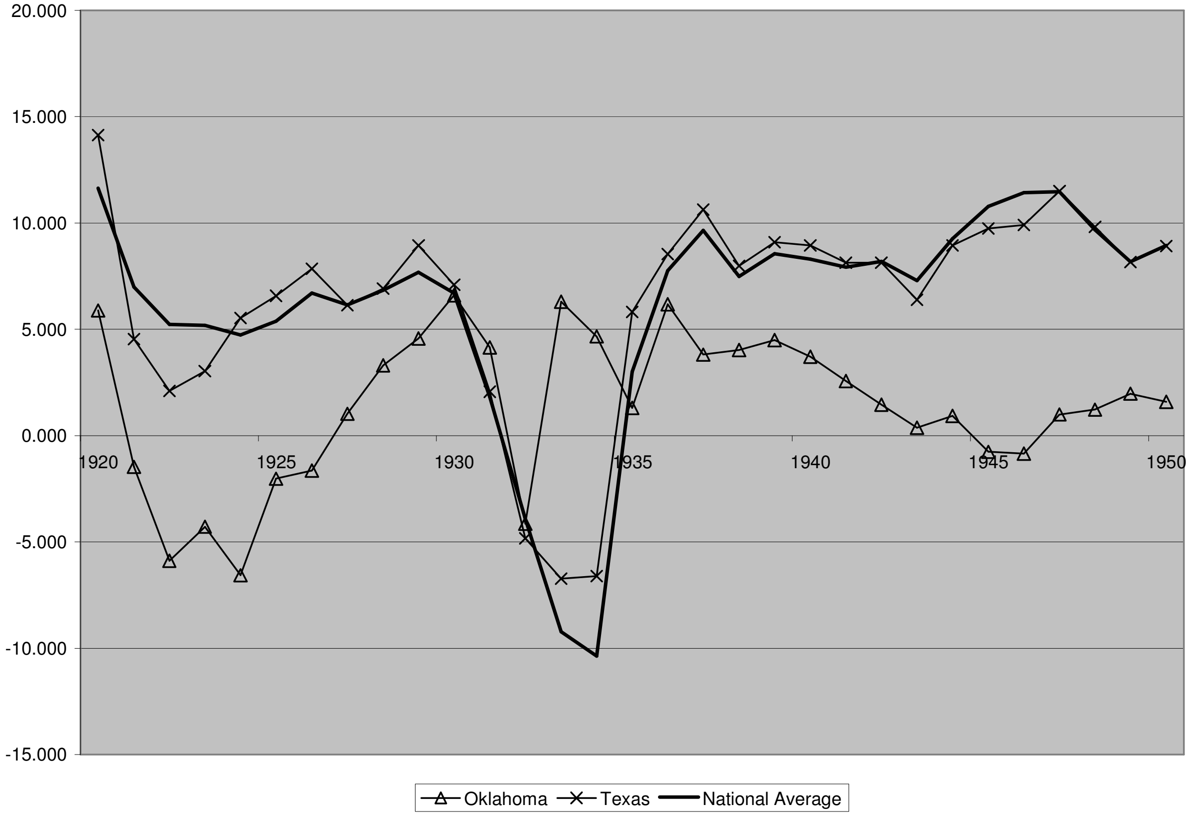

Chart 7. Rates of return on equity in National Banks, Oklahoma, Texas, and the National Average, 1920-1950.

Source: Scott Redenius, see text

References

Alley, William. 1984. The Palmer Drought Severity Index: Limitations and Assumptions. Journal of Applied Meterology. 23 (1984): 1100-09.

Andrew, A. Piatt. 1906. The influence of the crops upon business in America. *The Quarterly Journal of Economics* 20, (3) (May): 323-52.

Board of Governors of the Federal Reserve System (U.S.). 1959. *All-bank statistics, United States, 1896-1955*. Washington: .

Bogart, Ernest Ludlow. 1930. *Economic history of the American people*. New York, London etc.: Longmans, Green and Co.

Bogue, Allan G. 1969; 1955. *Money at interest: The farm mortgage on the middle border*. Lincoln: University of Nebraska Press.

Bordo, Michael D., Hugh Rockoff, and Angela Redish. 1994. The U.S. banking system from a northern exposure: Stability versus efficiency. *The Journal of Economic History* 54, (2, Papers Presented at the Fifty-Third Annual Meeting of the Economic History Association) (Jun.): 325-41.

Calomiris, Charles W. 2000. *U.S. bank deregulation in historical perspective*. Cambridge, UK ; New York: Cambridge University Press.

Carlson, Mark, and Kris James Mitchener. 2009. Branch banking as a device for discipline: Competition and bank survivorship during the great depression. *Journal of Political Economy* 117, (2) (April): 165-210.

Cook, E,R. and P.J. Krusic 2004. The North American Drought Atlas. http://iridl.ldeo.columbia.edu/SOURCES/.LDEO/.TRL/.NADA2004/.pdsi-atlas.html.

Coman, Katharine. 1911. *The industrial history of the United States*. New and revised ed. New York: The Macmillan Company.

Davis, Joseph H., Christopher Hanes, and Paul W. Rhode. Harvests and business cycles in nineteenth-century America. *National Bureau of Economic Research, Inc., Working Paper 14686, 2009.*

Davis, Lance E. 1965. The investment market, 1870-1914: The evolution of a national market. *The Journal of Economic History* 25, (3) (Sep.): 355-99.

Doti, Lynne Pierson, and Larry Schweikart. 1991. *Banking in the American west : From the gold rush to deregulation*. Norman: University of Oklahoma Press.

Fritts, H.C. 1976. Tree Rings and Climate. New York: Academic Press.

Hansen, Zeynep K., and Gary D. Libecap. 2004. Small farms, externalities, and the dust bowl of the 1930s. *Journal of Political Economy* 112, (3) (06): 665-94.

Heim, Richard R. 2002. A review of twentieth-century drought indices. *Bulletin of the American Meteorological Society* 83 (2002): 1149-66.

James, John A. 1976. The evolution of the national money market, 1888-1911. *The Journal of Economic History* 36, (1, The Tasks of Economic History) (Mar.): 271-5.

Jevons, William Stanley. 1884, 241-243. *"Commercial crises and sun-spots." in investigations in currency and finance,* Macmillan and co.

Jevons, H. Stanley. 1933. The causes of fluctuations of industrial activity and the price-level. *Journal of the Royal Statistical Society* 96, (4): 545-605.

Keynes, J. M. 1936. William Stanley Jevons 1835-1882: A centenary allocation on his life and work as economist and statistician. *Journal of the Royal Statistical Society* 99, (3): 516-55.

Libecap, Gary D., and Zeynep Kocabiyik Hansen. 2002. "Rain follows the plow" and dryfarming doctrine: The climate information problem and homestead failure in the upper great plains, 1890-1925. *The Journal of Economic History* 62, (1) (Mar.): 86-120.

Miller, Raymond Curtis. 1925. The background of populism in Kansas. *The Mississippi Valley Historical Review* 11, (4) (Mar.): 469-89.

Moore, Henry Ludwell. 1921. The origin of the eight-year generating cycle. *The Quarterly Journal of Economics* 36, (1) (Nov.): 1-29.

Nash, Stephen Edward. 1999. Time, Trees, and Prehistory. Salt Lake City: University of Utah Press.

Palmer, Wayne C. 1965. Meterological Drought. Research paper No. 45. U.S. Weather Bureau. Washington, DC: USGPO.

Ramirez, Carlos D. Did branch banking restrictions increase bank failures? Evidence from Virginia and West Virginia in the late 1920s. *Journal of Economics and Business* 55, (July-August, 2003): 331-352.

Redenius, Scott A. 2007b. Regional economic development and variation in postbellum national bank profit rates. *Business and Economic History on-Line* 5.

———. 2007a. New national bank loan rate estimates, 1887-1975. In *Research in economic history. volume 24.*, ed. Alexander J. Field, 55-104Coedited by Gregory Clark and William A. Sundstrom; San Diego and Amsterdam:; JAI Press, Elsevier.

Smallwood, James, and Oklahoma Heritage Association. 1979. *An Oklahoma adventure : Of banks and bankers*. Oklahoma horizons series. 1st ed. Norman: Published for the Oklahoma Heritage Association by the University of Oklahoma Press.

Smiley, Gene. 1975. Interest rate movement in the United States, 1888-1913. *The Journal of Economic History* 35, (3) (Sep.): 591-620.

Snowden, Kenneth. (1995). "Mortgage Securitization in the United States: Twentieth Century Developments in Historical Perspective." In *Anglo-American Financial Systems: Institutions and Markets in the Twentieth Century*, edited by M. Bordo and R. Sylla, pp. 261-298. New York: New York University, 262-98.

Sprague, O. M. W. 1910. *History of crises under the national banking system.* U. S. 61st cong., 2d sess. senate. doc. 538. Washington : Govt. Print. Off.: .

Stigler, George J. 1962. Henry L. Moore and statistical economics. *Econometrica* 30, (1) (Jan.): 1-21.

Sylla, Richard. 1969. Federal policy, banking market structure, and capital mobilization in the United States, 1863-1913. *The Journal of Economic History* 29, (4) (Dec.): 657-86.