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ABSTRACT

Standard tests find that no bubbles are present in the stock price data for the last one hundred years. In contrast, historical accounts, focusing on briefer periods, point to the stock market of 1928-1929 as a classic example of a bubble. While previous studies have restricted their attention to the joint behavior of stock prices and dividends over the course of a century, this paper uses the behavior of the premia demanded on loans collateralized by the purchase of stocks to evaluate the claim that the boom and crash of 1929 represented a bubble. We develop a model that permits us to extract an estimate of the path of the bubble and its probability of bursting in any period and demonstrate that the premium behaves as would be expected in the presence of a bubble in stock prices. We also find that our estimate of the bubble's path has explanatory power when added to the standard cointegrating regressions of stock prices and dividends, in spite of the fact that our stock price and dividend series are cointegrated.

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In the past decade a large literature has developed that tests for the presence of bubbles in the stock market. The rough consensus of the most recent papers (Campbell and Shiller (1987), Diba and Grossman (1988), Santoni (1990)) and general surveys (West, 1988) is that there are no rational bubbles, that is, self-fulfilling speculative price paths. Hamilton and Whiteman (1985) showed that any results suggesting the presence of bubbles can be the product of an incompletely specified model. This has led to a general skepticism (Hodrick and Flood, 1990) that any evidence can be marshalled to show the existence of bubbles.

These studies restrict their attention to the joint behavior of stock prices and dividends, and in a number of ways fail to capture what economic historians have described as bubbles. First, according to historical accounts, most bubbles were relatively brief and may not be adequately measured by the annual data typically used. The standard histories of the 1929 bubble (Allen (1931), Galbraith (1954)) claim that the boom began in March of 1928 and ended in October of 1929. End of year stock prices for 1928 and 1929 fail to pick up most of the rise and fall in the market. Second, historical evidence for bubbles is not strictly limited to stock prices and dividends. Further evidence for bubbles may be found in the striking anomalies that appeared in some financial markets. De Long and Shleifer (1990) point to the extraordinary premia for closed-end funds in 1929 as an indication of "excessive investor optimism." We find additional and more complete information in the anomalous behavior of interest rates for brokers' loans, which investors used to fund stock purchases. In this market, there was a dramatic rise in interest rates, establishing unusually high premia over other money market rates during the course of the 1928 - 1929 stock market boom.

Information from the market for brokers' loans enables us to examine the relative roles of fundamentals and a bubble component in accounting for the behavior of stock prices. Fundamentals are measured by a new quarterly index of dividends (White, 1990c) for the Dow Jones industrials from 1920 to 1934, and the bubble component is extracted from the spread of interest rates. Our results point to weaknesses in the standard tests for bubbles in asset prices. These tests show that our dividend and price series are cointegrated, indicating that no bubble is present. However, the independent measures of the bubble derived from the market for brokers' loans are significantly related to stock prices, after movements in dividends have been taken into account.

While our results resurrect the possibility of the stock market of 1929 being driven by a bubble, they are not immune to the criticism of this interpretation developed by Hamilton and Whiteman (1985) and Hamilton (1986). They show that movements in stock prices can be produced by dynamics of fundamentals seen by agents but not by econometricians. Shifts in preferences for savings and risk or anticipated changes in economic policy, such as tax rates, can all cause prices to depart from the path followed by dividends. Notwithstanding this criticism, we shall frame our discussion in the body of the paper around the idea of a bubble in stock prices, largely for the sake of simplicity. We shall return to the relationship of the putative bubble with fundamentals in the conclusion, where we note the absence of any compelling historical or econometric evidence for the extraordinary profile of expected fundamentals of the type described by Hamilton and Whiteman.

Section 1 provides a brief historical account of the American economy and the stock market in the twenties and explains why there is a reasonable presumption for the emergence of a bubble in the market. Section 2 discusses the nature of the market for brokers' loans in the late 1920s and suggests how the brokers' loan rate incorporates information on the presence of a bubble. Section 3 shows how this information can be combined with the equations for stock prices that have been the focus of tests for bubbles in the literature. Section 4 describes the estimation of the model and presents the empirical results.

1. The Stock Market and the Economy of the 1920s

Studies testing for the presence of bubbles in asset markets have been inspired by historians' accounts of manias and the madness of crowds. Economists have not, however, given much attention to the details of the bubbles as described by historians. While covering more than a century, the standard annual data on dividends and stock prices used for the study of bubbles do not fully capture the brief and dramatic swings in the market during the periods usually identified by historians as comprising the bubbles. All accounts of the 1929 market emphasize the relatively short duration of the bubble, beginning in early 1928 and ending in October 1929. End of year or average yearly data tend to mask many large swings in the market. For example, the end of year figures for the Dow-Jones industrials were 300 for 1928 and 248 for 1929, whereas the peak of 381 was reached on September 3, 1929. Even quarterly data captures the boom more fully: the Dow-Jones index reached 343 in the third quarter of 1929. To better examine the alleged bubble, this paper focuses on the stock market of the 1920s, using monthly and quarterly data.

Blanchard and Watson (1982) argue that bubbles are likely to arise in markets where the fundamentals become difficult to assess. This condition appears to have been satisfied in the 1920s when the American economy underwent a significant transformation, which altered the structure of industry and the capital markets. The post-World War I decade witnessed the full-scale emergence and growth of large commercial and industrial enterprises based on new continuous process technologies. Chandler (1977) describes the new methods of modern management that shaped the development of these firms, making them more efficient, vertically-integrated operations that captured economies of scale and scope. These developments were already underway before World War I, but they gathered renewed speed after the war.

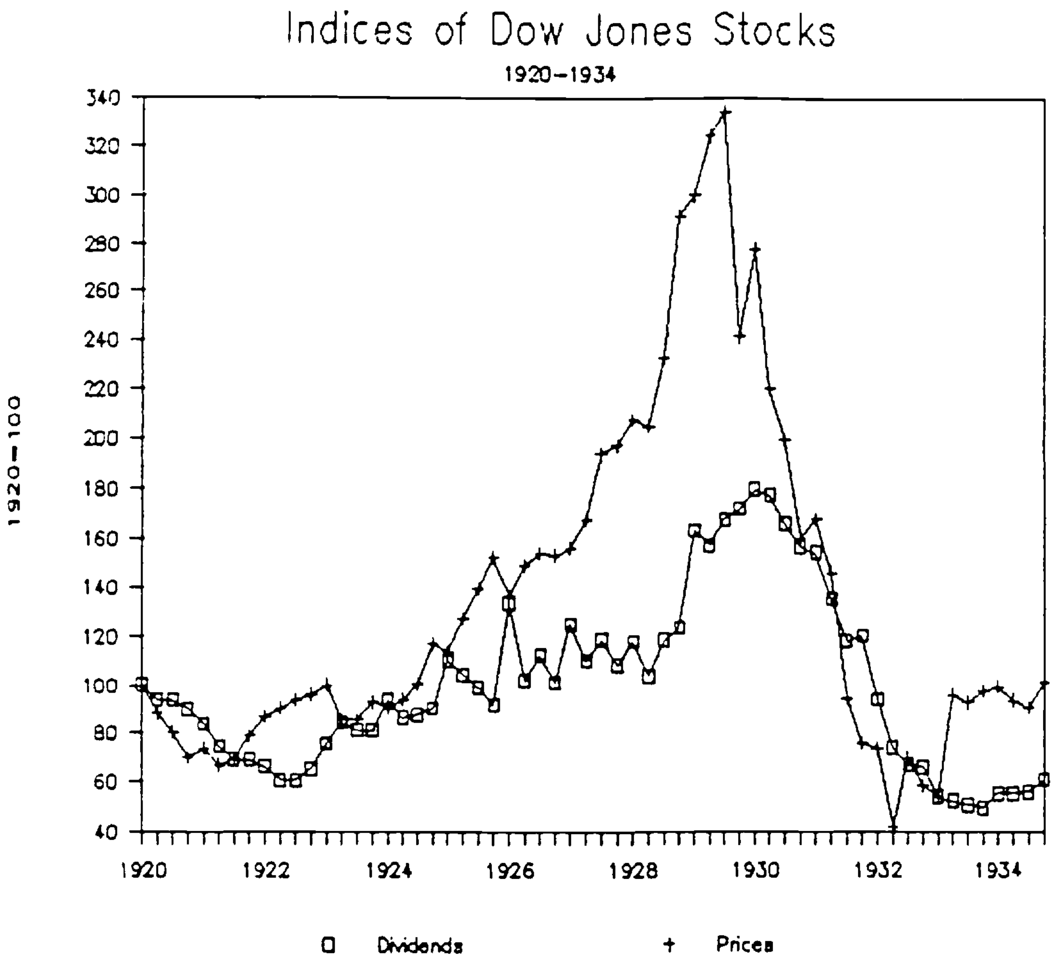
One characteristic of the 1929 stock market boom was the pre-eminence of stocks of firms that used new technologies or production methods (White, 1990a and 1990b). The two most heavily traded stocks were General Motors and RCA. General Motors took over first place in the automobile industry from Ford with its new system of management and organization, while RCA produced goods employing new technologies. One extraordinary feature of so prominent a stock as RCA was that it had never paid a dividend. While the stock might be bought in the expectation of future dividends, these expectations had to be extremely diffuse. Heavily traded stocks of many other firms also did not pay dividends. These included Radio-Keith-Orpheum, the Aluminum Company of America and the United Aircraft and Transport Corporation, all of which employed new technologies. The stocks of utility companies were also among the high-fliers. Relatively few of these firms paid dividends as they were reinvesting their earnings to capture the new economies of scale in production and transmission. These frontier industries figured prominently in the stock market boom, and their fundamentals were likely to be difficult to assess.

These new enterprises placed great demands on American capital markets, leading to a dramatic change in their character. Beginning in the late nineteenth century, regulations on commercial banks had severely limited their ability to give the new giant firms long-term loans. Firms responded by financing their investments out of retained earnings and increased issues of stocks and bonds. In the 1920s, the growing demand for funds by the new enterprises brought about the appearance of a full-fledged market for industrial equities. Commercial banks did not abandon their corporate customers, but they were forced to take up investment banking to meet their needs. Banks could not legally trade or hold equities; thus they set up wholly-owned securities affiliates, which permitted them fully to enter investment banking and the brokerage business (White, 1987). Commercial banks' security affiliates grew very rapidly during the decade, becoming the major competitors of traditional investment banks (Peach, 1941). Banks shifted away from direct lending to corporations and became more like agents that simply issued securities for firms and distributed them. In contrast to traditional brokerage houses, banks had a much broader customer base. Banks' securities affiliates sold stocks and bonds to many people who had little or no prior experience with investment in securities. This created another possibly favorable condition for a bubble to emerge.

The changes in industry and in financial markets offer some evidence that the necessary conditions for a bubble were present. Fundamentals were important, but they were not the sole factor as some contemporary observers like Dice (1929) and Fisher (1930) and more recently Sirkin (1975) have argued. The only data on fundamentals available to researchers until now has been annual data on dividends and earnings; but, as already argued, this masks most of the action during the 1929 boom.

A new quarterly index of dividends for firms in the Dow Jones Index from 1920 to 1934 was created to analyze the stock market. The starting point of the first quarter of 1920 was selected because in this quarter the Dow Jones index first included twenty stocks. The series was ended in the early 1930s, before the sweeping changes of the New Deal altered the operation of money and capital markets. This new index and stock prices are graphed in Figure 1. The movement of stock prices and dividends roughly reflects the standard historical view offered by Allen (1931) and Galbraith (1954) that the bubble began in March 1928. After moving together smoothly for most of the twenties, prices soared above

FIGURE 1



Indices of Dow Jones Stocks
1920–1934
1920=100
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
1920
1922
1924
1926
1928
1930
1932
1934
Dividends
Prices

dividends, suggesting the possibility of a bubble entering the market.[1] Many contemporaries were, in fact, surprised at how prices increased much faster than dividends. Most extraordinarily, several company presidents announced that their stock was grossly overvalued (White, 1990a).

The stock market was not alone in exhibiting surprising behavior during the years 1928-1929. Short-term money markets reveal a striking anomaly, shown in Figure 2. This figure graphs the quarterly interest rates for 4 to 6 month commercial paper, 90 day bankers' acceptances (a form of trade credit), and call and 90 day time brokers' loans[2]. The short-term money markets were well-integrated, and their yields typically moved very closely together over the business cycle because investors judged these assets to involve a similar exposure to risk. The one exception occurs during the period of the presumed bubble. Here, the call rate and the time rate for brokers' loans rose well above the other rates, suggesting that lenders no longer regarded brokers' loans as very safe and insisted on a sizeable premium[3].

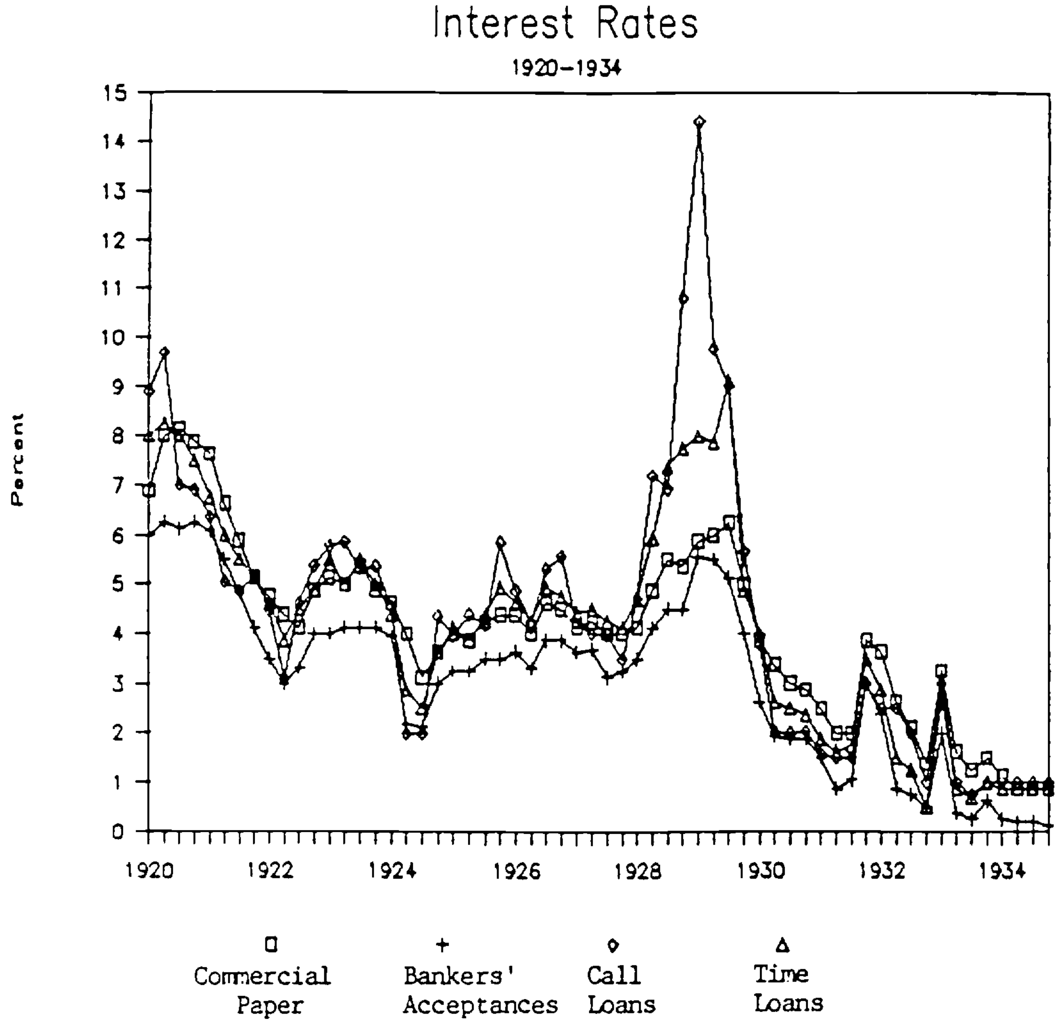
The large premia on brokers' loans are most unusual given what is known about the risk structure of interest rates. According to empirical studies (Jaffee (1975); Fama and French (1989)) of the cyclical variation in the risk structure of interest rates, risk premia against government securities typically decline when economic conditions are strong and rise

[1] The empirical analysis of Section 4 shows that dividends can only explain part of the behaviour of stock prices over the period. For the moment, it is worthwhile to note that the peak of dividends was actually reached in the first quarter of 1931. As Dominguez, Fair and Shapiro (1988) and Hamilton (1987) have demonstrated, the Great Depression was unexpected and unpredictable.

[2] These interest rates are to be found in Board of Governors of the Federal Reserve (1943).

[3] Monthly and weekly interest rate data reveal the same anomaly.

FIGURE 2


Interest Rates
1920–1934
Percent
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
1920
1922
1924
1926
1928
1930
1932
1934
Commercial Paper
Bankers' Acceptances
Call Loans
Time Loans

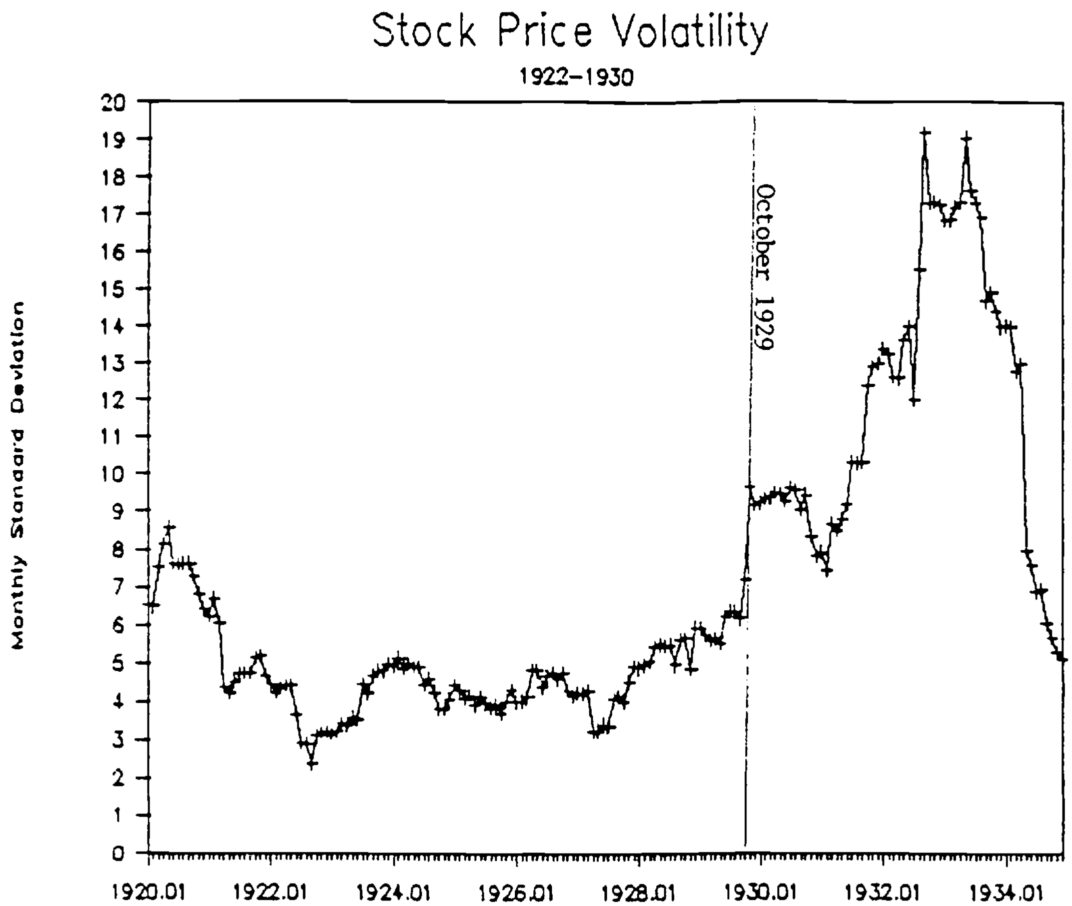
when they are weak. Merton (1974) showed that for a given maturity, the risk premium for corporate bonds is a function only of the variance or volatility of the firm's earnings and the ratio of the debt to the value of the firm. For a brokers' loan, the risk premium should be a function of the volatility on the stock returns and the ratio of the loan to the value of the stocks collateralizing the loan. The risk premium is an increasing function of both these variables.

Figure 3 graphs the monthly stock price volatility, as measured by the monthly standard deviation.[4] The stock market boom is not readily detected in this picture. Volatility was remarkably constant for the duration of the 1920s and only rose sharply in the month of the crash, indicated by the vertical line. If volatility did not contribute to the risk premium, then leverage should have been responsible. Evidence provided in this paper reveals that lenders were probably asking for more, not less, collateral as the boom progressed. Thus, the emergence of the risk premium suggests that these increases were insufficient to control for an increased risk of default given lenders' expectations about the future course of stock prices.

The large premia shown in Figure 2 thus suggest that lenders believed the stock market had become riskier and, perhaps, that prices contained a bubble that might burst, causing their borrowers to default. Before presenting our model of the market for brokers' loans and extracting information to analyze the stock market, it is necessary to describe in detail the operation of the market for brokers' loans in the 1920s.

[4] Other measures of volatility yielded very similar pictures.

Figure 3


Stock Price Volatility
1922-1930
Monthly Standard Deviation
October 1929
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
1920.01
1922.01
1924.01
1926.01
1928.01
1930.01
1932.01
1934.01

2. Brokers' Loans in the Twenties

A key feature of the stock market boom of the 1920s was the use of credit to purchase stock. Investors received margin loans from their brokers to buy securities. In turn, brokers obtained brokers' loans from their banks and the floor of the stock exchange to supply their customers and to fund their inventories of securities. In terms of examining the presence of a bubble in the market, information on the rates and volume of margin loans and broker's inventories of securities would be highly desirable, but very little of this data has survived. However, data on brokers' loans are available. Growing dramatically from $4.4 billion on January 1, 1928 to $8.5 billion on October 1, 1929, these loans were the focus of attention and concern and the rates paid on them were a key statistic of the money markets.

The market for brokers' loans changed considerably during World War I, and the arrangements used in the 1920s were only established in 1919. The markets changed once again with the institution of the New Deal's regulations governing the securities markets.[5] In the twenties, brokers' loans were divided into call loans, sometimes referred to as demand loans, and time loans. Both of these types of loans were contracted by brokers to assist them in carrying their inventories of securities and in making margin loans to their customers. In the pre-SEC era, margin requirements for the purchase of stock were solely determined by the brokerage house. In the mid-1920s, when an investor asked his or her broker for a loan to buy stock, he or she would perhaps have been asked to pay 20 to 25

[5] With the beginning of World War II, call loans ceased to be offered on the floor of the New York Stock Exchange (Leffler, 1957). Banks took over the market, and as funds were no longer auctioned, the rates on brokers' loans ceased to be an important indicator of money market conditions.

percent of the purchase in cash, collateralizing the margin loan with the full value of the securities. If stock prices dropped and the cushion provided by the margin disappeared, the broker had a right to sell the stock if the customer could not replenish the margin. While a brokerage firm could use its capital to make these loans, it typically would borrow funds in the form of brokers' loans from a bank or on the floor of the stock exchange, rehypothecating the customers' securities. In addition to meeting their customers' demand for credit, brokerage firms took brokers' loans to expand their inventories of securities. Annual new issues of common stock rose dramatically from between $500 and $600 million in the period 1924-1927 to $1.8 billion in 1928 and $4.4 billion in 1929.[6] While a substantial fraction of these new issues were sold to the public, brokers certainly increased their holdings of securities. Any increase in inventory of unseasoned stock exposed brokers to a drop in the market.

A broker could approach either his banker or the money desk on the floor of the exchange if he wished to obtain a brokers' loan. In either case, the broker would have to put up as collateral of his and his customers' securities. By assigning collateral in excess of the value of the loan to the lender, who could sell it without notice if the principle of the loan was threatened, the lender was provided with a margin of protection. In 1926, Dice reported that banks were requiring brokers to put up collateral with a market value of $125 for every $100 borrowed.

Many brokers preferred to borrow directly from banks where they were regular customers. These call loans had variable rates that moved with the market, but they also often had fixed maximum and minimum rates so that the broker was protected against wide fluctuations in the market. However, most of the information available on brokers' loans

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[6]Board of Governors of the Federal Reserve System, Banking and Monetary Statistics 1914-1941, (1943), p. 487.

is not from banks but the money desk at the stock exchange where the reported quotations on brokers' loans refer to minimum units of $100,000 on a mixed collateral in 100 share units of industrials and railroads.[7]

Each morning during the 1920s, corporations and others informed their brokers of the funds they wished to lend at the money desk of the exchange. Brokers wishing to borrow made their demands known to the desk, and it was the money desk clerk's job to bring together borrowing and lending members. Upon agreement there would be a transfer of collateral and funds. The rate was posted by the clerk at the desk. This was the market rate and when a new agreement with a different rate was reached, it was posted.

Call loans were theoretically callable at any time by the party making the loan or payable at any time by the borrower, but there was an unwritten rule that a loan could not be called for payment after 12:15 p.m.[8] Loans called before that time were paid the same day. As of 1926, it was not unusual for banks to call $25 to 50 million per day, at a time when the total demand loans outstanding were about $2 billion.[9] In addition to the constantly changing market rate, there was a renewal rate which remained the same throughout the day and applied to all call loans made on some previous day and renewed. The renewal rate was determined each morning by a committee consulting with the lending banks and the largest brokers and was posted at about 10:40 a.m.[10] Time loans had

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[7]Loans exclusively for industrials were not as highly regarded and a higher rate was asked, although this not appear to have been generally reported. Dice (1926), pp. 509-510.

[8]The purpose of this rule was to allow brokers time to obtain new loans or sell securities and prevent a wild scramble late in the day. Dice (1926), pp. 508-509.

[9]Dice (1926), p. 509 and New York Stock Exchange Yearbook (1931-1932), pp. 107-108.

[10]According to Dice (1926) and other observers, the renewal rate closely followed the average market rate.

varying maturities--60 days, 90 days, 4 months, 6 months, 9 months and occasionally one year. Time loans were made under a separate contract for each loan, unlike call loans. In 1926 and 1927, time loans accounted for between 21 and 32 percent of all broker's loans, but after mid-1928, they declined to under 10 percent. This may have been a sign of a growing unwillingness of banks to offer long-term loans with securities as collateral.[11]

The extensive market for brokers' loans has the potential for providing considerable information on some agents' apparently increasingly apprehensive view of the rise in stock prices. Lenders had three instruments available to limit their risk in a market where a bubble might be present. They could (1) raise the rate charged on the loan, (2) increase the margin requirement, and (3) alter the collateral mix. Unfortunately, we have been unable to find any data on the mix of collateral demanded or the margins for brokers' loans and only scattered references to margin requirements for margin loans.

The fragmentary evidence on margin requirements does, however, suggest that they increased during the boom. Margin rates were set by the individual brokerages in the 1920s, depending on the customer and the collateral. According to the recent work of Smiley and Keehn (1988), margin requirements rose during the period of the boom, increasing from perhaps 25 to 40 or 50 percent. Such increases would, ceteris paribus, have lowered the premium on brokers' loans. Thus, changes in margin requirements may have substituted for the rise in the premium attendant on an increased risk of default. Immediately after the crash, many brokerages sharply reduced their margin requirements. J. P. Morgan cut its requirement from 40 to 25 percent in the belief that there was a reduced risk in the market now that stock prices had dropped.[12] The rise and fall in margin requirements thus

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[11]Stock Exchange, Handbook (1926-1929).

[12]Commercial and Financial Chronicle (November 2, 1929), p. 2806.

appears to parallel the premium on brokers' loans in Figures 2 and 3. We shall now show how this information may be combined with data on the brokers' loan rate and other rates to provide a measure of the bubble in stock prices.

3. The Equilibrium Brokers' Loan Rate

In our search to ascertain the presence of a bubble in the 1920s stock market, we employed a standard formulation for decomposing the movements of stock prices into elements determined by fundamentals and a bubble. The observed price of the stock, P_t, is the sum of two components:

(1) $$P_t = P_t^* + B_t$$

(2) $$E_t P_{t+1}^* = P_t^* + d_t P_t^* - D_t \equiv P_t^* + S_t$$

where B_t is the bubble, P_t^* is the fundamentals solution to the arbitrage condition equating expected returns to the discount factor, $1/(1+d_t)$, and D_t is the dividend payout. S_t is shorthand for the difference between the return on the fundamental price at the discount rate, and the current dividend payout. The central issue has, of course, been how to measure the bubble, B_t.

In order to obtain a measure of the bubble from the market for brokers' loans, it is necessary first to develop a simple model of the market. To a first approximation, our model applies equally to the call rate and the time rate on brokers' loans. We shall talk in terms of the call rate, for the sake of brevity; however, the empirical analysis of the next section will use the 90-day time rate, since the loans involved were similar to other short-term instruments and there is an exact match of maturities for the reported rates and the rate on bankers' acceptances.

The call market rate will be determined in equilibrium by the condition that equates c_t (the lender's return to lending in the call market) to ρ_t, the sum of the expected return obtainable by lending elsewhere and the normal stock market risk premium. Consider the determination of the call rate in the general case where a bubble can be present. At time t, the representative broker needs to borrow $(1 - m_t)P_t$ per unit of stock, where m_t is the margin (proportion) he must pay with his own funds (or those of his customer, if margin loans are the origin of the transaction.)[13] The lender or banker makes the following calculations at t: If the bubble does not burst by (t+1) (when the loan contract expires), then, assuming margin has been set sufficiently high to cover all normal fluctuations in stock values, $E_tP_{t+1} > (1 - m_t)P_t$, so his return will be $c_tP_t(1 - m_t)$. On the other hand, if the bubble bursts by (t + 1), $E_tP_{t+1} = E_tP^*_{t+1} = P_t - B_t + S_t$, which is the expected value of the collateral. If margin calls are always expected to be unsuccessful, then the lender's expected return will be

(3) $\quad \text{Min } \{(1 - m_t)c_tP_t,\ m_tP_t - B_t + S_t\}.$

However, margin calls only occasionally failed, and the lender would have attached a probability (1-f) to the event that the margin call would be met. In this case, the lender's expected return would be

(3a) $\quad \text{Min } \{(1 - m_t)c_tP_t,\ (1\text{-}f)(1 - m_t)c_tP_t + f(m_tP_t - B_t + S_t)\}.$

The first element in (3a) represents the event that the bubble has burst but the collateral remains greater than the principal, so that the lender still receives the full interest. The second element represents the case where the bursting bubble wipes out the margin, and a margin call is required. 100(1-f) percent of margin calls are successful, and the lender expects the same return as before. In the case of the 100f percent of the loans for which margin calls fail, it is expected that there remains $P_t - B_t + S_t$, which, after subtracting the principal of the loan $(1 - m_t)P_t$, yields a return of $m_tP_t\text{-}B_t + S_t$, which may be positive or negative.

[13] The primary stimulus for this borrowing, the individual investor, will of course contract margin loans from his or her broker according to the same rules.

The equilibrium condition relating c_t to ρ_t is thus:

$$(4)\qquad (1 - m)\rho_t = \pi(1 - m)c_t$$
$$+ (1 - \pi)\mathrm{Min}\ \{(1 - m)c_t, (1\text{-}f)(1 - m_t)c_t + f(m_t - B_t/P_t + S_t/P_t)\},$$

where π is the probability that the bubble will persist over the term of the loan contract. The solution for c_t to this condition is:

$$(5)\quad c_t = \begin{cases} \rho_t & \text{if } (1-m_t)\rho_t \le m_t - B_t/P_t + S_t/P_t \\ \dfrac{\rho_t}{\pi+(1-\pi)(1-f)} - \dfrac{(1-\pi)f}{\pi+(1-\pi)(1-f)}\cdot\dfrac{m_t - B_t/P_t + S_t/P_t}{1 - m_t} & \text{otherwise} \end{cases}$$

We shall refer to the term $(m_t - B_t/P_t + S_t/P_t)/(1 - m_t)$ as the lenders' cushion.

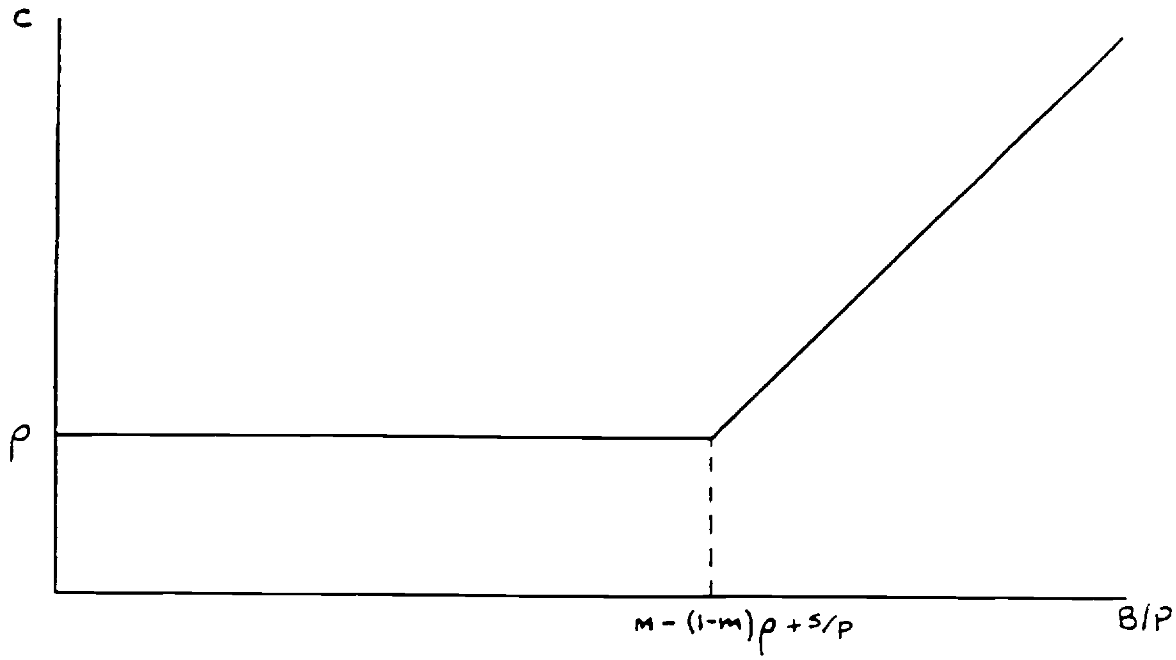
The important thing to notice is that, ceteris paribus, the call rate and its premium over ρ_t move with B_t. In the first part of (5), as long as the cushion is positive -- the margin supplied by the purchaser of the stock exceeds the loss that will occur when the bubbles bursts -- the call rate will be equal to the opportunity interest rate plus the "normal" risk. However, when the bubble rises above the level of the margin, the call rate will incorporate an additional premium, reflecting the presence of a bubble in the market. The relationship between the call rate and B_t/P_t is depicted in Figure 4, where the switching point is $m-(1-m)\rho+S/P$.

4. Estimation of the Model

The model described in the preceding section has a number of interesting econometric features. These will be discussed in the context of a particularly simple characterization of the bubble, but they carry over to more complex models. Note that equation (5) demonstrates that the rate on brokers' loans incorporates information about

FIGURE 4

Effect of a Bubble on the Brokers' Loan Rate



the presence or absence of bubbles. When a bubble is present, the premium of the brokers' loan rate over the market rate will move directly with the proportion of stock prices constituted by the bubble. Given a parametric model for the path of the bubble, it is, in principle, possible to estimate these parameters and extract an estimate for this path. The relationship of this estimated series for the path of the bubble with stock prices and dividends can then be examined, to provide direct tests for the presence of bubbles in stock prices. This approach contrasts with the indirect approach pursued in the literature, where the presence of bubbles is invoked as one of a number of possible explanations for discrepancies in the joint behavior of stock prices and dividends (West 1987, Campbell and Shiller 1987, Diba and Grossman 1988).

We shall first describe the data and econometric specification used in the estimation of the model of the brokers' loan rate. As mentioned above, in estimating the model, we will use the 90-day time rate, rather than the call rate, for c_t.

We treat the growth of the bubble prior to bursting as deterministic, that is:

$$(6)\quad B_{t+1} = \begin{cases} \alpha B_t & \text{with probability } \pi \\ 0 & \text{with probabilty } 1 - \pi \end{cases}$$

The parameter α describes the rate of ascent of the bubble, and exceeds unity.

From equations (4) and (5), it follows that if there is a bubble that grows sufficiently and does not burst too soon, it will affect the premium of the brokers' loan rate over other market rates after a date T_{12} such that[14]

$$(7)\quad B_{T_{12}} = (m_{T_{12}} - (1 - m_{T_{12}})\rho_{T_{12}})P_{T_{12}} = (m_{T_{12}} - (1 - m_{T_{12}})c_{T_{12}})P_{T_{12}}$$

From T_{12}, until the bubble bursts, at date T_{21} (treated as the last period of the bubble), the bubble will follow the path:

$$(8)\quad B_t = \alpha^{t-T_{12}} B_{T_{12}} \qquad T_{12} \le t \le T_{21}$$

A specification is also required for the unobservable alternative return and risk premium, ρ_t. We use the rate on 90-day banker's acceptances (r_t) to capture the return available elsewhere. There are two advantages for selecting this interest rate as the basis of comparison. First, in contrast to treasury securities, it provides an exact match in terms of maturity. Second, as mentioned above, it is expected to move in a manner similar to the brokers' loan rate over the course of the business cycle. A risk premium would be present in the normal relationship between the two interest rates if, ceteris paribus, brokers' loans were expected to have a higher default risk than acceptances. Since the probability of default on a brokers' loan depends on the value of the underlying collateral, we use measures of the volatility of stock prices to proxy for this risk. One is the standard deviation of the preceding twelve months' changes in stock prices (v_{1t}). The other measure is simply

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[14] This relationship is inexact only because of the discrete nature of the data. In the sequel, we shall ignore the term S_t/P_t that appears in equation (5). Including this term raises the problem of specifying the discount rate, d_t. Experimentation with each of the interest rates in the estimated model (c_t,r_t,and ρ_t) as proxies for d_t yields time series of values that are negligible in size compared to the rest of the cushion, $(m_t - B_t/P_t)/(1-m_t)$, even when the latter term (which depends on the estimate of the bubble path derived below) approaches zero, as it does around T_{12}. Given that S_t/P_t is negligible, our decision to regard it as zero is also influenced by the fact that, because it involves the interaction of an interest rate, d_t, with the bubble (via $P^*_t = P_t - B_t$), it increases greatly the degree of nonlinearity in the model.

a rough estimate of π to be extracted.

As previously explained, there currently exists no consistent time series for m_t. Using the fragmentary data available as a guide, m_t is set at .25 for the period prior to April 1927, after which it rises linearly to a maximum of .5 in October 1929. From November 1929 to December 1934 (the end of our sample), it is again set at .25. These were the values most commonly quoted in articles on brokers' loans in the Commercial and Financial Chronicle, and embody the movements suggested by Wigmore (1985, p. 29). We found that other time paths for m_t that remained constant outside the years 1927-1929, and rose monotonically during those years, did not alter the estimation results significantly.

The parameters of the systematic part of the model are thus T_{12}, T_{21}, β, α and ϕ. As long as ϕ and α differ from 0, all the parameters are identified. The brokers' loan rate equation was estimated by non-linear least squares, where the objective function was Σe_t^2 . Stock prices were treated as predetermined, but an instrumental variable was used for the bankers' acceptance rate[16]. The specification of the model thus satisfies the conditions sufficient for consistency of the parameter estimates laid out by White and Domowitz (1984).

The first two columns of Table I show estimates of the model excluding the bubble terms, while columns (iii) and (iv) contain estimates of the full model[17]. We used both monthly and quarterly data, spanning the period from the beginning of 1920 to the end of 1934. In the quarterly model, the bubble is estimated to become evident in the behavior of the brokers' loan rate in 1927.IV, and to grow at a rate of 22.35 per cent per quarter, until

[16]. The instruments used for r_t were the previous period's values of c and r. The estimates of the model differed little between the instrumental variable version, and the one described by equations (10a) and (10b).

[17] Columns (v) and (vi) describe estimates of a specification employing a multiplicative version of the bubble, which will be discussed below.

TABLE I
BROKERS LOAN RATE EQUATION

	No Bubble Model(10a)		Additive Bubble Model		Multiplicative Bubble Model	
	(i) Quarterly	(ii) Monthly	(iii) Quarterly	(iv) Monthly	(v) Quarterly	(vi) Monthly
Constant	-.0004 (.0014)	-.0002 (.0008)	.0022 (.0006)	.0011 (.0004)	.0024 (.0006)	.0013 (.0004)
r_t	1.2293 (.0822)	1.2781 (.0527)	1.0888 (.0448)	1.1534 (.0310)	1.0750 (.0451)	1.133 (.0307)
v_{1t}	.0024 (.0106)	.0140 (.0058)	-.0116 (.0045)	-.0012 (.0032)	-.0125 (.0046)	-.0028 (.0031)
v_{2t}	-.0024 (.0131)	.0165 (.0068)	-.0138 (.0058)	-.0048 (.0039)	-.0148 (.0058)	-.0065 (.0031)
y_t	.0161 (.0070)	.0227 (.0100)	.0138 (.0029)	.0211 (.0058)	.0142 (.0029)	.0210 (.0055)
T_{12}	-	-	1927.IV	June 1927	1927.IV	Dec. 1927
T_{21}	-	-	1929.III	Sept.1929	1929.III	Oct. 1929
α	-	-	1.2235 (.00015)	1.0903 (.00014)	.1914 (.0225)	.1938 (.0684)
ϕ	-	-	.0250 (.0076)	.0046 (.0024)	.0274 (.0086)	.0049 (.0012)
s.e.	1.3935	1.1826	.9284	.8354	.9137	.8130

Note : Standard errors are calculated using the estimator of Newey and West (1987). Eight lags are used for quarterly data, twelve for monthly data.

The table reports the sum of the distributed lag coefficients on y_t ($\tau(1)$).

bursting in 1929.III. The probability assigned to its bursting in any quarter <u>and</u> subsequent margin calls being unsuccessful is estimated to be 2.5%. The monthly model involves a somewhat faster rate of growth of the bubble (29.5% at a quarterly rate), and a correspondingly lower estimate of ϕ. The bubble is estimated to have become evident in the brokers' loan rate one quarter later. Both equations show that the measures of stock market risk, v_1 and v_2, fail to capture the behavior of the premium of the brokers' loan rate over that on bankers' acceptances. The variable v_1 has the wrong sign in both specifications, while v_2 (which can be regarded as a measure of the temporary overvaluation of the stock market) has a positive coefficient only in the monthly equation.

Because of the discontinuity of the objective function in these parameters, standard methods for deriving coefficient estimator variances based on Taylor series approximations are not applicable. The standard errors of the estimators in Table I are calculated conditionally on the estimates of T_{12} and T_{21}, and, following the argument of White and Domowitz (1984), are well-defined and asymptotically normal. It appears that not much inaccuracy in these standard errors is introduced by treating T_{21} as if it were known. Figure 5 exhibits the function

$$(11) \qquad L(T_{12},T_{21}) = 2 - \Sigma e_t^2(\hat{\alpha},\hat{\beta},\hat{\phi}|T_{12},T_{21})$$

for all possible values of T_{12} and T_{21}, using quarterly data[18]. That is, it depicts the optimum values of the objective function, conditional on T_{12} and T_{21}. (The sum of squared

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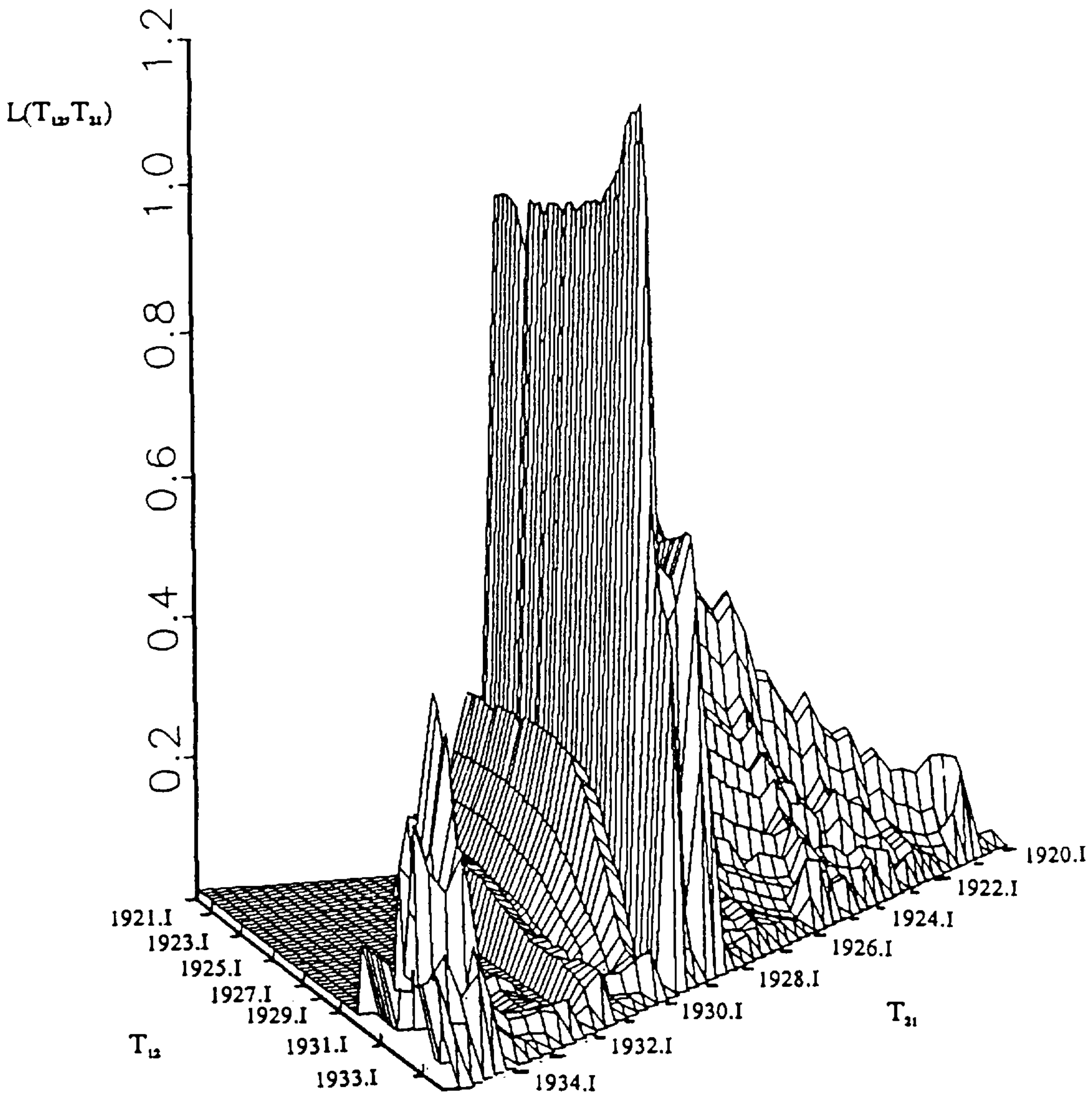
[18] $\hat{\alpha}$, $\hat{\beta}$, and $\hat{\phi}$ are the NLS estimates of these parameters, conditional on the given values of T_{12} and T_{21}.

FIGURE 5
OBJECTIVE FUNCTION
FOR
BROKERS' LOAN RATE EQUATION[a]



a. The graph depicts the values of two minus the minimum sum of squared residuals at each possible value of T_{12} and T_{21} for the model described in Equations (10a) and (10b). Quarterly data from 1920 to 1934 were used.
Note that the base of the diagram is triangular, with values of T_{21} marked along the hypotenuse.

residuals is subtracted from 2 to produce a clearer graph). Evidently, there is a dramatic ridge at T_{21} = 1929.III: this is the optimum value, irrespective of the value of T_{12} (prior to 1929.III). From a Bayesian perspective, if T_{12} and T_{21} were the only parameters of the model, Figure 5 could be interpreted as approximately proportional to the likelihood of the data, and would translate a non-informative prior into a posterior concentrated on T_{21} = 1929.III. Such a posterior suggests that there is little uncertainty about the value of T_{21} and therefore that standard errors of other parameter estimates computed as if T_{21} were known should not be misleading[19].

In contrast, T_{12} is not estimated very precisely, particularly at T_{21} = 1929.III, as the flatness of the surface in Figure 5 at this date attests. However, for all values of T_{12} prior to 1929.II, the optimal value of ϕ lies in the interval (0,.3], so its calculated standard error in Table I does not seem misleading. The corresponding range for α is [1.2,1.3], which is considerably wider than that suggested by the standard error of .00015. The value of α is important for the cointegration tests carried out below; however, since we use the values from both quarterly and monthly models, (1.2235 and 1.295, respectively), we cover the effective range of values for this parameter.

Although we do not obtain separate estimates of the probability of the bubble bursting, $(1 - \pi)$, and of the failure of a margin call, f, it is possible to speculate about some

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[19] Of course, these are not the only parameters of the model, and so it is possible, in principle, that for large ranges of α,β, and ϕ that are positively weighted by the prior, the likelihood at T_{21} = 1929.III is low. This would serve to diminish the mass of the posterior concentrated at this date. However, experimentation showed that, for $\phi \in [0.8,1.0)$, and $\alpha \in (1,4]$, $L(T_{12}, 1929.III)$ dominates all other values of T_{21}. This suggests that it is not unreasonable to regard the "maximum likelihood" surface of Figure 5 (as a function of T_{12} and T_{21}) as indicative of the shape of the entire likelihood surface.

reasonable values for π and f. Margin calls were apparently quite successful before and even during the crash. Brokers had continuously raised their customers' margin requirements, providing themselves with a larger cushion. When prices fell, stocks with a margin of 50 percent--not atypical of some brokerages--protected the broker adequately and by extension the lender of the broker's loan. According to Wigmore (1985), many brokers recognized the softening of the market in September 1929 and began to reduce their exposure on margin accounts and inventories. When the crash came, brokers reacted so quickly to any danger of default that some customers claimed their stock had been sold before their account had become undermargined or they had adequate time to respond.

Additional evidence also suggests that f would have been very small. Very few brokerages failed in 1929. The failure rate for stock exchange members was only 0.16 percent in 1929--low even in comparison to 0.27 percent average for the years 1922-1928.[20] Previous stock market panics had been accompanied by widespread brokerage failures, but the Federal Reserve Bank of New York had acted to prevented a general liquidity crisis by lending freely to the banks who were encouraged to lend to brokerages.[21] For these reasons, the probability that there would be a default on a brokers' loan was very small.

Table II contains the estimates of π implied by different values of f and the NLS estimates of ϕ from the monthly and quarterly models in Table I. In the light of the

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[20]New York Stock Exchange Yearbook (1932-1933), p. 108. The New York Stock Exchange was not severely battered by the crash. The price of membership did not fall substantially until well into the Depression.

[21]Backed by the Fed, some banks apparently even tolerated temporarily undermargined brokers' loans (Wigmore, p. 33) in the effort to prevent a general crisis that would have produced widespread defaults.

TABLE II IMPLIED ESTAMATES OF π							
Values of **f**		.01	.02	.05	.1	.15	.2
Values of ϕ	.025	-	-	.500	.750	.833	.875
	.0046	.540	.770	.908	.954	.969	.977

evidence presented above, it is hard to maintain that f exceeds 5%. Using the estimate of ϕ from the quarterly model (0.025) this implies an estimate of π not in excess of .5, and an expected (uncompleted) duration of the bubble of at most 2 quarters. The corresponding figures for the monthly model, when $f<0.05$, are $\pi \leq 0.91$, with an expected duration of at most 11 quarters. The implied average durations of completed bubbles are 4 and 10 quarters, respectively. Since the popular account of the bubble describes it as lasting about 7 quarters, these estimates are not unreasonable.

The residual variances of equations (iii) and (iv) are dramatically lower than those of equations (i) and (ii). Unfortunately, standard test statistics for the restrictions imposed by the no-bubble specification do not possess standard distributions, because the objective function does not satisfy the necessary regularity conditions when a bubble is absent: if $\alpha=0$, then π (ϕ) is not identified, while if π (ϕ) = 1, α is not identified.[22] However, it is possible to provide an indirect test of the restrictions imposed by models (i) and (ii).

If these restricted models were correct, the residuals would be symmetrically distributed. In contrast, were a bubble present, then one would expect the residuals of model (i) to display a particular kind of skewness: not only would there be positive outliers, but these outliers would be clustered together in time. If u_t is the result of "whitening" the residuals $\hat{e}_t$, "cross third moments" such as $Eu_t^2u_{t+1}$ and $Eu_{t-1}u_tu_{t+1}$ are also expected to be large and positive. These cross third moments appear in the third moments of moving averages of u_t. Rappoport (1990) tabulates the distributions of the sample skewness coefficients of moving averages of u_t, under the null hypothesis that the underlying variates

[22] A lucid discussion of the consequences of this problem, in the case of mixture models, is provided by Titterington, Makov and Smith (1985).

(u_t) are i.i.d normal. In the case of the model of the brokers' loan rate, these tests reject the null of symmetry of the whitened residuals at the one percent level, when the moving average spans one, two or three observations.[23] While one could maintain that the random component of the call rate risk premium (u_t) is skewed even in the absence of a bubble, it is less likely that these everyday conditions would cause the skewness to persist across quarterly observations. Thus, the skewness test supports the idea that the behavior of the brokers' loan rate is driven by the perception of a bubble.

We now consider the ability of our bubble estimates to account for movements in stock prices over the period. Several methods of assessing the presence or absence of bubbles in stock prices examine the extent of non-stationarity in stock prices, and their comovement with dividends. Diba and Grossman (1988) argue that, if a rational bubble is present, then successive differences of stock prices will be non-stationary, because the bubble component has a larger than unit root. Mattey and Meese (1986) examine the power of this test for a bubble process of the kind described by Blanchard and Watson (1982), and find it to be high. Similarly, Campbell and Shiller (1987) have shown that, when dividends have one unit root, and prices and dividends are linked by a present-value relation in the absence of bubbles, then prices and dividends will be cointegrated (and prices will have a single unit root).

Table III presents evidence on the presence of unit roots in these two series. The augmented Dickey-Fuller tests suggest that all three series examined are nonstationary in their levels. However, only for monthly stock prices do these tests reject nonstationarity in the first differences. The Phillips-Perron tests unambiguously validate nonstationarity in levels, and reject it for first differences. The distinction between these two types of test is

[23] Distributions have not been tabulated for longer moving average windows.

TABLE III UNIT ROOT TESTS FOR STOCK PRICES AND DIVIDENDS	Stock Prices						Dividends		
	(Monthly)			(Quarterly)			(Quarterly)		
	Level	1st Diff.	2nd Diff.	Level	1st Diff.	2nd Diff.	Level	1st Diff.	2nd Diff.
ADF Test[a]									
$\hat{\rho}$	.98	.30	-4.43	.90	.45	-1.37	.87	.58	-2.31
t_ρ	1.42	3.72	10.58	2.33	2.63	10.48	3.01	1.83	10.54
# lags[b]	1	6	6	3	2	1	4	3	(2)
Phillips-Perron Test[c]									
$\hat{\rho}$	.98	.14		.95	-.032		.94	-.21	
$Z(t_{\hat{\rho}})$	1.12	12.02		1.04	6.48		1.13	7.68	
Autocorrelation									
lag: 1	.98	.14		.94	-.03		.93	-.21	
2	.96	.00		.90	.29		.89	.39	
3	.95	-.16		.83	.23		.80	-.16	
4	.94	-.02		.73	.01		.73	.59	
5	.92	.03		.63	.06		.58	-.29	

Notes :

a. The Augmented Dickey-Fuller Test Examines the hypothesis $\rho = 1$ in the regression

$$y_t = \mu + \rho y_{t-1} + \sum_{j=1}^{r} \delta_j \Delta y_{t-j} + e_t$$

by referring the t-statistic of the OLS estimate of ρ to the tests provided by Fuller (1976).

b. The number of lags in the ADF equation was chosen using the Hannan-Quinn procedure, as described by West (1987).

c. The Phillips-Perron (1988) test calculates $Z(t_{\hat{\rho}})$, an alternative t-statistic for ρ where $p = 0$, and a correction is made for the resulting potential serial dependence and heterogeneity of e_t.

that the former corrects explicitly for residual serial correlation, while the latter provides a consistently estimated correction for the terms that arise as a result of ignoring the serial correlation in the regression of each series on its lagged value. We choose to follow the implications of the Phillips-Perron test and regard each series as requiring one difference for stationarity. However, we note in passing that this approach would be less sensitive than the Dickey-Fuller methodology to the presence of bubbles in stock prices, because it tends to average the autocorrelations of the series in question, rather than accounting for each explicitly.[24]

According to Diba and Grossman's approach, the fact that first differences of stock prices are stationary rules out the possibility of a bubble in stock prices. From Campbell and Shiller's perspective, it is possible to reject the presence of a bubble should stock prices and dividends be cointegrated. Table IV contains the results of tests designed to detect the presence of bubbles in stock prices. The first row of the Table shows that one can reject the hypothesis that prices and dividends are not cointegrated: the augmented Dickey-Fuller (ADF) statistic indicates that the residual from the regression of prices on dividends does not have a unit root. This result is interpreted in the literature as a rejection of the hypothesis that bubbles are present in stock prices.

The next two rows of the table repeat the analysis of the first row, including the path of the bubbles estimated from the brokers' loan rate model. These paths are constructed to grow at the rate α in each period from the beginning of the sample to the estimated date at which the bubble bursts (equation (8)), passing through the implied value of the bubble

[24] Phillips and Perron note that their tests are inferior to the Dickey-Fuller tests in certain instances when the first difference of the series is negatively serially correlated, as occurs for the dividend series.

TABLE IV
COINTEGRATION OF STOCK PRICES BUBBLES AND DIVIDENDS

COINTEGRATING REGRESSION	Bubble Model[a]	Dividend Coefficient (δ_1)	Bubble Coefficient (δ_2)	Augmented Dickey-Fuller Statistic[b]	Number of Lags[c] in ADF Regression	Regression of $\hat{u}_{1t}$ on Bubble: T-Statistic of bubble Coefficient[d]	Regression of $\hat{u}_{1t}$ on Bubble: 5% Critical Values[e]: "Extreme Dependence" Assumption	Regression of $\hat{u}_{1t}$ on Bubble: 5% Critical Values[e]: Independence Assumption
Additive Specifications $p_t=\delta_0+\delta_1 div_t+u_{1t}$	-	94.11	-	3.28*	4	-	-	-
$p_t=\delta_0+\delta_1 div_t+\delta_2 bubble_t+u_{2t}$	Additive, Quarterly	64.92	.95	4.00*	0	4.74	5.19	3.29
	Additive, Monthly	66.71	.82	3.87*	0	4.47	5.19	3.29
Multiplicative Specification $\ln(p_t)=\delta_0+\delta_1\ln(div_t)+u_{1t}$	-	1.02	-	3.31*	4	-	-	-
$\ln(p_t)=\delta_0+\delta_1\ln(div_t)+\delta_2\ln(bubble_t)+u_{2t}$	Multiplic. Quarterly	.73	1.21	3.27	0	3.04	-	1.96
	Multiplic. Monthly	.82	.34	2.95	0	2.11	-	1.96

Notes :

a. The bubble models are calculated from the values of α, T_{12} and T_{21} in the respective colums of TABLE I.

b. The 5% significance levels are taken from Engle and Yoo (1987).

c. Selected by the Hannan-Quinn procedure described in West (1987).

d. Calculated using the Newey-West (1987) correction for error dependence and heterogeneity.

e. Two-tailed significant levels. See text for description of calculation and dependence assumptions.

An asterisk indicates significance at the 5% level.

at T_{12} (from equation (7)). Subsequent to T_{21}, the bubble series take on the value zero.[25] Once again, the augmented Dickey-Fuller statistic indicates rejection of the null of no cointegration between stock prices and the regressors. However, it is difficult to assess whether this is driven by the earlier result that stock prices and dividends alone are cointegrated. Some incidental statistics suggest that the bubble terms contribute to the explanation of stock prices: the bubble coefficients (δ_2) are in the region of unity, as the additive bubble specification requires (equation (1)), and the number of lags of differences of residuals required for the ADF test goes down substantially when the bubble terms are included in the regression (from 4 to 0), suggesting that the serial correlation in the residuals of the standard cointegrating regression is the consequence of omitting the bubble term. However, a rigorous test of the marginal significance of the bubble term is still needed.

To assess the contribution of the bubble, we proceed in two stages, first regressing prices on dividends, and then regressing the residuals ($\hat{u}_{1t}$) on a constant and the bubble term. On the assumption that prices and dividends are cointegrated, u_1 is stationary, and so we can calculate the critical values for the t-statistic of the bubble term in this regression from a Monte Carlo simulation of the regression of realizations of stationary time series processes on series that initially grow exponentially, and then remain at zero[26]. Because

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[25] This type of path is implied by equation (6). This conforms to the restrictions derived for rational bubbles by Diba and Grossman (1987), who show that, in a representative agent framework, rational bubbles must have been present at the beginning of time if they were present at all, and that once they burst, rational bubbles cannot restart. However, we note that our estimation of the bubble from the brokers' loan rate equation does not require any statements about the rationality of the bubble.

[26] The simulations results used a sample size of 60. Since the residuals from the equation in the first row of the Table exhibited autocorrelations that decayed roughly exponentially from about 0.75, we experimented with a number of AR(2) process whose coefficients summed to .75, and took the critical values as the average critcal values across the results for these different autoregressive models.

the nature of the (stationary) time series dependence of u_1 is not known, we use the covariance matrix correction developed by Newey and West (1987), both in the simulations, and in the calculations reported in the table.

The far right column of the table reports that the two-sided 5% critical value for the t-statistic of the bubble term in the second stage regression is 3.29, while the calculated t-statistics are 4.74 in the case of the quarterly model, and 4.47 for the monthly model. Taken at face value, these results suggest a significant marginal role for the bubble estimates, especially since the first step of the procedure essentially allows dividends to act as an instrumental variable for the bubble. However, one may object that the bubble terms are already infected with price movements, because of the presence of prices in the brokers' loan rate model (see equation (10b)).

Two approaches may be taken to this problem. The first is to recompute the critical values for the test in a manner that takes into account the potential simultaneity of stock prices and the bubble estimates. An extreme version of this follows from the question: "If one picked the bubble path to maximize its t-statistic, and then presented the estimated t-statistic from such a regression, what would be the 5% critical value for such a test?". Accordingly, we reran our Monte Carlo simulations, regressing each realization of 60 observations from stationary processes on 60 different bubble series, each terminating on a different date, and picked the maximum t-statistic generated by each realization. The distribution of these maximum t-statistics across the set of runs of the simulation was tabulated, and the critical values read off. We repeated the experiment for values of α (the rate of ascent of the bubble) in a grid from 1.2 to 1.3, and averaged the critical values. The two-sided 5% value for this experiment is 5.19, which exceeds the t-statistics calculated from the regression of u_1 on the bubble series. Hence, this extreme interpretation of the simultaneity of stock prices and bubble estimates does not attribute a significant role to the bubble term. The one-sided 5% value of the extreme dependence test is 4.59, which would actually lead to a rejection of the null of no bubble effect by the quarterly model. One-sided tests are relevant if one believes that only positive bubbles are possible. From this viewpoint, the rejections of the no-bubble hypothesis are more marked than those reported in the table.

An alternative approach is to recast slightly the model of the bubble used in the brokers' loan rate equation. Instead of using the additive specification (1), we can define a multiplicative bubble, b_t, which enters into stock prices according to

$$(1') \qquad P_t = b_t P_t^*$$

and evolves according to

$$(6') \quad b_{t+1} = \begin{cases} 1 + e^{a}(b_t - 1) & \text{with probability } \pi \\ 1 & \text{with probability } 1 - \pi \end{cases}.$$

The important difference brought about by this change of specification is that the arguments of section 3 and 4 lead to the following econometric specification of the brokers' loan rate during the bubble period:[27]

$$(10b') \quad c_t = \frac{X_t\beta + e_t}{1 - \phi} - \frac{\phi}{1 - \phi}.(1 - m_t - 1/b_t) \qquad \text{for } T_{12} \le t \le T_{21}$$

[27] Equations (7) and (8) become

$$(7') \quad b_{T_{12}} = ((1 - m_{T_{12}})(1 + c_{T_{12}}))^{-1}$$

and

$$(8') \quad b_t = 1 + e^{a(t-T_{12})}(b_{T_{12}} - 1) \qquad T_{12} \le t \le T_{21},$$

respectively.

This equation does not contain stock prices, and so estimates of multiplicative bubble paths derived from it are immune to the criticism that they are determined simultaneously with stock prices.[28] The estimates for the multiplicative bubble version of the brokers' loan rate model are contained in Table I, columns (v) and (vi). The parameter estimates differ minimally from their additive model counterparts (except for α, which has a different interpretation).

The bottom half of Table IV repeats the cointegration tests described above, using logarithms of stock prices and dividends[29], and the (logarithms of) the multiplicative bubble models. The logs of stock prices and dividends are apparently cointegrated, according to the ADF test. However, when the logarithm of the bubble is added to the equation, the ADF statistics are no longer significant. Once again, we regress the residuals from the regression of log prices on log dividends on the log of the bubble terms (which follow linear trends prior to bursting), to assess the marginal significance of the bubble in explaining stock price movements. The critical values for this test can be calculated using the approach of Durlauf and Phillips (1985), from which it follows that the t-statistic of the bubble, corrected for residual serial correlation, is asymptotically standard normal, irrespective of the date at which the bubble term descends to zero.[30] Since, as we have argued, the multiplicative bubble

[28] The principal theoretical difference between multiplicative and additive bubbles, in the context of the representative agent model, is that multiplicative paths can only be rational if no dividends are paid out. Given this condition, multiplicative bubbles are actually immune to the difficulties discussed by Diba and Grossman (1987). For example, declining multiplicative bubbles are possible.

[29] As with the raw values of these series, the first differences of the logarithms appear stationary. We do not report these results explicitly, for the sake of brevity.

[30] It is also straightforward to apply this approach directly to the t-statistic of δ_2 in the logarithmic form of the cointegrating regression, although tabulation of the distribution requires simulations. We use the two-step approach for simplicity, and to maintain comparability with the additive bubble formulation.

path estimates are not contaminated by stock prices from the brokers' loan model, only the standard critical values (under the "independence assumption") are relevant. The calculated t-statistics show that the hypothesis that the bubble paths do not help to explain stock prices is rejected, for the bubbles extracted from both the quarterly and monthly brokers' loan rate models.

These results may be summarized as follows. The standard tests for bubbles in asset prices, based on the presence of unit roots in successive differences of stock prices, and on the cointegration of stock prices and dividends suggest that there was no bubble present in stock prices over the period 1920-1934. In contrast, explicit, independent measures of the potential bubble component turn out to be significantly positively correlated with stock prices, even after the comovement of prices with dividends has been taken into account.

5. Conclusion

This paper has examined the behavior of the premia demanded on loans collateralized by the purchase of stocks for information on the presence of bubbles in the stock market. Our estimation of the premium demanded on brokers' time loans generates estimates of the path of a putative bubble in stock prices at the time of the stock market crash of 1929. These estimates of the bubble path are significantly related to stock price movements after controlling for dividends, a result that stands in contrast to the negative verdict on bubbles in the stock market of the 1920's returned by standard tests based on cointegration between prices and dividends, and the presence of unit roots in successive differences of stock prices.

A precise description of what we have accomplished would note that we have isolated a component in the premium of the brokers' loan rate over the rate on bankers' acceptances, that helps to explain the deviation of stock prices from dividends. Whether this component was a speculative bubble, rational or irrational, is a further matter. Hamilton (1986) has provided examples in which prices depart from fundamentals for a period of time, because people's expectations rationally discount some "large event" that is expected to occur only once, and, prior to its occurrence, has only a small probability of occurring in each period. It is not difficult to show that these dynamics extend to the behavior of the brokers' loan market, as well.

For example, suppose that Congress is deliberating on a measure to cut taxes on stock earnings. On each date before Congress reaches a decision, there is a probability γ that they will pass the measure, a probability δ that it will be defeated, and a probability $1-\gamma-\delta$ they will continue their deliberations the following day. As long as $\gamma > 0$, stock prices will be elevated prior to a decision, because of the recognition that their value will increase if the tax changes are enacted. Similarly, prior to Congress reaching a decision, rates on brokers' loans could be elevated because of the lenders' recognition that the measure could fail, jeopardizing the value of the collateral. If γ and δ both increase over time, with γ rising faster than δ, the brokers' loan rate premium rises over time, and we have generated a common path followed by the brokers' loan premium and the discrepancy between stock prices and current dividends. This common path is in fact the consequence of a shared rational assessment of fundamentals that happen not to be distributed homogeneously in time.

In the context of the markets for stocks and brokers' loans of the 1920s, two weaknesses of this type of story stand out. First, the rare large event has to explain the growth in the spread between rates on brokers' loans and bankers' acceptances, as well as the runup in stock prices. Explanations idiosyncratic to the stock market, such as impending legislation on the tax treatment of earnings are plausible candidates in this case; impending dramatic changes in business conditions are not, since they should affect brokers' loan rates and bankers' acceptances similarly. In any event, contemporary (Dice (1929), Fisher, (1930)) and current (Sirkin, (1975), Barsky and De Long, (1990)) researchers who argue that the 1920s stock market boom was driven by fundamentals emphasize the very healthy state of the American economy.

Second, that a rare large event, such as an impending change in legislation, might come to pass is supposed to be common knowledge to participants in the market, prior to its occurrence. It is hard to believe that such events were entertained prior to the crash of 1929, that the crash itself was the reflection of some such large events occurring, and that, nevertheless, contemporaneous and historical accounts have failed to find even a smoking gun, let alone a culprit. Moreover, the joint behavior of the brokers' loan premium and margin requirements suggests that the putative event would have had to be very large indeed. By late 1929, margin rates had risen to about 50%, or double their level of the early 1920s, while we calculate that the premium of the brokers' loan rate over the rate on bankers' acceptances was 3.6 percentage points higher than would be forecast by the normal relationship with the bankers' acceptance rate[31]. Alternatively, while the Dow Jones index reached 343 at the end of the third quarter of 1929, the paths of the additive bubbles estimated from the brokers' loan rate model reach 188 (quarterly) and 177 (monthly) by this date. From either perspective, it appears to have been anticipated that the large event would knock out about 50% of the value of the stock market, returning it to its level of mid-1927. The only prospective event capable of producing a drop of this magnitude, that was widely discussed prior to the Crash of 1929, was the crash of the stock market itself.

[31] This follows from plugging the estimates in Table I into equation (10a).

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