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# Stock Margins and the Conditional Probability of Price Reversals

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The conclusions of this paper are those of the authors and not necessarily those of the Federal Reserve Bank of Chicago or the Federal Reserve Board of Governors.

## Abstract

The pattern of stock-price reversals is studied to determine the relationship between price reversals and levels of required margin. Reversals occur more frequently prior to the regulation of margin in 1934. This date coincides with a general increase in the level of margins. Our logit specifications indicate that reversal probabilities are conditional on the level of margin. Controls for the effects of time and the introduction of regulation do not alter this conclusion.

## I. Introduction

Examination of stock-price reversals has a long history in empirical finance. Niederhoffer and Osborne (1966) examine stock price reversals in their tests of the random walk model. More recently, Stoll and Whaley (1990) examine reversals for evidence that heavy trading occurring on "triple-witching" days leads to over reaction in stock prices. Kaul and Nimalendran (1991) show that interpreting the price reversals of individual securities as evidence of over-reaction requires adjustments for bid-ask errors. This paper offers a specification which enables testing for the conditionality of reversal probabilities. The specification is employed to examine the impact of margin levels on excess volatility. Our primary test procedure rejects the null of no association between margin levels and the probability of price reversals. Either or both of two explanations are possible: low margins induce price reversals or high margins induce price continuances. Our test specification rejects the null in favor of one or both of these alternatives.

Each of these alternatives has an economic rationale. If low margins encourage excessive participation by noise traders, then low margins can induce excessive volatility. If high margins discourage the participation of information traders, the responsiveness of prices to new information is impaired and return continuances are more likely. In the event both of these alternatives are true, our rejection of the null of no association implies an optimal level for margins.

Considerable research examines the relation between stock-return volatility and margin requirements for equity positions.[1] Hsieh and Miller (1989) demonstrate that interpreting this

[1] See Chance (1990) and France (1991) for reviews of this literature.

evidence is necessarily dependent on the specification presumed for the evolution of volatility. This paper re-frames the margin-volatility question by focusing on the excess-volatility argument which underlies the motivation to regulate margin.[2] Absent a generally accepted specification for excess volatility, an empirical definition is adopted here: Excess volatility is defined as stock-price changes which are subsequently reversed. The idea is that price changes at time t which can be attributed to over-reaction to news are likely to be reversed as initial (but under the null, faulty) valuations are re-assessed. If low margin levels encourage investors to over-react to current information by lowering their cost of placing speculative positions, then the probability of encountering a price reversal will be conditional on the level of required margin. Thus, evidence that reversal probabilities rise at low levels of margin is consistent with excess volatility.

While the reversals predicted by this characterization can occur at any time, we study reversals occurring at time t+1. Thus, our tests impose a restriction not required by the over-reaction hypothesis and, in this sense, our tests may be biased against finding evidence of over-reaction. The paper employs logit specifications to estimate the conditional probability of realizing reversals. We find that reversal probabilities are conditional on margin levels. Specifically, low margin levels are associated with slightly higher probabilities of realizing stock-price reversals. Though the observed impact on conditional probabilities is small, the timing restrictions implicit in our specifications may lead to low estimates of the true effect on reversal probabilities.

As previously indicated, our rejection of the null has two interpretations: margin levels

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[2] See Moser (1991).

may influence the propensity of stock price to reverse direction or to continue in the same direction. Thus, associating high margins with reductions in the probability of reversals is observationally equivalent to high margins increasing the probability of continuances. Such a result has an interesting interpretation. If margin levels increase the odds of continuances, one might argue that high margin levels decrease the rate at which available information is impounded into stock prices. Attempts are made to distinguish between these alternatives. We augment the specification with controls for SEC regulation and for temporal changes in the information-processing capacity of the stock market. Introduction of these controls does not alter our primary conclusion that the probability of price reversals is negatively related to the level of margin.

Section II introduces our data set. Our logit specification is developed in Section III. Section IV examines the sensitivity of our logit specification. Section V summarizes the paper.

## II. Preliminary Examination of Stock-Price Reversals

Reversals, denoted $r_t$, are determined for a sample of daily returns for a broad stock index over the period January 1, 1902 through December 31, 1987.[3] Reversals are computed using these stock returns, which are denoted $R_t$, as follows:

$$r_t = \begin{cases} 1 & \text{if } \tilde{\varepsilon}_t \cdot \tilde{\varepsilon}_{t-1} < 0 \\ 0 & \text{otherwise} \end{cases} \qquad (1)$$

[3] We are grateful to Bill Schwert who supplied the stock-return data. These data are described in Schwert (1990).

where

$$\tilde{\varepsilon}_t = \tilde{R}_t - E(\tilde{R}_t|\phi_t) \tag{2}$$

Equation (1) specifies an indicator variable assigned a value of one on sample dates when the unanticipated portion of the return at t has the opposite sign as that of the unanticipated return at t-1; on other dates, the indicator variable is set to zero. Equation (2) states that unanticipated returns are computed as actual returns minus their corresponding expectations. Expected returns are generated according to three characterizations of the market. The first assumes that stock prices can be described by a martingale; that is, $E(R_t)=0$. The second assumes that stock prices are a submartingale with constant expected returns; that is, $E(R_t)=\alpha$. The third assumes that stock prices are a submartingale with time-varying expected returns; that is, $E(R_t)=\alpha\sigma_t$. The third approach estimates $\sigma_t$ using the iterative method suggested by Schwert (1989) and extended in Bessembinder and Seguin (1993).

This iterative method first regresses the time series of stock returns on a constant. The absolute values of the residuals from this regression are used as risk estimates at each date in the sample. Returns are then regressed on five lags of these risk estimates. This obtains risk-adjusted expected returns. The residuals from this second regression thus allow for the possibility of time variation in risk-adjusted expected returns.

These reversals are classified according to their corresponding level of required margin and the relative frequencies within these classifications studied. Stating the frequency of reversals as a fraction of the number of observations constitutes an estimator for the probability of a reversal conditional on category i; that is,

$$\hat{P}_i = \frac{r_i}{n_i} \quad \textit{where} \quad r_i = \textit{Number reversals in category } i \qquad (3)$$
$$n_i = \textit{Number observations in category } i$$

Figure 1 illustrates this approach. Reversals are computed according to the martingale assumption, then classified by their year of occurrence and their relative frequencies calculated as in equation 3. The figure graphs these probability estimates. The graph suggests a modest but permanent decline in reversal probabilities occurring in the mid-1930s. Comparing pre- and post 1934 reversals, reversal occurrences averaged 48.4% of trading dates prior to 1934. After 1934, average reversal occurrences declined to 43.3% of trading dates.[4] Figure 2 gives margin requirements over this sample period. Initial margin requirements prior to October 15, 1934 were set by the industry. These were obtained from press accounts. After October 1934, margin requirements were set by the Federal Reserve's Board of Governors. We obtain these from Hardouvelis (1990). The higher margin requirements subsequent to their determination by regulatory authority does correspond to the lower reversal probabilities illustrated in Figure 1. However, the decline also corresponds to the increased regulation of the stock market through the provisions of the Securities and Exchange Commission (SEC). Alternatively, one might conclude that innovations such as those in communications technology led to a change in the occurrence of reversals. These

[4] A Student's t test adjusted for unequal variances rejects the equality of these means. The statistic is 5.61, indicating a reliable difference in the means of annual pre- and post-1934 reversal percentages at better than the 5% level.

possibilities are more rigorously examined in the next two sections of the paper.

Reversal frequencies can also be measured in units of the time between reversal occurrences. Let $T_t(r_t=1)$ be the date of a reversal which occurs at time t, then $\tau_t = T_t(r_t=1)-T_{t-k}(r_{t-k}=1)$ gives the days since a reversal occurring k periods previously. These times can be measured in calendar units or in trading-day units. Measured in calendar time, the average time between reversals prior to October 15, 1934 was 2.49 days.[5] After this date, the average increased to 3.11 days. Measured in trading time, the number of trading days between reversals, mean days between reversals go from 2.03 to 2.26 days. The trading time calculation eliminates nontrading intervals which accounts for the declines from the calendar time calculations. Comparing on a percentage basis however, the increase in time between reversals is greater on a calendar-time basis. The percentage increases are: 24.9% on the basis of calendar time and 11.3% on the basis of trading time.

Regressing $\tau_t$ on the percentage of required initial margin considers the relationship of margin with mean-time-between reversals. Measured in calendar units, this coefficient is .0175 and in trading time units it is .0066. Both coefficients are significant at better than the one-percent level. These coefficients imply that higher levels of margin increase the mean time between reversals. In terms of the primary focus of this paper, higher levels of margin decrease the relative frequency of reversals. Thus, these statistics, the average times between reversals and the regression coefficients, offer an alternative means of stating the results indicated by Figures 1 and 2: margin levels rose in 1934 and reversals declined after that

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[5] At the inception of World War I, trading was suspended on the New York Stock Exchange. Thus, the first reversal (dated December 12, 1914) following the resumption of trading is excluded from the calculation of this mean.

date. The next section restates these preliminary results in terms of their conditional probabilities.

## III. Logit Specification

Let $Z_i$ represent an index which measures the propensity of the market to produce a reversal. Under the null that low margins encourage over-reaction as demonstrated by reversals, then the index should be negatively related to levels of required margin. Thus, we would write

$$Z_i = \beta M_i \tag{4}$$

so that levels of the index are predicted by the product of ß and the level of margin. The over-reaction null predicts that ß will be less than zero. The level of this index might also be described as determining the probability of encountering a reversal at the ith level of margin. This can be written as, $P_i=F(Z_i)$. Taking F() to be the cumulative logistic probability function, then the probability of a reversal is given by

$$P_i = F(Z_i) = \frac{1}{1 + e^{-Z_i}} = \frac{1}{1 + e^{-\beta M_i}} \tag{5}$$

Taking logs and re-arranging gives the following logit specification

$$\log\left[\frac{P_i}{1 - P_i}\right] = \beta_0 M_i + \tilde{e}_i \tag{6}$$

The relative frequency of reversals at each level of required margins provides an estimate of the probability of a reversal at that level of margin as in equation (3) with i determined by the respective levels of margin.

Table 1 summarizes these categories, providing percentages of reversal occurrence at each level of required margin. A more precise focus on the excess-volatility hypothesis is obtained by classifying reversals according to the date on which the over reaction is hypothesized to have occurred. Thus, reversals occurring at t+1 are classified by the level of margin at t.[6] The table does suggest a relationship between conditional probability and margin requirements. The last line of the table gives the unconditional probability of a reversal for each of the expected-return models. Comparing these unconditional probabilities with the conditional probabilities in the corresponding columns, the conditional probabilities exceed the unconditional probability at each of the five lowest margin categories. For the remaining nine categories the unconditional probability is exceeded at the 55% margin level and at the 100% level for the martingale series. This result suggests that margin levels are negatively related to the odds of observing stock-price reversals.

Table 2 reports our logit estimates. Panel A provides estimates from the specification given in equation (6). For each of the expected-return models, conditional probabilities are negatively related to initial margin requirements. The impact of a 1% change in required margin on the probability of a reversal is obtained from the expression

[6] Classifying by the level of margin at t+1 does not alter our conclusions. This is not unexpected, margin changes are infrequent.

$$\Delta PROB \approx \beta_0 [\hat{P}_i(1 - \hat{P}_i)] \tag{7}$$

To obtain the effect of margin on reversal probabilities, we evaluate this expression at the unconditional probabilities given on the last line of Table 1. In each case, the effect of margin on reversal probabilities, while statistically significant, is economically small.

Panel B employs a weighted least-squares (WLS) approach suggested by Cox (1970) for its efficiency. This efficiency concern owes to the information lost through formation of classification categories, and increases as the relative probability for any category diverges from .5. Following this approach, the probability estimator is

$$\hat{P}_i = \frac{r_i + \frac{1}{2}}{n_i - r_i + \frac{1}{2}} \quad \textit{where} \quad \begin{aligned} r_i &= \textit{Number reversals in category } i \\ n_i &= \textit{Number observations in category } i \end{aligned} \tag{8}$$

and WLS weights are

$$V_i = \frac{(n_i + 1)(n_i + 2)}{n_i(r_i + 1)(n_i - r_i + 1)} \tag{9}$$

Results reported in panel B are similar to those in panel A. Both panels indicate that an increase in required margin from the present 50% to 60% would reduce reversal probabilities by less than one percent, a very modest impact. Further, one might conclude that the possibility that the higher margin levels observed after 1934 are absorbing impacts which are more properly attributed to other changes coming after that date. This possibility is explored in the next section.

## IV. Robustness of the logit specification

Figure 1 demonstrates a decline in the relative frequency of stock price reversals after the mid 1930s. This suggests that the margin effect evidenced in Table 2 might be attributable to factors other than the level of margin. This section examines two such possibilities: improvements in information technology and the introduction of regulatory oversight.

To control for these possibilities, the specification is augmented by including two variables. An indicator variable is used to control for the difference in regulation in the pre- and post-1934 periods. The observation year is also added to control for differences in information technology. This gives

$$\log\left[\frac{P_i}{1 - P_i}\right] = \beta_0 M_i + \beta_1 YEAR_i + \beta_2 REG_i + \tilde{e}_i \tag{10}$$

Table 3 reports results from this specification. As before, both the OLS and WLS results are provided. The coefficients on margin levels remain significant, we can reject the explanation that the margin coefficients of the previous specification are capturing the related effects of regulatory intervention or to the time component of innovations in information technology. Indeed, comparison of the margin coefficients of Table 2 with those of Table 3 suggests that the previous results understate the relationship of margin and reversal probabilities. Coefficients on the time variable in the WLS specification are positive and significant in the constant and time-varying expected-return models.

## V. Conclusion

Return reversals for stock indexes for the period 1902 through 1987 are examined.

Preliminary evidence suggests that reversal frequencies decreased substantially after 1934. This coincides with higher levels of required margin and with increased regulatory oversight of the stock markets. The results of our logit specifications imply that margin levels are negatively related to the probability of reversals. This permits us to reject the null that margin levels are unrelated to reversals. Rejection of this null implies that margin levels do influence the distribution of stock returns. One possible explanation is that the cost of placing margin deposits acts as a tax. At low levels of this tax noise traders enter the market increasing the odds that prices will diverge from their fundamental levels. Reversions occur when prices return to these levels. At high levels of the tax information traders find it costly to participate and innovations in prices evolve more slowly. This results in a greater frequency of stock price continuances and, consequently, reduces the frequency of reversals. Since neither of these explanations can be excluded by our rejection of the null, an optimal level of margins can be based on the social benefits and costs obtained from the participation of these classes of traders; that is, provided they can be identified.

## References


Bessembinder, Hendrik and Paul J. Seguin, "Price Volatility, Trading Volume, and Market Depth: Evidence from Futures Markets," *Journal of Financial and Quantitative Analysis* 28, 1993, pp. 21-39.

Chance, Don (1991): "The Effects of Volatility of Stocks and Derivative Markets: A Review of the Evidence," *Financial Markets, Institutions and Instruments*, no. 2, Basil Blackwell.

Cox, D.R. (1970): *Analysis of Binary Data*, (London: Methuen).

France, Virginia Grace (1992): "The Regulation of Margin Requirements," in Lester G. Telser, ed., *Margins and Market Integrity*, Mid America Institute and Probus Books, pp. 1-47.

Hardouvelis, Gikas A. (1990): "Margin Requirements, Volatility, and the Transitory Components of Stock Prices," *American Economic Review*, pp. 736-762.

Hseih, David and Merton Miller, "Margin Regulation and Stock Market Volatility," *Journal of Finance* 45, 1990, pp. 3-29.

Kaul, Gautam and M. Nimalendran, "Price Reversals: Bid-Ask Errors or Market Overreaction?" Working Paper no. 91-4, Mitsui Life Financial Research Center, University of Michigan.

Moser, James T. (1992): "Determining Margin for Futures Contracts: the Role of Private Interests and the Relevance of Excess Volatility," *Economic Perspectives* (March/April), p. 2-18.

Niederhoffer, Victor and M. F. M. Osborne, "Market Making and Reversal on the Stock Exchange," *Journal of the American Statistical Association* 61, 1966, pp. 897-916.

Schwert, G. William, "Business Cycles, Financial Crises, and Stock Volatility," *Carnegie-Rochester Conference Series on Public Policy* 31, 1989, p. 83-126.

Schwert, G. William, "Indexes of U.S. Stock Prices from 1802 to 1987," *Journal of Business* 63, 1990, no. 3, pp. 399-426.

Stoll, Hans and Robert Whaley, "Program Trading and Individual Stock Returns: Ingredients of the Triple-Witching Brew," *Journal of Business* 63, pp. s165-s192.

# Figure 1

Reversal percentages by year

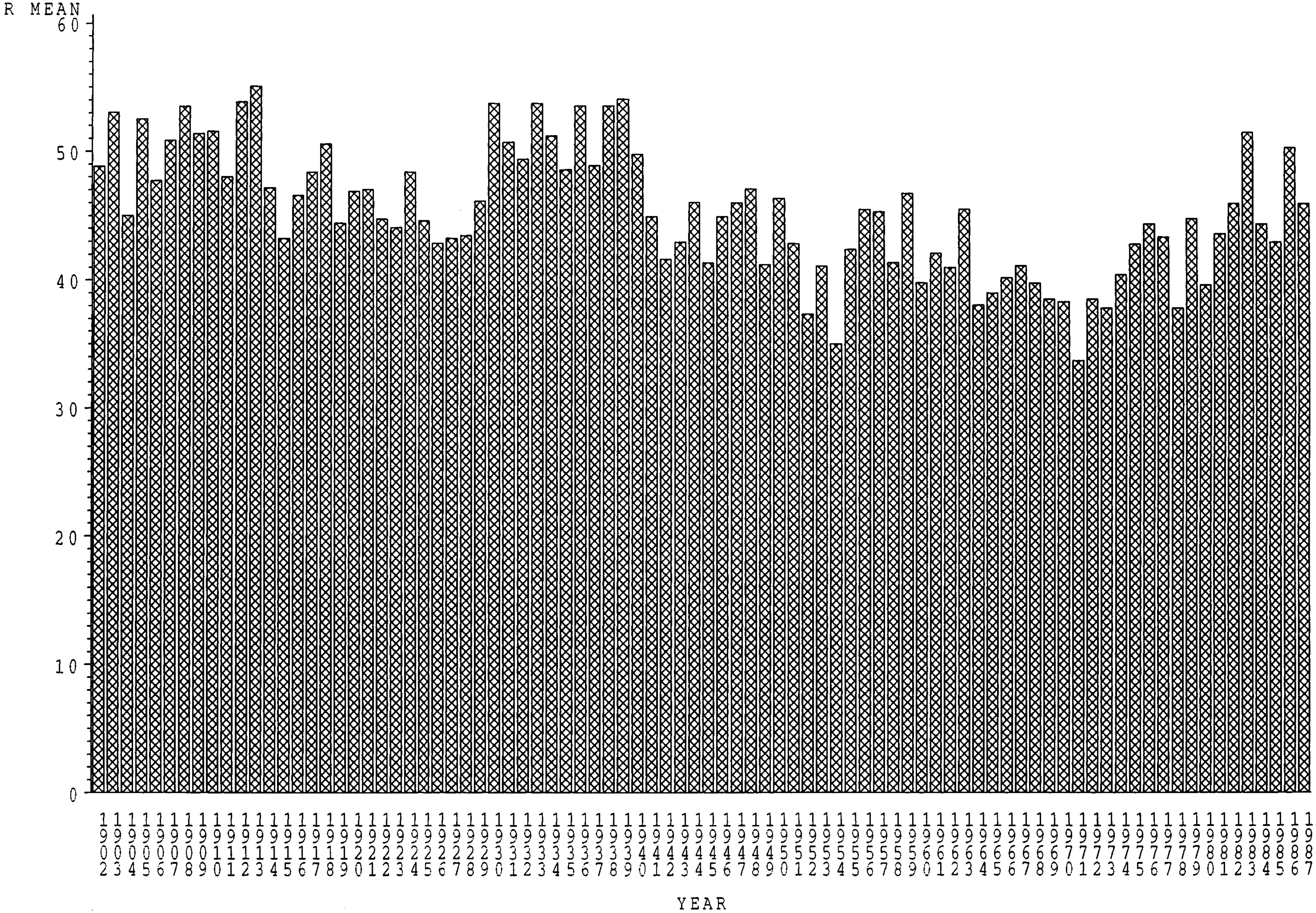
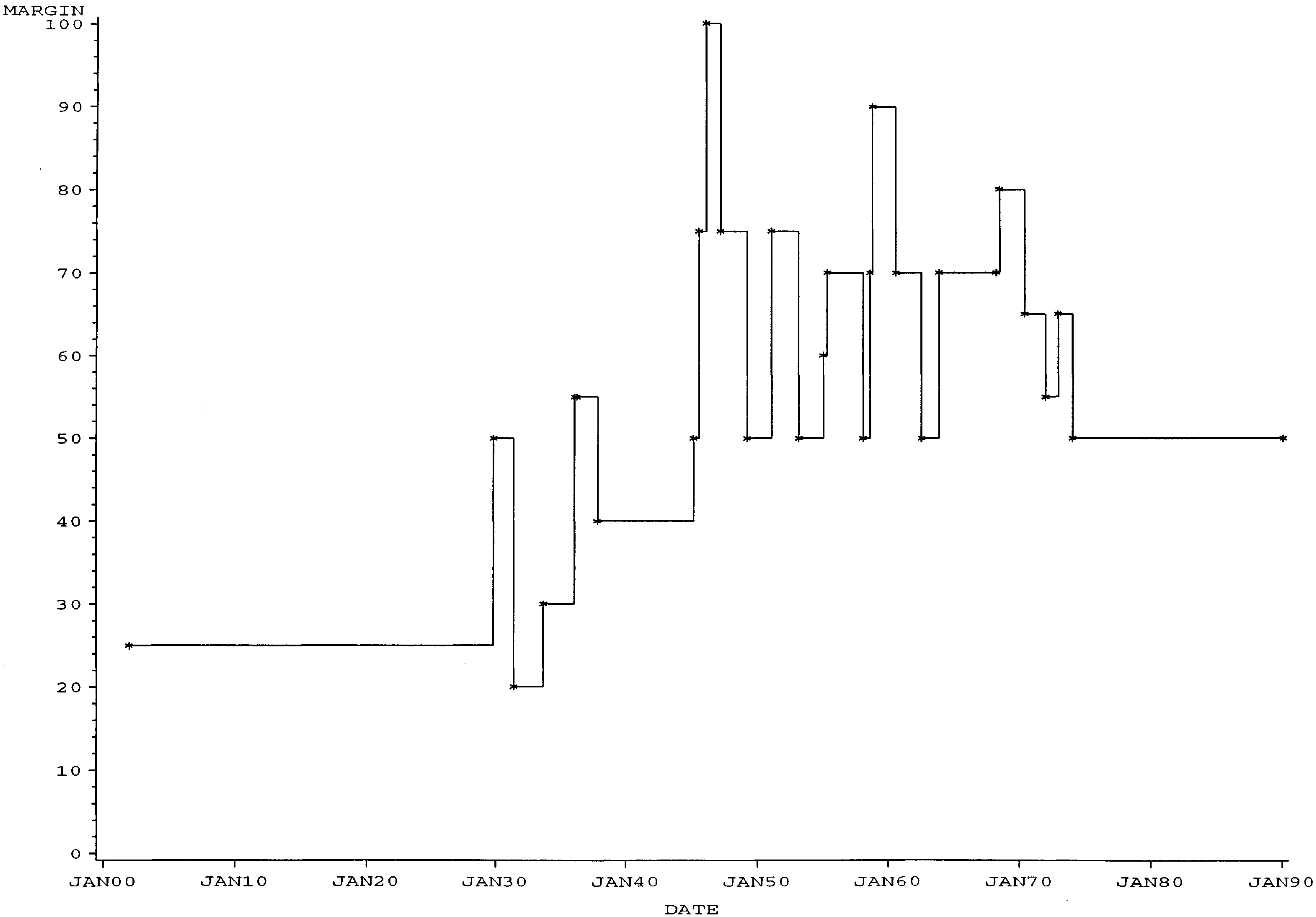


Figure 2
Initial Margin Requirements: 1902-1988




Margin requirements prior to 1934 are from news sources.
After 1934, initial margin set by the Federal Reserve Board of Governors.

**Table 1**
**Initial Margin Requirements and Stock Price Reversals**
**Sample Period: 1902-1987**

| *Initial Margin in Percent* | *Number Observations* | *Percentage of Observations in which Stock Return Reversed:* $E(R_t)=0$ | $E(R_t)=\alpha$ | $E(R_t)=\alpha\sigma_t$ |
|---|---|---|---|---|
| 20 | 410 | 50.244 | 50.244 | 50.244 |
| 25 | 8944 | 48.211 | 48.748 | 48.960 |
| 30 | 326 | 53.374 | 52.147 | 52.761 |
| 40 | 2182 | 47.434 | 48.808 | 48.258 |
| 45 | 390 | 50.256 | 51.795 | 50.256 |
| 50 | 5136 | 43.400 | 44.159 | 44.159 |
| 55 | 770 | 46.623 | 47.922 | 48.182 |
| 60 | 77 | 40.260 | 37.662 | 40.260 |
| 65 | 679 | 35.935 | 36.966 | 36.377 |
| 70 | 2382 | 41.478 | 42.149 | 42.107 |
| 75 | 1298 | 42.604 | 43.991 | 44.299 |
| 80 | 454 | 38.106 | 38.106 | 38.987 |
| 90 | 448 | 44.196 | 43.304 | 42.411 |
| 100 | 307 | 45.928 | 45.277 | 43.974 |
| At all levels of margin: | 23803 | 45.539 | 46.219 | 46.228 |

## Table 2
## Logit Regressions

$$\log\left[\frac{P_i}{1 - P_i}\right] = \beta_0 M_i + \tilde{e}_i$$

Panel a: OLS Estimates

$$\hat{P}_i = \frac{r_i}{n_i} \quad \textit{where} \quad r_i = \textit{Number reversals in category } i, \quad n_i = \textit{Number observations in category } i$$

| | Expected return method | | |
|---|---|---|---|
| | $E(R_t)=0$ | $E(R_t)=\alpha$ | $E(R_t)=\alpha\sigma_t$ |
| $\alpha_0$ | -0.003815 | -0.003721 | -0.003758 |
| | (0.00071) | (0.00073) | (0.00065) |
| $\Delta PROB$ | -0.00095 | -0.00092 | -0.00093 |

Panel b: WLS Estimates

$$\hat{P}_i = \frac{r_i + \frac{1}{2}}{n_i - r_i + \frac{1}{2}} \quad \textit{where} \quad r_i = \textit{Number reversals in category } i, \quad n_i = \textit{Number observations in category } i$$

| | Expected return method | | |
|---|---|---|---|
| | $E(R_t)=0$ | $E(R_t)=\alpha$ | $E(R_t)=\alpha\sigma_t$ |
| $\alpha_0$ | -0.004003 | -0.003663 | -0.003732 |
| | (0.00062) | (0.00062) | (0.00058) |
| $\Delta PROB$ | -0.00099 | -0.00091 | -0.00093 |

Note: Weights are as follows:

$$V_i = \frac{(n_i + 1)(n_i + 2)}{n_i(r_i + 1)(n_i - r_i + 1)}$$

(Standard errors in parentheses.)

**Table 3**
**Logit Regressions**

$$\log\left[\frac{P_i}{1 - P_i}\right] = \beta_0 M_i + \beta_1 YEAR_i + \beta_2 REG_i + \tilde{e}_i$$

Panel a: OLS Estimates

$$\hat{P}_i = \frac{r_i}{n_i} \quad \textit{where} \quad r_i = \textit{Number reversals in category } i$$

$$n_i = \textit{Number observations in category } i$$

| | Expected return method | | |
|---|---|---|---|
| | $E(R_t)=0$ | $E(R_t)=\alpha$ | $E(R_t)=\alpha\sigma_t$ |
| $\alpha_0$ | -0.003987 | -0.005744 | -0.004952 |
| | (0.00156) | (0.00161) | (0.00155) |
| $\alpha_1$ | 0.000028 | 0.000061 | 0.000054 |
| | (0.00003) | (0.00003) | (0.00003) |
| $\alpha_2$ | -0.085699 | -0.007549 | -0.048110 |
| | (0.06776) | (0.06998) | (0.06766) |
| $\Delta PROB$ | -0.000989 | -0.001428 | -0.001231 |

**Table 3--continued**
**Logit Regressions**

Panel b: WLS Estimates

$$\hat{P}_i = \frac{r_i + \frac{1}{2}}{n_i - r_i + \frac{1}{2}} \quad \textit{where} \quad r_i = \textit{Number reversals in category } i$$

$$n_i = \textit{Number observations in category } i$$

| | Expected return method | | |
|---|---|---|---|
| | $E(R_t)=0$ | $E(R_t)=\alpha$ | $E(R_t)=\alpha\sigma_t$ |
| $\alpha_0$ | -0.003824 | -0.004951 | -0.004572 |
| | (0.00151) | (0.00150) | (0.00147) |
| $\alpha_1$ | 0.0000204 | 0.000045 | 0.000044 |
| | (0.00003) | (0.00002) | (0.00002) |
| $\alpha_2$ | -0.081471 | -0.029023 | -0.054743 |
| | (0.06308) | (0.06250) | (0.06120) |
| $\Delta PROB$ | -0.000948 | -0.001231 | -0.001136 |

Note: Weights are as follows:

$$V_i = \frac{(n_i + 1)(n_i + 2)}{n_i(r_i + 1)(n_i - r_i + 1)}$$

(Standard errors in parentheses.)