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WHY DOES STOCK MARKET VOLATILITY CHANGE OVER TIME?

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ABSTRACT

This paper analyzes the relation of stock volatility with real and nominal macroeconomic volatility, financial leverage, stock trading activity, default risk, and firm profitability using monthly data from 1857-1986. An important fact, previously noted by Officer[1973], is that stock return variability was unusually high during the 1929-1940 Great Depression. Moreover, leverage has a relatively small effect on stock volatility. The amplitude of the fluctuations in aggregate stock volatility is difficult to explain using simple models of stock valuation.

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## WHY DOES STOCK MARKET VOLATILITY CHANGE OVER TIME?

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### 1. Introduction

Many researchers have noted that aggregate stock market volatility changes over time. Officer[1973] relates these changes to the volatility of macroeconomic variables. Black[1976] and Christie[1982] argue that financial leverage explains some of this phenomenon. Recently, there have been many attempts to relate changes in stock market volatility to changes in expected returns to stocks, including Merton[1980], Pindyck[1984], Poterba and Summers[1986], French, Schwert and Stambaugh[1987], Bollerslev, Engle and Wooldridge[1988], Genotte and Marsh[1987], and Abel[1988].

Shiller[1981a,1981b] argues that the level of stock market volatility is too high relative to the ex post variability of dividends in the context of a simple present value model. In present value models such as Shiller's, a change in the volatility of either future cash flows or discount rates causes a change in the volatility of stock returns. There have been many critiques of Shiller's work, notably Kleidon[1986]. Nevertheless, no one has analyzed the relation between time-variation in stock return volatility and fundamental determinants of value.

This paper characterizes the changes in stock market volatility through time. In particular, the goal is to relate stock market volatility to the time-varying volatility of a variety of economic variables. Relative to the 1857-1986 period, volatility was unusually high from 1929-1940 for many economic series, including inflation, money growth, industrial production, and

other measures of economic activity. I find evidence that stock market volatility increases with financial leverage, as predicted by Black and Christie, although this factor explains only a small part of the variation in stock market volatility. In addition, interest rate and corporate bond return volatility is correlated with stock return volatility. Finally, stock market volatility increases during recessions and is related to measures of corporate profitability. None of these factors, however, plays a dominant role in explaining the behavior of stock volatility over time.

Section 2 describes the time series properties of the data and the empirical strategy for modeling time-varying volatility. Section 3 analyzes the relations of stock and bond return volatility with the volatility of five important macroeconomic variables. Section 4 studies the relation between stock market volatility and corporate profitability. Section 5 analyzes the relation between financial leverage and stock return volatility, and the relation between stock market trading activity and volatility. Finally, section 6 synthesizes the results from the preceding sections and presents concluding remarks.

## 2. Time Series Properties of the Data

The Appendix describes the sources used to construct the data in this paper. Table 1 lists these variables. There are measures of: stock returns ( $Stock_t$ ), short ( $Int_t$ ) and long-term bond yields and returns ( $Hibond_t$  and  $Medbond_t$ ), inflation ( $PPI_t$ ), monetary growth ( $Base_t$ ), aggregate real economic activity ( $IP_t$ ,  $Fail_t$  and  $Bank_t$ ), financial leverage ( $S/V_t$ ), dividend ( $D/P_t$ ) and earnings yields ( $E/P_t$ ) for stocks, and stock market trading activity, including the growth rate of share trading volume ( $Volume_t$ ) and the number of trading days per month ( $Days_t$ ). The measure of stock market volatility based

Table 1  
 Monthly Variables Used in This Paper

Series	Description	Sample Period, Size
Stock	Monthly return to a value-weighted portfolio of New York Stock Exchange stocks (CRSP/Cowles/Macaulay)	2/1857 - 12/1986 T=1559
$\sigma_t$	Volatility of returns to Standard & Poor's composite index (French, Schwert and Stambaugh)	1/1926 - 12/1986 T=732
Int	Short-term interest rate on low risk debt instrument (CRSP/Macaulay)	1/1857 - 12/1986 T=1560
Hibond	Yield or return on high-grade long-term corporate debt (Moody's Aa/Macaulay)	1/1857 - 12/1986 T=1560
Medbond	Yield or return on medium-grade long-term corporate debt (Moody's Baa)	1/1919 - 12/1986 T=816
PPI	Inflation of producer price index for all commodities (BLS/Macaulay)	2/1862 - 12/1986 T=1499
Base	Growth rate of monetary base (high-powered money) (Friedman & Schwartz/NBER/Federal Reserve)	7/1878 - 12/1986 T=1302
IP	Growth rate of the index of industrial production (seasonally adjusted - Federal Reserve)	2/1889 - 12/1986 T=1175
Bank	Growth rate of bank clearings or debits (Macaulay/Federal Reserve)	1/1854 - 12/1986 T=1560
Fail	Growth rate of liabilities of business failures (Dun and Bradstreet)	2/1875 - 3/1986 T=1335
S/V	Market value of stock divided by firm value for S&P composite index (Holland and Myers)	1/1900 - 12/1986 T=1044
Volume	NYSE share trading volume (S&P/NYSE)	4/1881 - 12/1986 T=1268
Days	Number of NYSE trading days per month (S&P)	1/1928 - 12/1986 T=708
D/P	Dividend yield for Standard & Poor's composite index (S&P/Cowles)	1/1871 - 12/1986 T=1392
E/P	Earnings yield for Standard & Poor's composite index (S&P/Cowles)	1/1871 - 12/1986 T=1392

on daily stock returns within the month,  $\sigma_t$ , is from French, Schwert and Stambaugh[1987].

### 2.1 Volatility of Stock Returns

The French-Schwert-Stambaugh estimate of the monthly standard deviation of stock returns uses the daily Standard and Poor's (S&P) composite portfolio from January 1928 through December 1986. The estimate from January 1926 through December 1927 uses weekly data. Nonsynchronous trading of securities causes daily portfolio returns to be autocorrelated, particularly at lag one (see Fisher[1966] and Scholes and Williams[1977]). Because of this autocorrelation, the estimate of the variance of the monthly return to the S&P portfolio is the sum of the squared daily returns plus twice the sum of the products of adjacent returns,

$$\sigma_t^2 = \sum_{i=1}^{N_t} r_{it}^2 + 2 \sum_{i=1}^{N_t-1} r_{it}r_{i+1,t}, \quad (1)$$

where there are  $N_t$  daily returns,  $r_{it}$ , in month  $t$ . There is no adjustment for the sample mean because this adjustment is small (see Merton[1980]). Using nonoverlapping samples of daily data to estimate the monthly variance creates estimation error that is uncorrelated through time.<sup>1</sup>

Daily and weekly stock return data are not readily available prior to 1926,

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<sup>1</sup>If the data are normally distributed, the variance of the estimate  $\sigma_t$  is  $\sigma_t^{*2}/2N_t$ , where  $\sigma_t^{*2}$  is the true variance (Kendall and Stuart[1969, p. 243]). Thus, for  $N_t = 22$  and  $\sigma_t^* = .04$ , the standard error of  $\sigma_t$  is .006, which is small relative to the level of  $\sigma_t^*$ . Since this is a classic errors-in-variables problem, the autocorrelations of the estimates  $\sigma_t$  will smaller than, but will decay at the same rate as, the autocorrelations of the true values  $\sigma_t^*$ .

so monthly returns are used to calculate estimates of stock market volatility with the following algorithm:

- (i) estimate a 12<sup>th</sup> order autoregression for the returns, including dummy variables  $D_{jt}$  to allow for different monthly mean returns, using all data available for the series,

$$R_t = \sum_{j=1}^{12} \alpha_j D_{jt} + \sum_{i=1}^{12} \beta_i R_{t-i} + \epsilon_t; \quad (2a)$$

- (ii) estimate a 12<sup>th</sup> order autoregression for the absolute values of the errors from (2a), including dummy variables to allow for different monthly standard deviations,

$$|\epsilon_t| = \sum_{j=1}^{12} \gamma_j D_{jt} + \sum_{i=1}^{12} \rho_i |\epsilon_{t-i}| + u_t; \quad (2b)$$

- (iii) the regressand  $|\epsilon_t|$  is an estimate of the standard deviation of the stock market return for month t analogous to  $\sigma_t$  (although it uses 1 rather than 22 observations). The fitted values from (2b) estimate the conditional standard deviation of  $R_t$ , given information available before month t.<sup>2</sup>

This method is a generalization of the 12-month rolling standard deviation estimator used by Officer[1973], Fama[1976] and Merton[1980], because it allows the conditional mean return to vary over time (in (2a)), and it allows the different weights for lagged absolute unexpected returns (in (2b)). It is similar to the autoregressive conditional heteroskedasticity (ARCH) model of

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<sup>2</sup>Since the expected value of the absolute error is less than the standard deviation from a Normal distribution,  $E|\epsilon_{st}| = \sigma_t(2/\pi)^{1/2}$ , all absolute errors are multiplied by the constant  $(2/\pi)^{-1/2} \approx 1.2533$ . Dan Nelson suggested this correction.

Engle[1982]. Davidian and Carroll[1987] argue that standard deviation specifications such as (2b) are more robust than variance specifications based on  $\epsilon_t^2$ .

Figure 1 plots the predicted standard deviations  $|\hat{\epsilon}_{st}|$  for 1859-1986, along with the predicted standard deviations  $\hat{\sigma}_t$  (from a 12<sup>th</sup> order autoregression for  $\sigma_t$  as in (2b)) for 1926-1986 (denoted "+"). It is apparent from Figure 1 that the predicted volatility series are similar and persistent over time, indicating that the stock market volatility is autocorrelated.

Table 2A contains means, standard deviations, skewness coefficients and autocorrelations of the estimates of stock return volatility based on monthly and daily data,  $|\epsilon_{st}|$  and  $\sigma_t$ . It also contains summary statistics for estimates of the volatility of: short and long-term bond returns,  $|\epsilon_{rst}|$ ,  $|\epsilon_{rht}|$  and  $|\epsilon_{rmt}|$ ; inflation,  $|\epsilon_{pt}|$ ; money growth,  $|\epsilon_{mt}|$ ; and aggregate real economic activity,  $|\epsilon_{it}|$ ,  $|\epsilon_{dt}|$  and  $|\epsilon_{ft}|$ . Table 2B summarizes the autoregressions used to predict volatility. The sum of the autoregressive coefficients measures the persistence of the volatility series, where a value of unity implies nonstationarity (see Engle and Bollerslev[1986] for a discussion of integrated conditional heteroskedasticity). The F-test measures whether there is significant deterministic seasonal variation in the average volatility estimates. The coefficient of determination  $R^2$  and the Box-Pierce[1970] statistic  $Q(24)$  measure the adequacy of the fit of the model. Table 2C contains cross correlations between the predictions for December volatility of the variables in Table 2A with the one lead, current and one lag of predicted stock return volatility  $|\epsilon_{st}|$ . These annual cross correlations show the timing relations among these volatility series.

As suggested by the analysis in footnote 1, the estimates of volatility



# Predicted Stock Market Volatility

Based on Monthly or Daily Returns

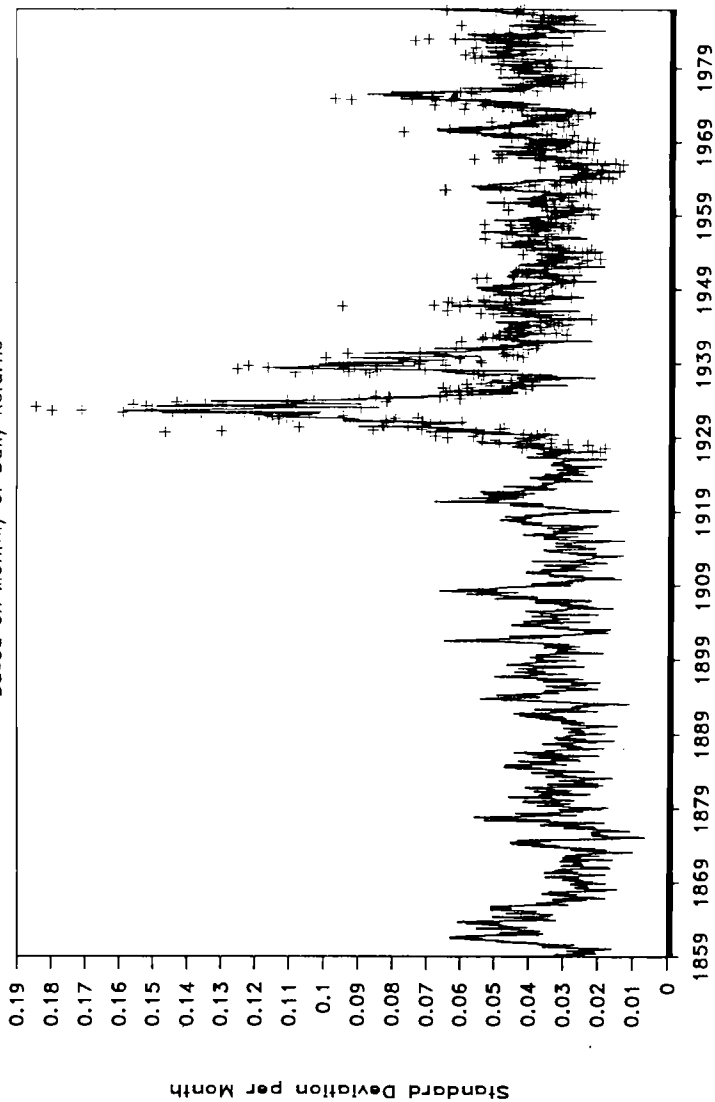


Figure 1. January 1859 - December 1986  
— Monthly  
+ Daily

from daily data have much less error than the estimates from monthly data. The sample standard deviation of  $|\epsilon_{st}|$  is about fifty percent larger than that of  $\sigma_t$  from 1926-1986, though the average values are similar. Moreover, the autocorrelations of  $\sigma_t$  are much larger than those of  $|\epsilon_{st}|$ , though they decay slowly for both series. This slow decay shows that stock volatility is highly persistent, perhaps nonstationary (see Poterba and Summers[1986] and Schwert[1987] for further discussion). The correlation between  $|\epsilon_{st}|$  and  $\sigma_t$  is .61 from 1926-1986, and the correlation between the volatility predictions  $|\hat{\epsilon}_{st}|$  and  $\hat{\sigma}_t$  is .85 from 1927-1986. The two methods of predicting volatility have similar time series properties. This is fortunate since daily and weekly data are not readily available before 1926.

It is interesting that the autocorrelations in Table 2A, and the summary statistics for the estimated models in Table 2B, are similar for all of the volatility series. The autocorrelations are small (between .2 and .4), but they decay very slowly. This is consistent with conditional volatility being an integrated moving average process, so shocks to volatility have both permanent and transitory components. The 'unit root' tests in Table 2B show that the sum of the autoregressive coefficients is reliably different from unity using the tables in Fuller[1976]. However, Schwert[1987,1988] shows that the Fuller critical values are misleading in situations such as this. The estimation error from using a single absolute error in (2b) biases the unit root estimates toward stationarity.<sup>3</sup> The results for the estimate of stock volatility from daily data support this conclusion, since the sum of the autoregressive coefficients is closer to unity, and the test statistic is

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<sup>3</sup>Also see Pagan and Ullah[1988] for a discussion of the errors-in-variables problem associated with models such as (2b).

Table 2A

Monthly Estimates of the Standard Deviations of  
Stock Market Returns and Other Variables, 1859-1986

Means, Standard Deviations, Skewness, and Autocorrelations of Volatility

Series		Sample Period	Sample Size	Mean	Std Dev	Skew	$r_1$	$r_2$	$r_3$	$r_4$	$r_{11}$	$r_{12}$	Q(24)
Stock	$ e_{st} $	1858-1986	1548	.0392	.0394	3.20	.26	.25	.27	.21	.22	.21	1487
Stock	$ e_{st} $	1926-1986	732	.0487	.0487	2.93	.24	.23	.26	.19	.25	.21	665
Stock	$\sigma_t$	1926-1986	732	.0466	.0318	2.89	.71	.59	.55	.54	.49	.45	3633
Int	$ e_{rst} $	1858-1986	1548	.0004	.0005	4.11	.31	.30	.26	.24	.15	.18	1287
Hibond	$ e_{rht} $	1858-1986	1548	.0082	.0106	3.16	.42	.35	.37	.33	.24	.22	2731
Medbond	$ e_{rmt} $	1920-1986	804	.0130	.0178	5.38	.37	.33	.38	.37	.26	.22	1398
PPI	$ e_{pt} $	1863-1986	1487	.0113	.0169	5.02	.48	.41	.41	.33	.26	.24	2785
Base	$ e_{mt} $	1879-1986	1290	.0078	.0096	3.11	.38	.28	.21	.17	.28	.28	1335
IP	$ e_{it} $	1890-1986	1164	.0193	.0207	2.16	.41	.26	.27	.21	.20	.17	1351
Bank	$ e_{dt} $	1858-1986	1548	.0712	.0676	2.49	.18	.18	.12	.13	.19	.22	945
Fail	$ e_{ft} $	1876-1986	1323	.2657	.2363	1.92	.21	.17	.09	.10	.13	.14	438

Note: For the variables described in Table 1, the algorithm in equations (2a,b) is used to estimate the monthly standard deviation of the return or growth rate (e.g.,  $|e_{st}|$  for the monthly stock return estimate of volatility). Briefly, a 12th order autoregression with different monthly intercepts is used to model the growth rates, then the absolute values of the errors from this model estimate the monthly standard deviation. Table 2A contains means standard deviations, autocorrelations at lags 1, 2, 3, 4, 11, and 12 and the Box-Pierce statistic for 24 lags of the autocorrelations Q(24). The only exception is the estimate of stock market volatility based on daily stock returns within the month from French, Schwert and Stambaugh[1987], denoted  $\sigma_t$ .

Table 2B  
 Monthly Estimates of the Standard Deviations of  
 Stock Market Returns and Other Variables, 1859-1986  
Autoregressive Predictive Models for Volatility

Series		Sum of AR Coefficients (t-test vs 1)	F-test for Equal Monthly Intercepts (p-value)	R <sup>2</sup>	Q(24)
Stock	$ \epsilon_{st} $	.7690 (-2.42)	2.91 (.0007)	.203	24.9
Stock	$\sigma_t$	.8994 (-1.88)	1.89 (.036)	.586	16.8
Int	$ \epsilon_{rst} $	.7198 (-3.97)	1.45 (.144)	.200	30.0
Hibond	$ \epsilon_{rht} $	.7885 (-3.15)	1.25 (.246)	.288	50.0
Medbond	$ \epsilon_{rmt} $	.8101 (-1.53)	1.34 (.195)	.361	29.3
PPI	$ \epsilon_{pt} $	.7933 (-2.23)	0.76 (.681)	.333	51.1
Base	$ \epsilon_{mt} $	.7804 (-3.23)	1.35 (.187)	.237	23.1
IP	$ \epsilon_{it} $	.7437 (-4.56)	0.72 (.719)	.232	31.0
Bank	$ \epsilon_{dt} $	.7212 (-4.23)	1.31 (.216)	.139	29.3
Fail	$ \epsilon_{ft} $	.6101 (-5.61)	1.79 (.050)	.106	36.1

Note: Table 2B contains summary statistics for the 12th order autoregression for the volatility estimates in equation (2b), including the sum of the autoregressive coefficients (indicating the persistence of the series), a 't-test' for whether the sum equals unity (indicating non-stationarity), an F-test for the equality of the 12 monthly intercepts and its p-value, the coefficient of determination R<sup>2</sup>, and the Q(24) statistic for the residual autocorrelations (which should be distributed as  $\chi^2(12)$  in this case).

Table 2C  
Cross Correlations of Annual Stock Volatility Predictions with  
Annual Predictions of Other Volatility Series

Series -- $X_t$	Sample Period	Sample Size	$\text{Cor}(X_t,  \hat{\epsilon}_{st-1} )$	$\text{Cor}(X_t,  \hat{\epsilon}_{st} )$	$\text{Cor}(X_t,  \hat{\epsilon}_{st+1} )$	
Int	$ \epsilon_{rst} $	1859-1986	127	-.03	.08	-.12
Hibond	$ \epsilon_{rht} $	1859-1986	127	.25	.50	.38
Medbond	$ \epsilon_{rmt} $	1921-1986	66	.47	.72	.65
PPI	$ \epsilon_{pt} $	1864-1986	123	-.01	.03	.01
Base	$ \epsilon_{mt} $	1881-1986	107	.22	.31	.39
IP	$ \epsilon_{it} $	1891-1986	96	.16	.24	.19
Bank	$ \epsilon_{dt} $	1859-1986	127	.03	.08	.06
Fail	$ \epsilon_{ft} $	1877-1986	110	-.06	.03	.03

Note: Table 2C contains the cross correlations between the predictions of December volatility for each of the variables in the first column with the predicted volatility of stock returns  $|\hat{\epsilon}_{st}|$  for the current year, the previous year, and the next year. These measures of predicted volatility are the fitted values from the models estimated in Table 2B.

smaller.

## 2.2 Volatility of Short and Long-term Bond Returns

To provide perspective on the time-varying volatility of stock returns, I also analyze the volatility of short and long-term bond returns. Monthly interest rate volatility is estimated from 1859-1986 using equations (2a,b). Since these short-term securities are essentially default-free, the volatility of  $\text{Int}_t$  measures time variation in the ex ante nominal interest rate, not 'risk.'<sup>4</sup> Figure 2a plots the predicted values of short-term interest rate volatility  $|\hat{\epsilon}_{rst}|$  for 1859-1986.

If the underlying 'business risk' of the firm rises, the risk of both the stock and the bonds of the firm should increase. Also, if leverage increases, both the stocks and the bonds of the firm become more risky. Thus, in many instances the risk of corporate stock and corporate debt should change over time in similar ways. High-grade (Aa) and medium-grade (Baa) bond return volatility,  $|\epsilon_{rht}|$  and  $|\epsilon_{rmt}|$ , is estimated using equations (2a,b). The high-grade series is from 1858-1986 and the medium-grade series is from 1920-1986. Figure 2b plots the predicted values of long-term high-grade bond return volatility  $|\hat{\epsilon}_{rht}|$  from 1859-1986.

Summary statistics for the estimates of interest rate and bond return volatility are in Tables 2A and 2B. As expected, the average level of volatility is highest for the medium-grade bond returns, next highest for high-grade bond returns, and lowest for short-term interest rates. All of these assets have much lower volatility than the stock returns. Nevertheless, the autocorrelations are similar to those for the monthly stock return

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<sup>4</sup>See Fama[1976] for an analysis of the variability of short-term nominal interest rates.

## Predicted Shortterm Interest Volatility

Based on Monthly Yields

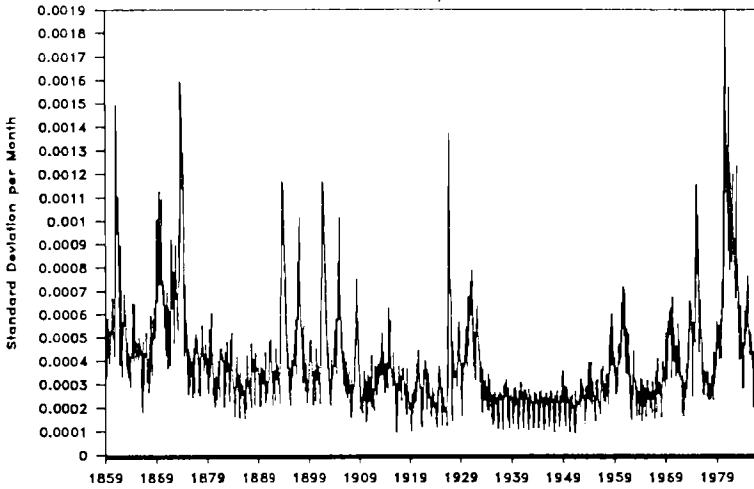


Figure 2a. January 1859 - December 1986

## Predicted Bond Return Volatility

Based on Monthly Aa Bond Returns

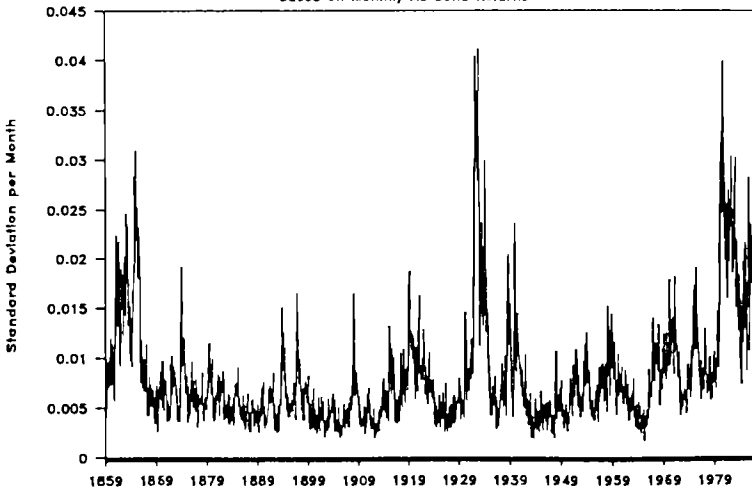


Figure 2b. January 1859 - December 1986

volatility series. The cross correlations in Table 2C between predicted short-term interest rate volatility and predicted stock return volatility are small. However, both of the predicted bond return volatility measures have large positive cross correlations with predicted stock return volatility at all three lags.

There are many similarities among the predicted volatilities of stock and bond returns in Figures 1, 2a and 2b. In particular, volatility was very high from 1929-1940 relative to the rest of the 1859-1986 period. Moreover, bond returns were unusually volatile in the periods during and immediately following the Civil War (1861-1865) and World War I (1914-1918). This phenomenon is less obvious in the plot of stock return volatility in Figure 1. In recent times, the 'OPEC oil shock' (1973-1974) caused an increase in the volatility of stock returns, bond returns and short-term interest rates. Finally, it is apparent from Figures 2a and 2b that bond return volatility increased dramatically around 1979. There is not a similar increase in stock return volatility. As noted by Huizinga and Mishkin[1986], the Federal Reserve Board changed its operating procedures to focus on monetary aggregate targets at this time. Thus, the time pattern of interest rate and bond return volatility has both similarities with and differences from the behavior of stock return volatility. The rest of the paper provides detailed analysis of these relations.

### 3. Relations between Stock Market Volatility and the Volatility of Macroeconomic Variables

It is useful to think of stock prices as the discounted present value of expected future cash flows to stockholders (dividends and capital gains),

$$E_{t-1}(D_{t+k}),$$



$$P_t = \sum_{k=1}^{\infty} \frac{E_{t-1}(D_{t+k})}{[1 + E_{t-1}(R_{t+k})]^k} \quad (3)$$

where  $E_{t-1}(R_{t+k})$  is the expected discount rate for period  $t+k$  based on information available at time  $t-1$ . The conditional variance of the stock price at time  $t-1$ ,  $\text{Var}_{t-1}(P_t)$ , depends on the conditional variances of expected future cash flows and of future discount rates, and of the conditional covariances between these series.<sup>5</sup>

At the aggregate level, the value of corporate equity clearly depends on the health of the economy. If discount rates are constant over time in (3), the conditional variance of security prices is proportional to the conditional variance of the expected future cash flows. Thus, it is plausible that a change in the level of uncertainty about future macroeconomic conditions would cause a proportional change in stock return volatility.<sup>6</sup> If macroeconomic data provide information about the volatility of either future expected cash flows, or future discount rates, it can help explain why stock return volatility has changed over time. Of course, if securities markets are subject to 'fads' or 'bubbles,' stock market volatility would be unrelated to the volatility of fundamental valuation factors.

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<sup>5</sup>The variance of the sum of a sequence of ratios of random variables is not a simple function of the variances and covariances of the variables in the ratios, but standard asymptotic approximations depend on these parameters.

<sup>6</sup>For positively autocorrelated variable, such as the volatility series in Table 2A, an unexpected increase in the variable implies an increase in expected future values of the series for many steps ahead. Given the discounting in (3), the volatility series will move almost proportionally. See Poterba and Summers[1986] for a simple model that posits a particular ARIMA process for the behavior of the time-varying parameters in a related context.

It is easy to imagine that wars, business cycles, and major changes in factor prices (e.g., the OPEC oil shock), could affect the volatility of real activity, inflation and asset values. In fact, several analysts have noted that the volatility of macroeconomic variables changes over time. Officer[1973] finds that industrial production and money growth are more volatile from 1929-1933 than in his overall 1919-1969 sample period. He finds that stock market volatility is more closely related to industrial production volatility than to money growth volatility. Mascaro and Meltzer[1982] find a positive relation between money growth volatility and the level of short and long-term interest rates. Lauterbach[1988] finds that industrial production volatility and consumption volatility are related to expected returns to short-term debt securities for 1964-1985. It is important to note, however, that faulty data collection procedures probably affect the measured volatility of many macroeconomic series before 1940. See Romer[1986a,b,c] for a discussion of unemployment, industrial production and gross national product data, respectively.

### 3.1 Volatility of Inflation and Monetary Growth

The stock and bond returns analyzed above all measure nominal (dollar) payoffs. When inflation of goods' prices is uncertain, the volatility of nominal asset returns should reflect inflation volatility. I use the algorithm in equations (2a,b) to estimate monthly inflation volatility from 1863-1986 for the PPI inflation rate. Figure 3a plots the predicted PPI inflation volatility  $|\hat{\epsilon}_{pt}|$  from 1864-1986. Figure 3b plots the predicted

volatility of the monetary base growth rates  $|\hat{\epsilon}_{mt}|$  from 1880-1986.<sup>7</sup> Summary statistics for these estimates are in Tables 2A and 2B.

The volatility of the inflation was extremely high around the Civil War (1864-1871), reflecting changes in the value of currency relative to gold after the United States (US) went off the gold standard in 1862. Since the United Kingdom (UK) remained on the gold standard, this also represents volatility in the exchange rates between US and UK currencies. The Spanish-American War (1898), World War I and its aftermath (1914-1921), and World War II (1941-1946) are also periods of high inflation uncertainty. Another increase in inflation volatility occurred during the 1973-1974 OPEC oil crisis. While inflation volatility increased during the 1929-1940 period, this change is minor compared with the volatility that occurred during wars.

The volatility of money base growth rates rose during the bank panic and recession of 1893 and remained high until about 1900. The next sharp increase in volatility occurred during the bank panic of 1907. The period following the formation of the Federal Reserve System (1914-1923) was another period of high volatility. Finally, the period of the Great Depression (1929-1940) was a period of very high volatility. Since the early 1950s, the volatility of the monetary base growth rate has been relatively low and stable.

The annual cross correlations between inflation volatility and stock volatility in Table 2C are small. The cross correlations between stock volatility and money growth volatility are reliably positive at all three lags.

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<sup>7</sup> I also analyzed the Bureau of Labor Statistics Consumer Price Index inflation volatility from 1915-1986, and money supply (M2) growth volatility from 1910-1986. The results were similar to the PPI and Base volatility series, so they are not presented.

## Predicted Volatility of Inflation Rates

Monthly Producer Price Index Data

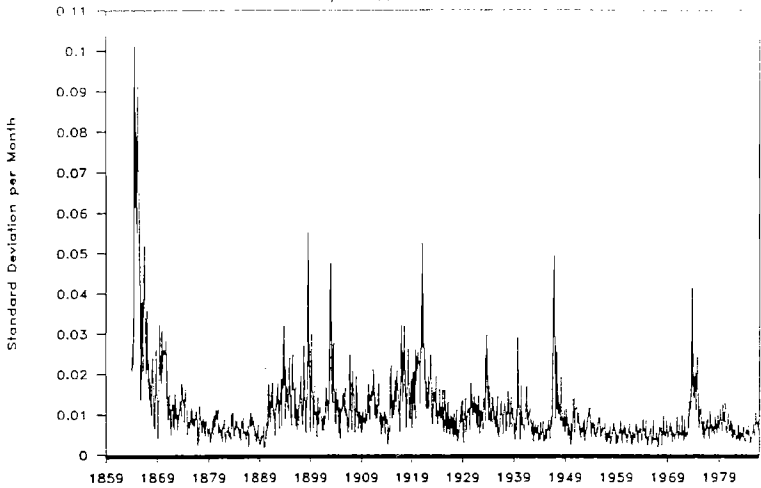


Figure 3a. January 1864 - December 1986

## Predicted Volatility of Money Growth

Monthly Monetary Base Data

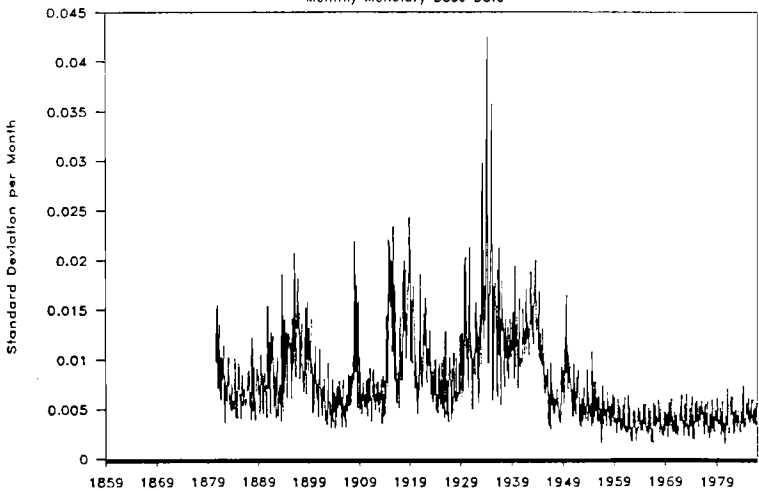


Figure 3b. July 1880 - December 1986

Table 3A contains tests of the incremental predictive power of 12 lags of PPI inflation volatility  $|\epsilon_{pt}|$  in a 12<sup>th</sup> order vector autoregressive (VAR) system for stock volatility, high-grade bond return volatility  $|\epsilon_{rht}|$ , and short-term interest volatility  $|\epsilon_{rst}|$ , that allows for different monthly intercepts. The VAR model uses both the monthly measure of stock return volatility  $|\epsilon_{st}|$  and the daily measure  $\sigma_c$ .<sup>8</sup> These VAR models are generalizations of the autoregressive model in (2b), but they include lagged values of other variables to help volatility. The F-tests in Table 3A measure the significance of the lagged values of the column variable in predicting the row variable, given the other variables in the model.

The pattern of results in Table 3A is clear: the volatilities of close substitutes are most correlated. The largest F-statistics are on the main diagonal of these matrices, and the size of the statistics decreases away from the diagonal. For example, lagged stock volatility is the most important variable in predicting current stock volatility. Lagged bond return volatility also helps in most sample periods, and lagged short-term interest volatility contributes less. Likewise, stock volatility helps predict bond return volatility in most periods, but it rarely improves predictions of interest rate volatility. In most sample periods, short-term interest volatility helps predict bond return volatility and vice versa.

The strongest evidence that inflation volatility affects stock return volatility is from 1953-1986. For both measures of stock volatility, the F-

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<sup>8</sup> Models using the volatility of medium-grade bond return volatility,  $|\epsilon_{rmt}|$ , instead of high-grade bond return volatility, yielded similar results for the post-1926 periods. Medium-grade bond volatility is more strongly related to the stock volatility, and more weakly related to the short-term interest rate volatility, but the relations with the macroeconomic volatility series are generally similar. Because these data are only available from 1920-1986, and the results are similar, they are not reported.

statistic is greater than 3.6, much larger than the .01 critical value. Most of the other tests are small, except predicting long-term bond return volatility from 1864-1926.

The present value relation in (3) is forward-looking. In an efficient market speculative prices will react in anticipation of future events. Thus, it is also of interest to see whether asset return volatility helps forecast subsequent volatility of macroeconomic variables. Except 1864-1926, when long-term bond return volatility helps predict inflation volatility, there is little evidence to suggest that asset return volatility helps predict future inflation volatility. Perhaps this is because the major changes in inflation volatility occur during wars, and there seems to be little effect of wars on stock or bond return volatility.

Table 3B contains tests of the incremental predictive power of 12 lags of monetary base growth volatility  $\{\epsilon_{mt}\}$  in a 12<sup>th</sup> order VAR system similar to Table 3A. The relations among the measures of financial return volatility are similar to Table 3A. Except 1881-1926 with long-term bond returns, there is little evidence that money growth volatility helps predict the volatility of asset returns. On the other hand, in 1927-1952 (and the sample periods that include this subperiod), stock return volatility helps predict the volatility of the base growth rate.

Thus, the relations between inflation or money growth volatility with the volatility of asset returns are not strong. It is surprising that these macroeconomic measures of nominal volatility are not more closely linked with the volatility of short and long-term bond returns.

Table 3A

Estimates of the Relations Among Stock, Bond, Interest Rate and  
PPI Inflation Volatility, 1864-1986 and Subperiods

Vector Autoregressive Models for Stock, Bond and  
Interest Rate Volatility, Including Volatility of PPI Inflation

Dependent Variable	<u>F-tests with Monthly Stock Volatility</u>				<u>F-tests with Daily Stock Volatility</u>			
	Stock	Bond	Int	PPI	Stock	Bond	Int	PPI
				<u>1864-1986</u>				
Stock	18.65	3.11	1.26	0.75				
Hibond	$\begin{matrix} \epsilon_{rht} \\ \epsilon_{rst} \\ \epsilon_{pt} \end{matrix}$	5.50	23.35	2.52	2.34			
Int		2.14	3.24	20.15	0.69			
PPI		0.79	2.08	0.72	56.73			
				<u>1864-1926</u>				
Stock	3.31	1.39	0.95	1.16				
Hibond	$\begin{matrix} \epsilon_{rht} \\ \epsilon_{rst} \\ \epsilon_{pt} \end{matrix}$	1.44	9.24	1.19	4.95			
Int		1.74	1.94	11.49	0.39			
PPI		1.22	4.70	0.65	14.90			
				<u>1927-1986</u>				
Stock	8.19	2.31	1.26	1.01	42.83	2.48	0.55	0.96
Hibond	$\begin{matrix} \epsilon_{rht} \\ \epsilon_{rst} \\ \epsilon_{pt} \end{matrix}$	4.82	6.53	4.56	1.37	2.63	6.96	4.37
Int		1.81	4.90	8.22	1.00	1.56	5.05	8.04
PPI		1.51	1.66	0.45	11.66	1.92	2.02	0.56
				<u>1927-1952</u>				
Stock	1.76	2.44	2.61	0.48	10.88	4.12	3.28	0.35
Hibond	$\begin{matrix} \epsilon_{rht} \\ \epsilon_{rst} \\ \epsilon_{pt} \end{matrix}$	7.23	2.87	3.77	1.04	3.00	4.23	3.69
Int		1.08	1.66	13.97	0.31	1.52	2.06	14.36
PPI		1.22	1.41	0.84	4.08	1.53	2.10	0.85
				<u>1953-1986</u>				
Stock	1.80	1.13	1.30	4.44	10.54	0.84	0.50	3.67
Hibond	$\begin{matrix} \epsilon_{rht} \\ \epsilon_{rst} \\ \epsilon_{pt} \end{matrix}$	1.43	4.54	2.72	0.87	1.15	4.33	3.01
Int		2.57	5.49	3.13	1.55	2.71	5.31	2.75
PPI		0.67	0.59	0.89	14.39	0.84	0.59	0.63

Note: A 4-variable, 12th order VAR model is estimated for stock, bond, interest rate and PPI inflation volatility, including dummy variables for monthly intercepts. The F-tests reflect the ability of the column variable to predict the respective row variables. Measures of stock return volatility based on monthly data  $|\epsilon_{st}|$  are used in the first four columns, and measures of stock return volatility based on daily data  $\sigma_t$  are used in the last four columns. The .05 and .01 critical values for the F-statistic with 12 and 200 degrees of freedom are 1.80 and 2.28, respectively.

Table 3B

Estimates of the Relations Among Stock, Bond, Interest Rate and Money Base Growth Volatility, 1881-1986 and Subperiods

Vector Autoregressive Models for Stock, Bond and Interest Rate Volatility, Including Volatility of Money Base Growth

Dependent Variable	<u>F-tests with Monthly Stock Volatility</u>				<u>F-tests with Daily Stock Volatility</u>			
	Stock	Bond	Int	Base	Stock	Bond	Int	Base
	<u>1881-1986</u>							
Stock	13.98	2.99	1.58	1.23				
Hibond	$\left  \begin{array}{c} \epsilon_{rht} \\ \epsilon_{st} \\ \epsilon_{mt} \end{array} \right $	5.52	18.11	3.31	1.91			
Int		2.39	3.84	15.84	1.02			
Base		4.06	1.48	0.79	20.28			
	<u>1881-1926</u>							
Stock	3.09	1.14	0.60	1.25				
Hibond	$\left  \begin{array}{c} \epsilon_{rht} \\ \epsilon_{st} \\ \epsilon_{mt} \end{array} \right $	1.96	2.47	1.00	2.48			
Int		2.62	1.56	8.19	0.76			
Base		1.81	1.61	1.05	2.33			
	<u>1927-1986</u>							
Stock	6.48	2.12	1.30	1.67	39.73	2.66	0.64	2.23
Hibond	$\left  \begin{array}{c} \epsilon_{rht} \\ \epsilon_{st} \\ \epsilon_{mt} \end{array} \right $	4.17	6.75	4.50	1.63	3.02	7.63	4.61
Int		1.42	5.02	7.69	0.50	1.00	5.01	7.99
Base		5.24	2.09	0.74	17.65	3.74	1.87	0.66
	<u>1927-1952</u>							
Stock	1.39	2.37	2.62	0.91	10.79	4.08	3.49	1.49
Hibond	$\left  \begin{array}{c} \epsilon_{rht} \\ \epsilon_{st} \\ \epsilon_{mt} \end{array} \right $	5.99	2.71	3.54	0.74	3.20	4.74	3.82
Int		0.97	1.64	14.18	0.83	1.41	1.89	14.46
Base		2.72	1.49	0.91	4.31	1.87	1.38	1.12
	<u>1953-1986</u>							
Stock	1.87	0.83	1.28	1.27	15.38	0.37	0.38	0.51
Hibond	$\left  \begin{array}{c} \epsilon_{rht} \\ \epsilon_{st} \\ \epsilon_{mt} \end{array} \right $	1.29	4.64	2.69	0.95	1.16	4.53	2.76
Int		2.37	5.82	3.24	0.79	2.39	5.69	2.60
Base		0.86	0.85	1.01	2.54	0.93	0.93	1.08

Note: A 4-variable, 12th order VAR model is estimated for stock, bond, interest rate and money base growth volatility, including dummy variables for monthly intercepts. The F-tests reflect the ability of the column variable to predict the respective row variables. Measures of stock return volatility based on monthly data  $\left| \epsilon_{st} \right|$  are used in the first four columns, and measures of stock return volatility based on daily data  $\sigma_{\epsilon}$  are used in the last four columns. The .05 and .01 critical values for the F-statistic with 12 and 200 degrees of freedom are 1.80 and 2.28, respectively.



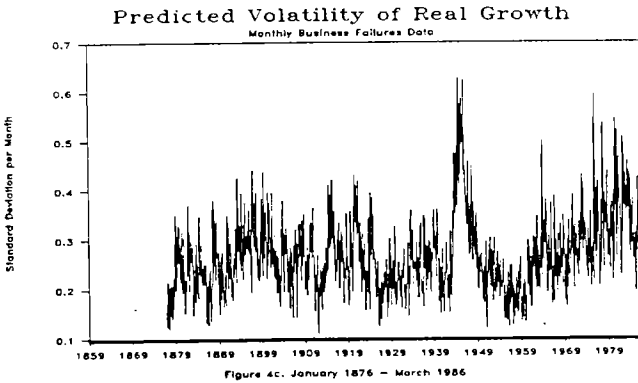
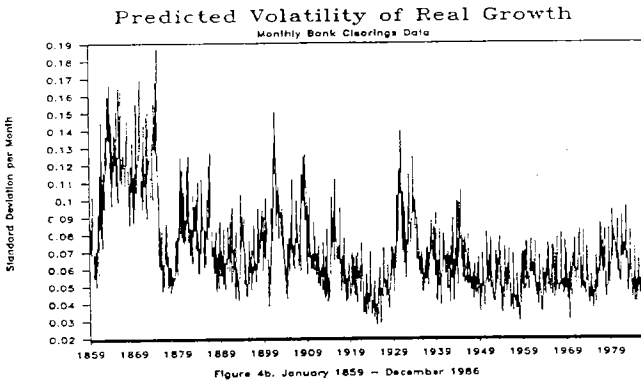
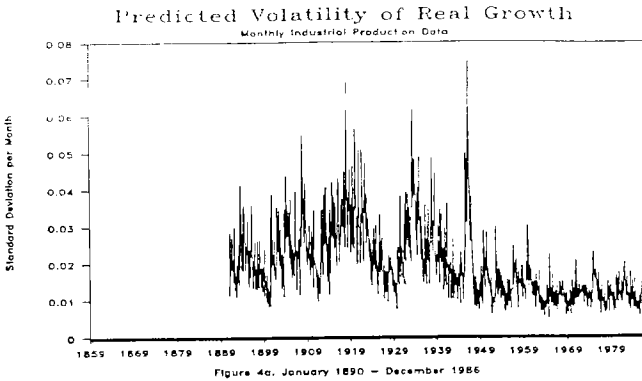
### 3.2 Real Macroeconomic Volatility

Since common stocks reflect claims on future profits of corporations, it is plausible that the volatility of real economic activity is a major determinant of stock return volatility. In the present value model (3), the volatility of future expected cash flows, as well as discount rates, will change if the volatility of real activity changes.

Figures 4a, 4b and 4c contain plots of the predicted volatility of the growth rates of industrial production  $|\hat{\epsilon}_{it}|$ , of bank clearings (debits)  $|\hat{\epsilon}_{dt}|$ , and of liabilities of business failures  $|\hat{\epsilon}_{ft}|$ , respectively. Summary statistics for these estimates are in Tables 2A and 2B.

Industrial production volatility in Figure 4a was high during the mid-1930s, during World War I, and especially during the post-World War II period. There is a small increase in volatility during the 1973-1974 recession. Romer[1986b] argues that data collection procedures cause part of the higher volatility of this series before 1929.

Bank clearings are a measure of transactions that have been popular for measuring business cycle activity at least since Macaulay[1938]. The plot in Figure 4b shows that clearings volatility rose during the Civil War and remained high until the 1873-1879 recession. There was a sharp increase in volatility in the early 1900s and another brief increase in the recession and bank panic of 1907-1908. Both World War I and World War II led to moderate increases in volatility, and volatility was higher during the 1929-1940 period. With this series, especially, the effect of changes in measurement have probably had important effects on the secular behavior of volatility. In the mid-19<sup>th</sup> century, the only banks in the sample were in New York City. Over time, the sample of banks has expanded in a succession of discrete



increments, currently covering virtually all commercial banks. While I have spliced these series so the levels are continuous, the diversification effect of using larger samples probably explains the downward trend in volatility in Figure 4b.<sup>9</sup>

It is interesting that the sample used to measure stock return volatility has many of the same problems as the sample used to measure clearings. There are relatively few stocks in the sample in 1857, and they are all railroad stocks. Nevertheless, they represent the majority of actively traded equity securities at that time (as the New York banks held a dominant position in the banking industry). Even though the number of securities and industries included has grown over time, the plot of stock return volatility in Figure 1 does not show a downward trend similar to the picture of bank clearings volatility in Figure 4b.

The volatility of the growth rate of the liabilities of business failures in Figure 4c was high during World War II and in the 1980s. Surprisingly, this series does not show unusually high volatility during 1929-1940.

The annual cross correlations between industrial production volatility and stock volatility are positive in Table 2C. The cross correlations of stock volatility with both bank clearings volatility and business failures volatility are small at all three lags.

Tables 4A, 4B, and 4C contain tests of the incremental predictive power of 12 lags of industrial production volatility  $|\epsilon_{it}|$ , bank clearings volatility  $|\epsilon_{dt}|$ , and business failures volatility  $|\epsilon_{ft}|$ , respectively, in a 12<sup>th</sup> order VAR system similar to those in Tables 3A and 3B. The results for the

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<sup>9</sup>A similar pattern is observable in the CPI inflation series, where expansions of the Bureau of Labor Statistics monthly sample lead to noticeable reductions in the variance of measured inflation rates.

financial variables are similar to those reported in Table 3A.

The F-statistics measuring the ability of real activity volatility to predict financial volatility are small. For the pre-1926 period, there is weak evidence that bond return volatility is related to industrial production or business failures volatility. Nevertheless, these results are weaker than the comparable results using inflation and monetary volatility in Tables 3A and 3B. For 1859-1926, there is weak evidence (F-statistics of 2.37 and 2.52) that bank clearings volatility helps predict short-term interest rate volatility. This suggests that the 'bank panics' in the 19<sup>th</sup> century (1873, 1884, 1890, 1893, 1899, and 1907) were short-term phenomena -- they did not affect the volatility of long-term bond returns or stock returns.

There is somewhat stronger evidence that financial volatility helps predict real activity volatility in Tables 4A, 4B and 4C. In Table 4A, stock return volatility predicts industrial production volatility for the 1891-1986, 1927-1986 and 1927-1952 periods. In Table 4B, both stock return and short-term interest rate volatility predict bank clearings volatility in the 1859-1986, 1859-1926, and 1927-1986 periods. There is little evidence that financial volatility helps predict the volatility of liabilities of business failures in Table 4C.

Thus, there is weak evidence that macroeconomic volatility provides incremental information about future stock return volatility. There is somewhat stronger evidence that financial volatility helps predict macroeconomic volatility. While many of the macroeconomic volatility series are high during 1929-1940, none increases by a factor of three as stock return volatility did.

Table 4A

Estimates of the Relations Among Stock, Bond, Interest Rate and  
Industrial Production Volatility, 1891-1986 and Subperiods

Vector Autoregressive Models for Stock, Bond and  
Interest Rate Volatility, Including Volatility of Industrial Production

Dependent Variable	<u>F-tests with Monthly Stock Volatility</u>				<u>F-tests with Daily Stock Volatility</u>			
	<u>Stock</u>	<u>Bond</u>	<u>Int</u>	<u>IP</u>	<u>Stock</u>	<u>Bond</u>	<u>Int</u>	<u>IP</u>
	<u>1891-1986</u>							
Stock	13.71	3.05	1.48	0.95				
Hibond	$\left  \begin{matrix} \epsilon_{rht} \\ \epsilon_{rst} \\ \epsilon_{it} \end{matrix} \right $	4.81	16.16	3.15	0.76			
Int		2.24	3.56	15.88	0.58			
IP		4.17	0.74	0.63	24.03			
	<u>1891-1926</u>							
Stock	2.55	1.00	0.80	1.22				
Hibond	$\left  \begin{matrix} \epsilon_{rht} \\ \epsilon_{rst} \\ \epsilon_{it} \end{matrix} \right $	1.03	4.05	0.59	2.16			
Int		2.47	1.71	6.61	0.90			
IP		1.52	0.61	0.60	3.05			
	<u>1927-1986</u>							
Stock	7.29	2.20	1.23	1.85	37.56	2.72	0.64	0.90
Hibond	$\left  \begin{matrix} \epsilon_{rht} \\ \epsilon_{rst} \\ \epsilon_{it} \end{matrix} \right $	3.78	6.57	4.42	0.89	2.68	7.30	4.28
Int		1.25	4.77	7.61	0.41	0.83	4.72	7.83
IP		5.09	0.94	0.81	9.61	4.44	0.83	0.65
	<u>1927-1952</u>							
Stock	1.65	2.47	2.35	1.07	10.05	4.48	3.44	0.52
Hibond	$\left  \begin{matrix} \epsilon_{rht} \\ \epsilon_{rst} \\ \epsilon_{it} \end{matrix} \right $	5.85	2.91	3.77	0.78	2.80	4.35	3.90
Int		0.90	1.68	12.95	0.54	1.72	1.96	13.59
IP		2.08	1.34	1.01	3.86	1.52	1.08	1.06
	<u>1953-1986</u>							
Stock	2.01	0.86	1.46	1.40	15.22	0.51	0.39	0.92
Hibond	$\left  \begin{matrix} \epsilon_{rht} \\ \epsilon_{rst} \\ \epsilon_{it} \end{matrix} \right $	1.38	3.87	2.82	0.58	1.14	3.86	3.01
Int		2.68	5.79	3.40	1.41	2.00	5.76	2.81
IP		0.72	1.07	0.73	2.83	0.58	1.12	1.05

Note: A 4-variable, 12th order VAR model is estimated for stock, bond, interest rate and industrial production volatility, including dummy variables for monthly intercepts. The F-tests reflect the ability of the column variable to predict the respective row variables. Measures of stock return volatility based on monthly data  $|\epsilon_{st}|$  are used in the first four columns, and measures of stock return volatility based on daily data  $\sigma_t$  are used in the last four columns. The .05 and .01 critical values for the F-statistic with 12 and 200 degrees of freedom are 1.80 and 2.28, respectively.

Table 4B

Estimates of the Relations Among Stock, Bond, Interest Rate and Bank Clearings Volatility, 1859-1986 and Subperiods

Vector Autoregressive Models for Stock, Bond and Interest Rate Volatility, Including Volatility of Bank Clearings

Dependent Variable	F-tests with Monthly Stock Volatility				F-tests with Daily Stock Volatility			
	Stock	Bond	Int	Bank	Stock	Bond	Int	Bank
	<u>1859-1986</u>							
Stock	19.32	3.09	1.11	1.31				
Hibond	$\left  \begin{array}{c} \epsilon_{rht} \\ \epsilon_{rst} \\ \epsilon_{dt} \end{array} \right $	5.36	22.56	2.93	0.56			
Int		2.02	2.67	16.96	2.37			
Bank		2.14	1.49	3.12	16.15			
		<u>1859-1926</u>						
Stock	2.80	1.84	0.63	1.64				
Hibond	$\left  \begin{array}{c} \epsilon_{rht} \\ \epsilon_{rst} \\ \epsilon_{dt} \end{array} \right $	0.83	15.49	0.86	1.04			
Int		1.68	1.84	7.94	2.52			
Bank		3.61	2.07	3.20	4.88			
		<u>1927-1986</u>						
Stock	7.77	2.26	1.23	1.21	44.67	3.02	0.74	1.52
Hibond	$\left  \begin{array}{c} \epsilon_{rht} \\ \epsilon_{rst} \\ \epsilon_{dt} \end{array} \right $	4.12	6.73	4.59	0.83	2.56	7.47	4.39
Int		1.76	4.62	8.41	0.85	1.29	4.56	8.47
Bank		2.47	0.58	0.34	2.59	3.53	0.61	0.37
		<u>1927-1952</u>						
Stock	2.02	2.56	2.84	1.52	12.07	4.77	3.14	1.39
Hibond	$\left  \begin{array}{c} \epsilon_{rht} \\ \epsilon_{rst} \\ \epsilon_{dt} \end{array} \right $	6.31	3.17	4.04	1.85	2.67	4.82	3.99
Int		0.92	1.38	11.91	1.07	2.08	1.62	12.21
Bank		0.95	1.15	1.69	0.86	2.03	1.27	1.16
		<u>1953-1986</u>						
Stock	1.52	0.82	1.20	1.07	14.43	0.53	0.39	0.55
Hibond	$\left  \begin{array}{c} \epsilon_{rht} \\ \epsilon_{rst} \\ \epsilon_{dt} \end{array} \right $	1.53	4.22	2.79	0.78	1.11	4.01	2.91
Int		2.80	5.33	3.32	0.61	2.21	5.28	2.75
Bank		1.32	0.97	0.52	1.61	1.12	0.98	0.61
		<u>1953-1986</u>						

Note: A 4-variable, 12th order VAR model is estimated for stock, bond, interest rate and bank clearings volatility, including dummy variables for monthly intercepts. The F-tests reflect the ability of the column variable to predict the respective row variables. Measures of stock return volatility based on monthly data  $\left| \epsilon_{st} \right|$  are used in the first four columns, and measures of stock return volatility based on daily data  $\sigma_t$  are used in the last four columns. The .05 and .01 critical values for the F-statistic with 12 and 200 degrees of freedom are 1.80 and 2.28, respectively.

Table 4C

Estimates of the Relations Among Stock, Bond, Interest Rate and Business Failures Volatility, 1878-1986 and Subperiods

Vector Autoregressive Models for Stock, Bond and Interest Rate Volatility, Including Volatility of Business Failures

Dependent Variable	F-tests with Monthly Stock Volatility				F-tests with Daily Stock Volatility			
	Stock	Bond	Int	Fail	Stock	Bond	Int	Fail
<u>1878-1986</u>								
Stock	16.38	3.61	1.64	0.94				
Hibond	$\left  \begin{array}{c} \epsilon_{rht} \\ \epsilon_{rst} \\ \epsilon_{ft} \end{array} \right $	5.53	18.60	3.15	1.12			
Int		2.68	4.13	16.72	1.73			
Fail		0.74	0.61	1.66	9.44			
<u>1878-1926</u>								
Stock	2.75	0.92	0.68	1.41				
Hibond	$\left  \begin{array}{c} \epsilon_{rht} \\ \epsilon_{rst} \\ \epsilon_{ft} \end{array} \right $	1.52	7.08	1.28	1.95			
Int		2.42	1.69	7.68	1.30			
Fail		0.65	1.74	1.00	2.23			
<u>1927-1986</u>								
Stock	10.24	2.30	1.46	1.42	55.38	3.56	0.65	0.99
Hibond	$\left  \begin{array}{c} \epsilon_{rht} \\ \epsilon_{rst} \\ \epsilon_{ft} \end{array} \right $	4.71	6.82	4.07	0.91	2.94	7.58	3.81
Int		1.75	4.95	7.77	1.43	1.34	4.87	7.89
Fail		0.77	0.65	1.70	6.96	0.51	0.68	1.89
<u>1927-1952</u>								
Stock	1.80	2.56	2.37	0.49	12.19	4.57	3.29	0.87
Hibond	$\left  \begin{array}{c} \epsilon_{rht} \\ \epsilon_{rst} \\ \epsilon_{ft} \end{array} \right $	7.05	2.94	3.66	0.86	2.90	4.18	3.49
Int		1.09	1.85	12.64	0.93	1.47	2.27	13.32
Fail		0.73	1.29	0.85	5.53	0.95	1.28	0.86
<u>1953-1986</u>								
Stock	1.39	0.84	1.42	1.46	16.61	0.78	0.35	1.67
Hibond	$\left  \begin{array}{c} \epsilon_{rht} \\ \epsilon_{rst} \\ \epsilon_{ft} \end{array} \right $	1.27	4.56	2.40	0.77	0.98	4.44	2.50
Int		2.70	6.21	2.94	1.72	2.00	5.96	2.44
Fail		1.14	1.58	1.70	1.52	0.63	1.58	1.87

Note: A 4-variable, 12th order VAR model is estimated for stock, bond, interest rate and business failures volatility, including dummy variables for monthly intercepts. The F-tests reflect the ability of the column variable to predict the respective row variables. Measures of stock return volatility based on monthly data  $|\epsilon_{st}|$  are used in the first four columns, and measures of stock return volatility based on daily data  $\sigma_t$  are used in the last four columns. The .05 and .01 critical values for the F-statistic with 12 and 200 degrees of freedom are 1.80 and 2.28, respectively.

### 3.3 Macroeconomic and Financial Volatility During Recessions

Table 5 contains a final test of the relation between stock volatility and macroeconomic activity. It contains estimates of the coefficient of a dummy variable added to equation (2b) equal to unity during recessions as defined by the National Bureau of Economic Research (NBER), and zero otherwise. If this coefficient is reliably greater than zero, the volatility of the series is greater during recessions than during expansions.<sup>10</sup>

Table 5 shows that volatility is higher during recessions, since most of the estimates are positive and none is more than 1.5 standard errors below 0. Except 1859-1926, all of the estimates for stock volatility are more than 2.5 standard errors above zero. Moreover, the estimates of the percentage increase in volatility in recessions relative to expansions, in brackets ( ) below the standard errors, are quite large (up to 299 percent in 1927-1952 using the daily estimates of volatility). Along with the measures of stock market volatility  $\{\epsilon_{st}\}$  and  $\sigma_t$ , the volatility of industrial production  $\{\epsilon_{it}\}$  shows the most reliable increases during recessions. There is weaker evidence that bond returns, short-term interest rates, money growth rates, and business failures have higher volatility during recessions.

Thus, stock market volatility is related to the general health of the economy. One interpretation of this evidence is that it is caused by leverage. Stock prices are a leading indicator, so stock prices fall (relative to bond prices) before and during recessions. Thus, leverage increases during recessions, causing an increase in the volatility of levered stocks. Section 5 addresses this question directly.

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<sup>10</sup>Since the NBER announces the timing of recessions and expansions 6 to 9 months after they have begun, this evidence does not imply that the recession variable can be used to help predict future volatility.



Table 5

Estimates of the Relation Between Business Cycles and Financial and Macroeconomic Volatility, 1859-1986 and subperiods

Average Increase in Volatility During Recessions

(asymptotic standard errors in parentheses under coefficients)

Dependent Variable	1859-1986	1859-1926	1927-1986	1927-1952	1953-1986
Stock $ \epsilon_{st} $	.0057 (.0020) { 76%}	.0006 (.0017) { 3%}	.0206 (.0046) { 189%}	.0283 (.0082) { 239%}	.0136 (.0045) { 59%}
Stock $\sigma_t$			.0103 (.0026) { 227%}	.0154 (.0049) { 299%}	.0059 (.0021) { 59%}
Hibond $ \epsilon_{rht} $	.0006 (.0005) { 39%}	.0004 (.0004) { 28%}	.0018 (.0011) { 84%}	.0028 (.0015) { 153%}	.0012 (.0015) { 51%}
Int $ \epsilon_{rst} $	.00005 (.00003) { 55%}	.00002 (.00003) { 15%}	.00008 (.00005) { 130%}	.00001 (.00003) { 37%}	.00021 (.00009) { 188%}
PPI $ \epsilon_{pt} $	-.0006 (.0008) { -24%}	-.0016 (.0012) { -43%}	.0000 (.0006) { 1%}	-.0004 (.0011) { -8%}	-.0007 (.0006) { -54%}
Base $ \epsilon_{mt} $	.0014 (.0006) { 115%}	.0015 (.0008) { 43%}	.0006 (.0008) { 75%}	.0014 (.0014) { 52%}	-.0004 (.0003) { -21%}
IP $ \epsilon_{it} $	.0039 (.0013) { 96%}	.0011 (.0021) { 9%}	.0044 (.0017) { 148%}	.0054 (.0030) { 76%}	.0028 (.0011) { 50%}
Bank $ \epsilon_{dt} $	.0010 (.0035) { 5%}	-.0026 (.0051) { -10%}	.0048 (.0042) { 19%}	.0120 (.0074) { 38%}	-.0022 (.0043) { -7%}
Fail $ \epsilon_{ft} $	.0173 (.0133) { 18%}	.0424 (.0173) { 32%}	.0039 (.0208) { 4%}	-.0042 (.0254) { -7%}	.0168 (.0326) { 12%}

Note: All tests use the White[1980] heteroskedasticity consistent standard errors. In each case, a dummy variable equal to 1 during months designated as recessions by the NBER is added to a regression containing 12 monthly dummy variables and 12 lags of the dependent variable, as in Table 2B and equation (2b). The estimates in this table represent the increase in average volatility for each of the series in Table 2B during periods of recession. The percentage increase in volatility during recessions relative to expansions is in brackets { } below the standard errors. The estimates in the first two columns use as much data as are available for the respective series, back to 1859 if possible.

Alternatively, it is plausible that 'operating leverage' (i.e., the proportion of fixed costs in total costs) rises during recessions.<sup>11</sup> An increase in either financial or operating leverage will have similar effects on the volatility of stock returns.

#### 4. Stock Volatility and Corporate Profitability

In addition to general macroeconomic factors, it is interesting to measure the relation between stock volatility and the health of the corporate sector of the economy. Many authors use the dividend yield  $(D/P)_t$  as an indicator of future stock returns (e.g., Campbell and Shiller[1988] and Fama and French[1988]). Given the evidence that dividend yields track time-varying expected returns, they may also predict time-varying volatility. By similar logic, the earnings yield  $(E/P)_t$  and the 'payout ratio'  $(D/E)_t$  could provide information about the health of corporations. Finally, Keim and Stambaugh[1986] have noted that the yield spread between high and low risk corporate bonds predicts future stock returns. When these yield spreads reflect increased probability of default, they are likely to predict time-varying stock volatility.

##### 4.1 Relation of Stock Yields with Volatility

Figures 5a, 5b and 5c contain plots of the payout ratio  $(D/E)_t$ , the dividend yield  $(D/P)_t$  and the earnings yield  $(E/P)_t$ , respectively, from 1871-1986. In Figure 5a, the payout ratio was much more variable before 1953. In particular, during recessions the payout ratio was often greater than 1, implying that dividend payments exceeded corporate earnings. This implies that managers perceive recessions are transitory, and they have a preference

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<sup>11</sup>I am grateful to Fischer Black for suggesting this interpretation.

for not changing dividends frequently (Lintner[1956]). Since 1953, however, the payout ratio has been relatively stable.

The  $(E/P)_t$  data are only available on an annual basis from 1871-1934 and on a quarterly basis from 1935-1954. This explains the step function behavior of the payout ratios in Figure 5a. The  $(E/P)_t$  series is interpolated to a monthly basis using the monthly  $(D/P)_t$  data and assuming a constant payout ratio during the year or quarter. See the Appendix for more details.

It is curious that the behavior of the payout ratio has changed so much over time. In many ways this is similar to the other macroeconomic variables. While the sample of securities used to calculate this ratio is smaller before 1926, the measurement techniques used have not changed over time. Thus, it is unlikely that Romer's[1986a,b,c] measurement error explanation for high volatility of pre-1926 data can explain this behavior.

In contrast, the dividend yield series  $(D/P)_t$  in Figure 5b seems relatively homogeneous over the 1871-1986 period. There is a tendency for yields to rise in periods of economic crisis, such as the end of World War I, the Great Depression, World War II and the OPEC oil shock. Nevertheless, the movement in these yields is neither volatile nor persistent. The plot of earnings yields  $(E/P)_t$  in Figure 5c is drawn to the same scale as the  $(D/P)_t$  plot in Figure 5b to emphasize the greater volatility of this series. Moreover, the  $(E/P)_t$  series seems to have persistent changes in the level of the series, with periods of relative stability (e.g., 1880-1914 and 1958-1972) intermingled with periods of high variability. Interestingly, 1929-1940 does not seem more variable than the rest of 1915-1953, nor than the post-OPEC period.

Table 6 contains estimates of the cumulative effects of 12 lagged values of

### Monthly Payout Ratios, D/E

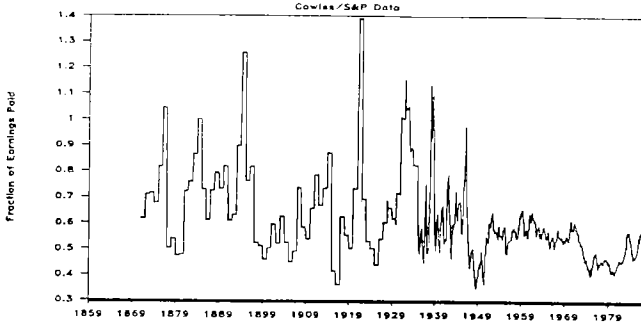


Figure 5a. January 1871 - December 1986

### Dividend Yields, D/P

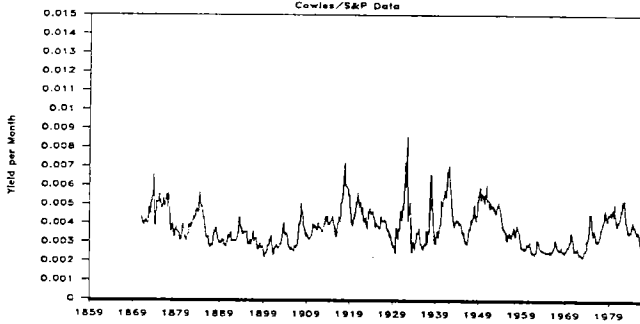


Figure 5b. January 1871 - December 1986

### Earnings Yields, E/P

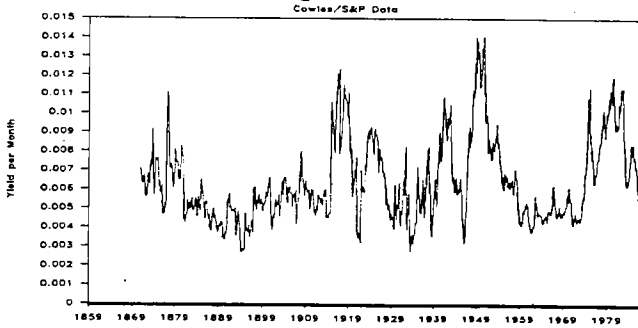


Figure 5c. January 1871 - December 1986

Table 6

Estimates of the Relations Between Firm Profitability and Stock Volatility

Autoregressive Predictive Models for Stock Volatility,  
Including 12 Lags of Firm Profitability Measures:  
the Payout Ratio (D/E), the Dividend Yield (D/P),  
or the Earnings Yield (E/P)

(asymptotic standard errors in parentheses under coefficients)

<u>Dependent Variable</u>	<u>Sample Period</u>	<u>Sum of (D/E) Coefficients</u>	<u>Sum of (D/P) Coefficients</u>	<u>Sum of (E/P) Coefficients</u>
<u>Estimated Standard Deviation from CRSP Monthly Returns</u>				
$\{\epsilon_{st}\}$	1872-1986	.0033 (.0068)	.8849 (1.195)	-.0037 (.4191)
$\{\epsilon_{st}\}$	1872-1926	-.0014 (.0053)	.6275 (1.204)	.4564 (.5297)
$\{\epsilon_{st}\}$	1927-1986	.0471 (.0209)	1.649 (1.681)	-.4733 (.5851)
$\{\epsilon_{st}\}$	1927-1952	.0838 (.0321)	1.486 (3.194)	-1.509 (1.044)
$\{\epsilon_{st}\}$	1953-1986	-.0567 (.0308)	1.518 (2.089)	.9029 (.8652)
<u>Estimated Standard Deviation from S&amp;P Daily Returns</u>				
$\sigma_t$	1927-1986	.0230 (.0082)	.7358 (.8150)	-.2992 (.3037)
$\sigma_t$	1927-1952	.0437 (.0143)	.7889 (1.689)	-.8704 (.6421)
$\sigma_t$	1953-1986	-.0323 (.0123)	.7439 (.9002)	.5041 (.3625)

Note: All tests use the White[1980] heteroskedasticity consistent covariance matrix. Columns 3, 4 and 5 contain the sums of the 12 lagged coefficients of  $(D/E)_t$ ,  $(D/P)_t$  and  $(E/P)_t$ , respectively, with asymptotic standard errors in parentheses. In each case, 12 monthly dummy variables and 12 lags of the dependent variable are also included in the regression, as in Table 2B and equation (2b).

corporate profitability measures on stock return volatility. These lagged measures are added to the autoregressive model in (2b). Except for the payout ratio after 1926, none of the t-tests in Table 6 are large. The relation between stock volatility and the payout ratio is reliably positive from 1927-1952 and reliably negative from 1953-1986. Thus, this relation is not stable over time. From Figures 1 and 5a, payout rose during 1929-1940 as did stock volatility. Payout fell during the 1973-1986 period when stock volatility rose. These opposite associations suggest there is no stable relation between earnings or dividend policy and stock volatility.

#### 4.2 Relation of Bond Yields with Volatility

Figures 6a and 6b plot the spreads between medium (Baa) and high (Aa) grade corporate long-term bonds ( $Medbond_t - Hibond_t$ ), and between long and short-term high grade bonds ( $Hibond_t - Int_t$ ), respectively. Assuming that Moody's rating classes reflect consistent information over time, the spread between yields on different bonds of different quality should measure the price of default risk. Thus, the plot in Figure 6a should vary with uncertainty about corporate profitability, and should be related to stock volatility. Indeed, quality yield spreads are higher in 1929-1940 than in the subsequent periods. They also increase in the OPEC period and since 1979.

The spread between long and short-term yields in Figure 6b reflects a different phenomenon. First, since the long-term yields are for corporate debt, and the short-term yields are for Treasury securities (since 1926), part of this maturity spread measures the default risk of the long-term corporate debt. There are many periods, however, when the maturity spread is negative,

### (Medium-High) Grade Bond Yield Spreads

Moody's (Baa-Aa)

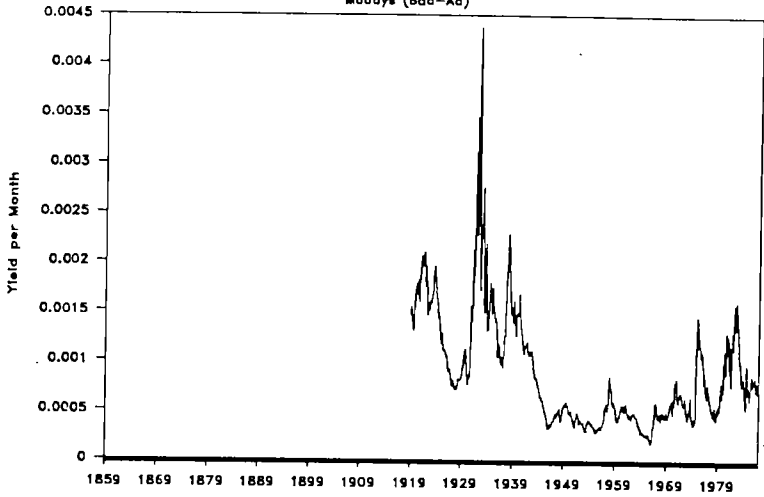


Figure 6a. January 1919 - December 1986

### High Grade (Long-Short) Yield Spreads

Macauly/Moody's (Aa-Tbll)

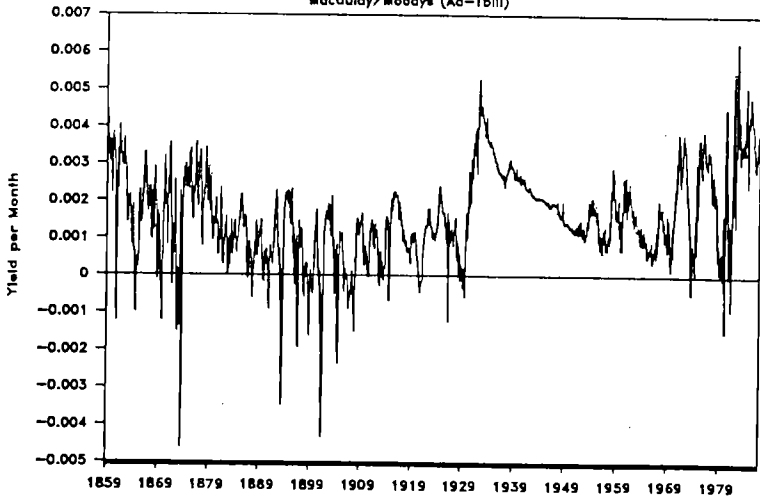


Figure 6b. January 1859 - December 1986

reflecting a downward-sloping term structure of interest rates.<sup>12</sup> The short-term rate is highly variable in the 19<sup>th</sup> century (see Figure 2a), and there were many 'bank panics' where short rates were very high for brief periods. Long rates did not rise much during these panics, so there are large negative maturity spreads. If term premiums reflect risk, increased term premiums would cause larger spreads to reflect this risk. The maturity spread rose rapidly in 1929 and decreased gradually throughout 1929-1940. On the other hand, the maturity spread fell dramatically in 1973-1974 and in 1979. Thus, although the maturity spread has changed at the same time as stock volatility, the direction of the change was not always the same.

Table 7 contains estimates of the cumulative effects of 12 lagged values of bond yield spreads on stock return volatility. These lagged measures are added to the autoregressive model in (2b). As in Table 6, most of the t-statistics in Table 7 are small. The exception is for the quality spread from 1927-1952, where increases in the spread precede increases in stock volatility. This relation is positive for 1953-1986, but not reliably different from zero. The evidence in Table 7 is similar to the evidence from the VAR models in Tables 3A through 4C, where long-term bond return volatility helps predict stock volatility, particularly in 1927-1952. The quality yield spread proxies for bond risk measured from holding period returns.

Thus, the evidence in Tables 6 and 7 shows there are weak relations between corporate profitability and stock volatility. While the plots in Figures 5a through 6b suggest that changes in volatility, payout ratios and yield spreads are related, the direction of relations is not consistent across episodes.

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<sup>12</sup> Long-term corporate yields are always greater than comparable long-term government yields.



Table 7

Estimates of the Relations Between Yield Spreads and Stock Volatility

Autoregressive Predictive Models for Stock Volatility,  
Including 12 Lags of Bond Yield Spreads

(asymptotic standard errors in parentheses under coefficients)

<u>Dependent Variable</u>	<u>Sample Period</u>	<u>Sum of (Medium-High) Coefficients</u>	<u>Sum of (High-Short) Coefficients</u>
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Estimated Standard Deviation from CRSP Monthly Returns

$ \epsilon_{st} $	1859-1986		.5261 (.8769)
$ \epsilon_{st} $	1859-1926		-.2480 (1.004)
$ \epsilon_{st} $	1927-1986	19.39 (6.460)	-1.198 (1.691)
$ \epsilon_{st} $	1927-1952	23.27 (8.284)	3.121 (4.952)
$ \epsilon_{st} $	1953-1986	.9560 (7.301)	-2.292 (1.517)

Estimated Standard Deviation from S&P Daily Returns

$\sigma_t$	1927-1986	8.691 (2.859)	-.5298 (1.147)
$\sigma_t$	1927-1952	9.633 (3.694)	.1499 (3.698)
$\sigma_t$	1953-1986	1.501 (3.591)	-.4150 (.6141)

Note: All tests use the White[1980] heteroskedasticity consistent covariance matrix. Columns 3 and 4 contain the sums of the 12 lagged coefficients of (Medbond-Hibond) and (Hibond-Int), respectively, with asymptotic standard errors in parentheses. In each case, 12 monthly dummy variables and 12 lags of the dependent variable are also included in the regression, as in Table 2B and equation (2b). All yield spreads are expressed in units of yield per month (i.e., the same units as the returns and growth rates in the other tables).

## 5. Effects of Leverage on Stock Market Volatility

### 5.1 Leverage and Stock Volatility

One explanation of time-varying stock volatility is that leverage changes as relative stock and bond prices change. In particular, the variance of the return to the assets of a firm  $\sigma_{vt}^2$  can be expressed in terms of the variances of the returns to the stock  $\sigma_{st}^2$  and the bonds  $\sigma_{bt}^2$ , and the covariance of the returns  $\text{cov}(R_{st}, R_{bt})$ ,

$$\sigma_{vt}^2 = \left[ \frac{S_{t-1}}{V_{t-1}} \right]^2 \sigma_{st}^2 + \left[ \frac{B_{t-1}}{V_{t-1}} \right]^2 \sigma_{bt}^2 + 2 \left[ \frac{S_{t-1}}{V_{t-1}} \right] \left[ \frac{B_{t-1}}{V_{t-1}} \right] \text{cov}(R_{st}, R_{bt}), \quad (4)$$

where  $S_{t-1}$ ,  $B_{t-1}$  and  $V_{t-1}$  represent the market value of the stock, the bonds and the firm at time  $t-1$ . Consider a firm with riskless debt ( $\sigma_{bt}^2 = \text{cov}(R_{st}, R_{bt}) = 0$ ), where the variance of the assets of the firm  $\sigma_v^2$  is constant over time. The standard deviation of the stock return is  $\sigma_{st} = \sigma_v (V/S)_{t-1}$ . This shows how a change in the leverage of the firm causes a change in the volatility of stock returns. Figure 7 plots the predictions of stock market volatility  $|\hat{\sigma}_{st}|$  from Figure 1 along with the estimates implied by changing leverage ( $(V/S)_{t-1}$  scaled to have a mean equal to the average of  $|\hat{\sigma}_{st}|$  -- the heavier line) for 1900-1986. It is clear from Figure 7 that changing leverage explains a small portion of the increase in stock market volatility in the early 1930s and the mid 1970s. Changing leverage cannot explain most of the variation in  $|\hat{\sigma}_{st}|$ .

Christie[1982] proposes regression tests for the effects of changing leverage on the volatility of stock returns. First, he notes that (4) implies the regression model,

$$\sigma_{st} = \alpha_0 + \alpha_1 (B/S)_{t-1} + u_t, \quad (5)$$

where  $\alpha_0 = \alpha_1 = \sigma_v$  in the riskless debt case. With risky consol bonds

# Effects of Leverage on Stock Volatility

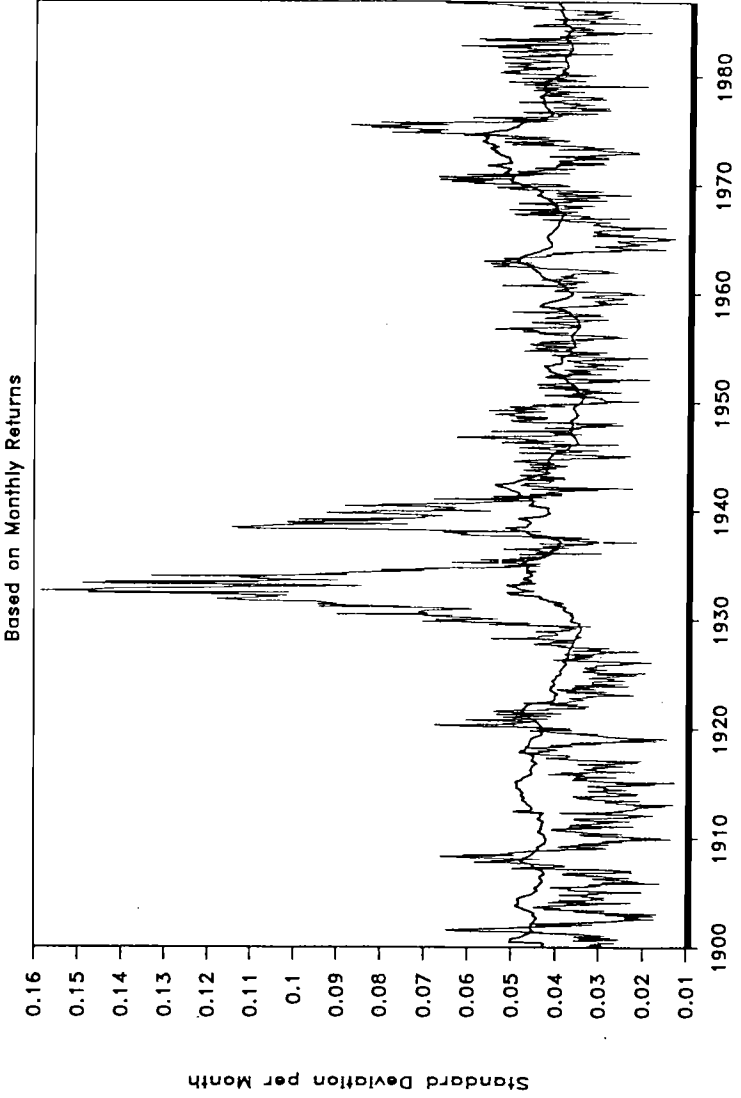


Figure 7. January 1900 - December 1986

— Effect of Leverage  
- - - Predicted Std Dev

containing protective covenants, as modeled by Black and Cox[1976], Christie shows that  $\alpha_0 - \sigma_v > \alpha_1$ .

Table 8 contains generalized least squares (GLS) estimates of equation (5) for 1901-1986, 1927-1986, 1927-1952 and 1953-1986. There is substantial residual autocorrelation using ordinary least squares, hence the GLS estimates use an ARMA(1,3) model for the errors. This is similar to the French, Schwert and Stambaugh[1987] model for  $\sigma_t$ . The results depend on the sample period used for estimation. For 1953-1986, the intercept  $\alpha_0$  is close to the slope  $\alpha_1$  as predicted by the riskless debt model. For the other sample periods, the intercept  $\alpha_0$  is less than the slope  $\alpha_1$ , a result that is inconsistent with all of the leverage models. The t-test in the last column of Table 8 tests the hypothesis that the slope equals the intercept. The p-value in parentheses is for the two-sided alternative hypothesis. Many of the estimates of  $\alpha_1$  are reliably greater than zero, showing that an increase in the debt/equity ratio  $(B/S)_{t-1}$  leads to an increase in stock return volatility. Nevertheless, none of the t-statistics in the last column is greater than .67. This, along with the substantial residual autocorrelation, shows that leverage alone cannot explain the historical movements in stock volatility.

## 5.2 Stock Market Trading and Volatility

French and Roll[1986] observe that stock volatility is higher when stock exchanges are open for trading. In particular, they find that the variance of stock returns over weekends and holidays is much less than a typical one-day variance times the number of calendar days since trading last occurred. Most peculiarly, during 1968, when the NYSE closed on Wednesdays due to the 'paper-work crunch,' the variance of Tuesday to Thursday returns was not much larger than a one-day variance. This occurred even though the stock exchanges were

Table 8

Estimates of the Relation Between Leverage and the Standard Deviation of  
Stock Market Returns, 1901-1986 and Subperiods

Regressions of Stock Volatility on Debt/Equity Ratios

(asymptotic standard errors in parentheses under coefficients)

$$\sigma_{st} = \alpha_0 + \alpha_1 (B/S)_{t-1} + u_t \quad (5)$$

<u>Dependent Variable</u>	<u>Sample Period</u>	<u><math>\alpha_0</math></u>	<u><math>\alpha_1</math></u>	<u>S(u)</u>	<u>R<sup>2</sup></u>	<u>Q(24)*</u>	<u>t-test * <math>\alpha_0 - \alpha_1</math></u>
<u>Estimated Standard Deviation from CRSP Monthly Returns</u>							
$ \epsilon_{st} $	1901-86	.0266 (.0100)	.0434 (.0189)	.0399	.181	46.4 (.000)	-0.61 (.539)
$ \epsilon_{st} $	1927-86	.0297 (.0119)	.0517 (.0227)	.0447	.173	45.1 (.001)	-0.67 (.499)
$ \epsilon_{st} $	1927-52	.0332 (.0215)	.0776 (.0465)	.0572	.179	35.2 (.019)	-0.69 (.493)
$ \epsilon_{st} $	1953-86	.0303 (.0058)	.0244 (.0128)	.0317	.059	21.4 (.374)	0.32 (.747)
<u>Estimated Standard Deviation from S&amp;P Daily Returns</u>							
$\sigma_t$	1927-86	.0272 (.0110)	.0528 (.0177)	.0211	.565	38.3 (.008)	-0.98 (.329)
$\sigma_t$	1927-52	.0324 (.0185)	.0762 (.0347)	.0285	.534	27.1 (.132)	-0.89 (.372)
$\sigma_t$	1953-86	.0280 (.0054)	.0232 (.0117)	.0128	.409	10.8 (.951)	0.29 (.772)

Note: GLS estimates include an ARMA(1,3) process for the errors  $u_t$ .  $(B/S)_{t-1}$  is an estimate of the debt/equity ratio for the aggregate stock market portfolio at the end of month t-1. S(u) is the standard deviation of the errors, R<sup>2</sup> is the coefficient of determination including the effects of estimating the ARMA(1,3) process for the errors, and Q(24) is the Box-Pierce[1970] statistic for 24 lags of the residual autocorrelations, which should be distributed as  $\chi^2(20)$ , with the p-value in parentheses under the test. The t-test for  $\alpha_0 - \alpha_1$  tests whether the riskless debt model is an adequate approximation to the effect of leverage on stock return volatility, where  $\alpha_0 > \alpha_1$  is implied by the risky debt model.

\*The p-values for the Box-Pierce statistic and for the two-sided alternative  $\alpha_0 \neq \alpha_1$  are in parentheses under the test statistics.

the only economic institutions taking holidays. Table 9A contains regressions,

$$\sigma_{st} = \alpha_0 + \alpha_1 \sqrt{\text{Days}_t} + u_t, \quad (6)$$

where  $\text{Days}_t$  is the number of trading days the NYSE was open during month  $t$ . If variance is proportional to trading time,  $\alpha_1$  represents the standard deviation per trading day and  $\alpha_0$  should equal 0. If volatility is unrelated to trading activity, the intercept  $\alpha_0$  estimates the average monthly standard deviation and  $\alpha_1$  should equal 0. Table 9A contains GLS estimates of equation (6) for 1928-1986, 1928-1952 and 1953-1986. These estimates do not provide strong support for either hypothesis, but the French-Roll scenario is more consistent with the data. All but one of the estimates of the trading time coefficient  $\alpha_1$  are positive, and several are reliably greater than 0. On the other hand, many of the estimated intercepts are negative, and none is more than two standard errors above 0. Thus, NYSE trading activity explains part of the variation in stock volatility. Nevertheless, this relation does not explain much of the variation in volatility through time.

Another measure of stock trading activity is share trading volume. Table 9B contains estimates of the regression

$$\sigma_{st} = \alpha_0 + \frac{\beta}{(1-\delta L)} \text{Vol}_t + u_t, \quad (7)$$

where  $\text{Vol}_t$  is the growth rate of volume from month  $t-1$  to month  $t$ , and the errors  $u_t$  follow an ARMA(1,3) process. This model relates stock volatility to a distributed lag of past share volume growth, where the coefficient of volume

growth decreases geometrically.<sup>13</sup> The estimates in Table 9B also show a positive relation between stock volatility and trading activity. The estimates of  $\beta$  are generally more than two standard errors above 0. The estimates of  $\delta$  are all positive. For the estimates of volatility based on daily S&P data  $\sigma_t$ , they are several standard errors above 0. For the estimates of volatility based on monthly data  $|\epsilon_{st}|$ , the estimates of  $\delta$  are closer to 0, though for 1883-1986 it is three standard errors above 0. Thus, the evidence in Table 9B supports the proposition that stock market volatility is higher when trading activity is greater.

Table 9C contains tests of the incremental predictive power of 12 lags of NYSE share volume growth  $\text{Vol}_t$  in a 12<sup>th</sup> order VAR system for stock volatility, high-grade bond return volatility  $|\epsilon_{rht}|$ , and short-term interest volatility  $|\epsilon_{rst}|$ , that allows for different monthly intercepts. This model is similar to those used in Tables 3A, 3B, 4A, 4B and 4C. The F-statistics measuring the ability of share volume growth to predict financial volatility are small, except 1927-1986 using monthly stock volatility  $|\epsilon_{st}|$ . There is somewhat stronger evidence that financial volatility helps predict future trading volume growth. The F-statistics using monthly stock volatility are 2.48, 3.19 and 2.34 for 1883-1986, 1883-1926 and 1927-1952, respectively. The F-statistic using daily stock return volatility  $\sigma_t$  is 3.68 for 1927-1986.

In general, high trading activity and high volatility occur together. Of course, these regressions cannot show whether this relation is due to 'trading noise,' or to the flow of information to the stock market.

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<sup>13</sup>This model was suggested by the pattern of regression coefficients in an unrestricted regression of volatility on current and 4 lags of volume growth.  $L$  is the lag operator,  $L^k X_t = X_{t-k}$ .

Table 9A

Estimates of the Relation Between Stock Market Trading Activity and the Standard Deviation of Stock Market Returns, 1928-1986 and Subperiods

Regressions of Stock Volatility on Square Root of Trading Days

(asymptotic standard errors in parentheses under coefficients)

$$\sigma_{st} = \alpha_0 + \alpha_1 \sqrt{\text{Days}_t} + u_t \quad (6)$$

<u>Dependent Variable</u>	<u>Sample Period</u>	<u><math>\alpha_0</math></u>	<u><math>\alpha_1</math></u>	<u>S(u)</u>	<u>R<sup>2</sup></u>	<u>Q(24)</u>
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Estimated Standard Deviation from CRSP Monthly Returns

$ \epsilon_{st} $	1928-86	-.0390 (.0390)	.0167 (.0082)	.0365	.174	41.9 (.003)
$ \epsilon_{st} $	1928-52	-.0253 (.0715)	.0152 (.0143)	.0473	.174	33.8 (.028)
$ \epsilon_{st} $	1953-86	-.0319 (.0439)	.0140 (.0096)	.0257	.058	14.5 (.805)

Estimated Standard Deviation from S&P Daily Returns

$\sigma_t$	1928-86	.0377 (.0215)	.0021 (.0042)	.0214	.561	39.2 (.006)
$\sigma_t$	1928-52	.0809 (.0424)	-.0043 (.0080)	.0292	.520	26.3 (.157)
$\sigma_t$	1953-86	.0002 (.0175)	.0082 (.0038)	.0128	.410	11.3 (.939)

Note: GLS estimates include an ARMA(1,3) process for the errors  $u_t$ .  $\sqrt{\text{Days}_t}$  is the square root of the NYSE trading days in the month. S(u) is the standard deviation of the errors, R<sup>2</sup> is the coefficient of determination including the effects of estimating the ARMA(1,3) process for the errors, and Q(24) is the Box-Pierce[1970] statistic for 24 lags of the residual autocorrelations, which should be distributed as  $\chi^2(20)$ , with the p-value in parentheses under the test.



Table 9B

Regressions of Stock Volatility on Growth in Trading Volume

(asymptotic standard errors in parentheses under coefficients)

$$\sigma_{st} = \alpha_0 + \frac{\beta}{(1-\delta L)} \text{Vol}_t + u_t \quad (7)$$

Dependent Variable	Sample Period	$\alpha_0$	$\beta$	$\delta$	S(u)	R <sup>2</sup>	Q(24)
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Estimated Standard Deviation from CRSP Monthly Returns

$ \epsilon_{st} $	1883-1986	.0335 (.0042)	.0314 (.0027)	.2525 (.0868)	.0289	.257 (.259)	45.2 (.001)
$ \epsilon_{st} $	1927-1986	.0398 (.0063)	.0449 (.0047)	.0991 (.1066)	.0343	.262 (.278)	35.9 (.016)
$ \epsilon_{st} $	1927-1952	.0497 (.0121)	.0489 (.0069)	.0114 (.1411)	.0433	.291 (.319)	31.1 (.054)
$ \epsilon_{st} $	1953-1986	.0315 (.0021)	.0349 (.0071)	.3124 (.1993)	.0251	.107 (.119)	20.5 (.427)

Estimated Standard Deviation from S&P Daily Returns

$\sigma_t$	1927-1986	.0474 (.0083)	.0214 (.0031)	.7575 (.1089)	.0206	.561 (.594)	38.0 (.009)
$\sigma_t$	1927-1952	.0607 (.0152)	.0234 (.0048)	.7872 (.1427)	.0277	.561 (.571)	26.1 (.161)
$\sigma_t$	1953-1986	.0372 (.0028)	.0143 (.0037)	.5820 (.2701)	.0127	.427 (.431)	10.3 (.963)

Note: All models include an ARMA(1,3) process for the errors  $u_t$ . The distributed lag model for the effect of current and lagged share volume growth on the monthly standard deviation of stock returns implies geometric decay. The implied coefficient for lag  $k$  is  $\beta\delta^k$ . S(u) is the standard deviation of the errors, R<sup>2</sup> is the coefficient of determination (with the R<sup>2</sup> from an unconstrained model with current and 4 lags of Vol<sub>t</sub> in parentheses below), and Q(24) is the Box-Pierce[1970] statistic for 24 lags of the residual autocorrelations, which should be distributed as  $\chi^2(20)$  in this case, with the p-value in parentheses under the test.

Table 9C

Estimates of the Relations Among Stock, Bond, and Interest Rate Volatility  
with Trading Volume Growth, 1883-1986 and Subperiods

Vector Autoregressive Models for Stock, Bond and  
Interest Rate Volatility, Including Stock Trading Volume

Dependent Variable	<u>F-tests with Monthly Stock Volatility</u>				<u>F-tests with Daily Stock Volatility</u>				
	Stock	Bond	Int	Vol	Stock	Bond	Int	Vol	
				<u>1883-1986</u>					
Stock	15.12	2.99	1.59	1.44					
Hibond	$\begin{vmatrix} \epsilon_{rht} \\ \epsilon_{rst} \end{vmatrix}$	5.63	18.33	3.34	0.92				
Int		2.48	4.05	16.65	0.56				
Vol		2.48	1.44	0.68	11.64				
				<u>1883-1926</u>					
Stock	2.63	1.09	0.54	0.54					
Hibond	$\begin{vmatrix} \epsilon_{rht} \\ \epsilon_{rst} \end{vmatrix}$	1.77	7.21	0.82	1.06				
Int		2.56	1.62	7.89	0.82				
Vol		3.19	1.89	0.97	5.10				
				<u>1927-1986</u>					
Stock	9.46	2.02	1.31	2.30	55.01	2.26	0.56	1.67	
Hibond	$\begin{vmatrix} \epsilon_{rht} \\ \epsilon_{rst} \end{vmatrix}$	4.26	6.88	3.91	0.56	3.46	7.52	4.14	1.21
Int		1.76	5.40	7.98	0.61	1.51	5.43	8.30	0.85
Vol		1.60	1.38	0.61	7.82	3.68	0.98	0.55	8.25
				<u>1927-1952</u>					
Stock	2.24	2.32	2.01	1.30	12.33	3.66	3.10	0.76	
Hibond	$\begin{vmatrix} \epsilon_{rht} \\ \epsilon_{rst} \end{vmatrix}$	7.81	2.76	2.18	0.76	4.31	3.50	1.98	1.29
Int		0.90	1.80	12.83	0.76	1.10	2.26	12.97	0.68
Vol		2.34	2.96	0.83	3.20	1.46	1.40	0.40	2.94
				<u>1953-1986</u>					
Stock	2.15	0.78	1.19	1.19	15.42	0.49	0.32	0.46	
Hibond	$\begin{vmatrix} \epsilon_{rht} \\ \epsilon_{rst} \end{vmatrix}$	1.40	4.44	2.79	0.46	1.17	4.37	3.11	0.53
Int		2.75	5.91	3.13	0.60	2.48	5.79	2.71	0.91
Vol		0.46	0.74	0.92	7.50	1.42	0.66	1.01	7.61

Note: A 4-variable, 12th order VAR model is estimated for stock, bond, and interest rate volatility, and stock trading volume growth, including dummy variables for monthly intercepts. The F-tests reflect the ability of the column variable to predict the respective row variables. Measures of stock return volatility based on monthly data  $|\epsilon_{st}|$  are used in the first four columns, and measures of stock return volatility based on daily data  $\sigma_t$  are used in the last four columns. The .05 and .01 critical values for the F-statistic with 12 and 200 degrees of freedom are 1.80 and 2.28, respectively.

## 6. Summary and Conclusions

Given that stock volatility has changed substantially over time, it is interesting to ask why it has changed. This paper analyzes many factors related to stock volatility, but it does not test for causes of stock price volatility. Rather, the hypotheses involve associations between stock volatility and other variables.

For example, the analysis of the volatility of bond returns, inflation rates, money growth, and real macroeconomic variables, along with stock volatility, seeks to determine whether these aggregate volatility measures change together through time. In most general equilibrium models, fundamental factors such as consumption and production opportunities and preferences would determine all of these parameters (e.g., Abel[1988] or Genotte and Marsh[1987]). Nevertheless, the process of characterizing stylized facts about economic volatility helps define the set of interesting questions, leading to tractable theoretical models.

### 6.1 Joint Effects of Leverage and Macroeconomic Volatility

Most of the tests above analyze financial volatility along with one additional nonfinancial factor. To summarize all of these relations between stock volatility and nonfinancial factors, Table 10 contains estimates of the multiple regression,

$$\ln |\epsilon_{st}| = \alpha_e + \alpha_r D_t + \beta_1 \ln |\hat{\epsilon}_{rst}| + \beta_2 \ln |\hat{\epsilon}_{pt}| + \beta_3 \ln |\hat{\epsilon}_{mt}| + \beta_4 \ln |\hat{\epsilon}_{it}| + \beta_5 \ln |\hat{\epsilon}_{dt}| + \gamma \ln (V/S)_{t-1} + u_t. \quad (8)$$

In (8),  $\alpha_e$  represents the constant term during expansions, and  $(\alpha_e + \alpha_r)$  represents the constant term during recessions. The slope coefficients  $\beta_1$  through  $\beta_5$  represent the elasticities of stock return volatility with

predicted short-term interest rate volatility, predicted inflation volatility, predicted money growth volatility, predicted industrial production volatility and predicted bank clearings volatility, respectively. The coefficient  $\gamma$  measures the effect of leverage on volatility. Table 10 shows estimates of equation (8) for both stock and bond return volatility. There is no correction for autocorrelation in the errors from (8), although the standard errors use Hansen's (1982) heteroskedasticity and autocorrelation consistent covariance matrix.<sup>14</sup>

Equation (8) measures the contributions of these conditional volatility factors, along with leverage, in explaining the time series variation in corporate stock and bond return volatility. From (4),  $\sigma_{st}^2 \approx (V/S)_{t-1}^2 \sigma_{vt}^2$ , since the variance of bond returns and the covariance of bond returns with stock returns will be much smaller than  $\sigma_{vt}^2$ . Thus, equation (8) is an approximation of (4), where the predicted volatilities of the macroeconomic factors affect firm volatility  $\sigma_{vt}^2$ . The elasticity with leverage should be  $\gamma=1$ . The sum of the elasticities ( $\beta_1+\beta_2+\beta_3+\beta_4+\beta_5$ ) measures the response of firm volatility to a one percent increase in the volatility of all of the macroeconomic factors.

The results for stock volatility are interesting. First, the average level of volatility is much higher during recessions (consistent with Table 5). The column labeled 'Recess' in Table 10 contains estimates of  $\alpha_r$ , the differential intercept during recessions, between .17 and .50 across the different measures

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<sup>14</sup>Since many of the regressors in (8) are fitted values from first stage regressions (2b), the 'generated regressors' problem discussed by Pagan [1984] is relevant here. In brief, to the extent that there are omitted variables that could be used to help predict the volatility of some of these series, the coefficients of all of these second stage regressors will be biased. Experimentation with instrumental variables estimation, the technique recommended by Pagan, yielded similar results.

Table 10

Estimates of the Relation of Stock and Bond Return Volatility with the Predicted Volatility of Macroeconomic Variables, and the Effect of Leverage, 1900-1986 and Subperiods

Sample Period	Recess	Measures of Predicted Volatility					Sum	Leverage		
		$\ln \hat{\epsilon}_{rst} $	$\ln \hat{\epsilon}_{pt} $	$\ln \hat{\epsilon}_{mt} $	$\ln \hat{\epsilon}_{it} $	$\ln \hat{\epsilon}_{dt} $		$\ln(V/S)_t$	$R^2$	Q(24)
Estimated Standard Deviation from CRSP Monthly Returns, $\ln \epsilon_{st} $										
1900-86	.287 (.118)	.022 (.115)	.008 (.082)	.114 (.082)	-.072 (.103)	.208 (.196)	.280 (.253)	.164 (.393)	.021	120 (.000)
1927-86	.497 (.102)	.093 (.090)	.151 (.085)	.047 (.080)	.195 (.103)	.159 (.165)	.645 (.207)	.728 (.293)	.084	26 (.332)
1927-52	.492 (.153)	.236 (.153)	.058 (.115)	-.291 (.151)	.031 (.139)	.543 (.243)	.578 (.266)	2.10 (.547)	.125	24 (.442)
1953-86	.401 (.091)	.176 (.117)	.226 (.113)	-.229 (.136)	.011 (.141)	-.402 (.215)	-.217 (.290)	.077 (.350)	.064	29 (.237)
Estimated Standard Deviation from S&P Daily Returns, $\ln\sigma_t$										
1927-86	.255 (.076)	.146 (.047)	.208 (.044)	.171 (.044)	.256 (.053)	.201 (.082)	.982 (.122)	.528 (.188)	.387	346 (.000)
1927-52	.357 (.095)	.112 (.083)	.169 (.080)	.095 (.087)	.308 (.066)	.235 (.142)	.918 (.143)	.880 (.455)	.383	108 (.000)
1953-86	.166 (.078)	.238 (.064)	.232 (.056)	-.012 (.065)	.008 (.077)	-.021 (.102)	.455 (.197)	.208 (.227)	.256	220 (.000)
Estimated Standard Deviation of Long-term Corporate Bond Returns, $\ln \epsilon_{rht} $										
1900-86	.041 (.154)	.586 (.199)	-.041 (.107)	.042 (.154)	-.105 (.163)	-.045 (.267)	.437 (.383)	.318 (.543)	.046	723 (.000)
1927-86	-.078 (.154)	.920 (.143)	.036 (.130)	-.167 (.166)	.206 (.157)	.509 (.263)	1.50 (.266)	.724 (.481)	.146	145 (.000)
1927-52	-.008 (.249)	.693 (.246)	.398 (.208)	-.098 (.217)	.276 (.209)	.426 (.376)	1.70 (.315)	1.75 (1.07)	.129	57 (.000)
1953-86	.110 (.152)	.938 (.201)	-.115 (.158)	-.191 (.163)	-.034 (.237)	.397 (.327)	.995 (.429)	-.330 (.466)	.154	63 (.000)

Note: Asymptotic standard errors are in parentheses under the coefficient estimates. All tests use Hansen's [1982] heteroskedasticity and autocorrelation consistent covariance matrix, using 12 lags and leads and a damping factor of .7. The regression model includes a constant, a dummy variable equal to unity during recessions, the logarithms of the predicted standard deviations of short-term nominal interest rates  $|\hat{\epsilon}_{rst}|$ , of PPI inflation  $|\hat{\epsilon}_{pt}|$ , of money growth  $|\hat{\epsilon}_{mt}|$ , of industrial production  $|\hat{\epsilon}_{it}|$ , and of bank clearings growth  $|\hat{\epsilon}_{dt}|$ , and the logarithm of leverage (V/S). The predicted standard deviations are from the estimates of equation (2b) in Table 2B. The logarithm of the stock return volatility measures,  $|\epsilon_{st}|$  and  $\sigma_t$ , and high-grade bond return volatility  $|\epsilon_{rht}|$  are the regressands.  $R^2$  is the coefficient of determination and Q(24) is the Box-Pierce [1970] statistic for 24 lags of the residual autocorrelations, which should be distributed as  $\chi^2(24)$  in this case, with the p-value in parentheses under the test. The column labeled Sum contains the sum of the coefficients of predicted volatilities.

of stock volatility and different time periods. In all cases, it is reliably greater than zero. If the recession dummy variable proxies for variation in operating leverage, it is interesting that it remains important for stock volatility even when other factors are included.

Second, the effect of financial leverage is positive, although it is not precisely measured. In the 1953-1986 period, the estimate of  $\gamma$  seems to be reliably below unity. Perhaps this reflects the imperfect proxies for this and other regressors, and the collinearity among them. In the other sample periods, the coefficient of financial leverage is within two standard errors of 1.

Third, the estimates of the predicted macroeconomic volatility coefficients are generally positive, and many are reliably greater than zero. For example, using the stock volatility measure from daily data  $\ln \sigma_t$  for 1927-1986, all of these coefficients are at least 2.5 standard errors above 0. The sum of these coefficients is .98, with a standard error of .12. Thus, if the volatility of interest rates, inflation rates, money growth, industrial production, and bank clearings all increase one percent, stock volatility increases by .98 percent. Across both monthly and daily measures of stock volatility, and across all subperiods, the coefficient estimates of predicted short-term interest rate volatility and predicted inflation volatility are reliably positive most frequently.

The results for bond return volatility in Table 10 are also interesting. First, there seems to be no direct effect of recessions. Second, the theoretical motivation for including financial leverage is less clear, given that the dependent variable is the volatility of returns to Aa rated bonds. Presumably if financial leverage causes a substantial increase in the default

risk of corporate debt, the bond rating would decrease. Since I use bonds of a constant quality class over time, the imprecise estimates of the financial leverage coefficient are not surprising. The only predicted volatility measure that has reliably positive coefficient estimates is short-term interest rate volatility. These coefficient estimates are between .59 and .94, depending on the sample period. This implies that a one percent increase in predicted short-term interest rate volatility is associated with a .6 to .9 percent increase in long-term corporate bond return volatility. Note that this result is not limited to the post-1979 period when both short and long-term interest rates exhibited unusual volatility. Thus, the results in Table 10 suggest that macroeconomic volatility has differential effects on the volatility of corporate stock and bond returns.

## 6.2 Synthesis

Many economic series were more volatile in the 1929-1940 Great Depression. Nevertheless, stock volatility increased by a factor of two or three during this period relative to the usual level of the series (see Figure 1). There is not other series in this paper that experienced similar behavior. In this period, stock volatility is positively related to measures of corporate profitability, such as the payout ratio and the quality yield spread for corporate bonds (Tables 6 and 7). For sample periods that do not include 1929-1940, however, these profitability measures are not related to stock volatility.

Second, there is evidence that many aggregate economic series are more volatile during recessions (Table 5). This is particularly true for financial asset returns and for measures of real economic activity. One interpretation of this evidence is that 'operating leverage' increases during recessions.

Third, there is weak evidence that macroeconomic volatility can help predict stock and bond return volatility (Tables 3A, 3B, 4A, 4B and 4C). The evidence is somewhat stronger that financial asset volatility helps predict future macroeconomic volatility. This is not surprising since the prices of speculative assets should react quickly to new information about economic events.

Fourth, financial leverage affects stock volatility. When stock prices fall relative to bond prices, or when firms issue new debt securities in larger proportion to new equity than their prior capital structure, stock volatility increases (Table 8). However, this effect explains only a small proportion of the changes in stock volatility over time (Figure 7).

Fifth, there seems to be a relation between trading activity and stock volatility. The number of trading days in the month is positively related to stock volatility, especially in 1953-1986 (Table 9A). This reinforces the evidence in French and Roll[1986]. Also, share trading volume growth is positively related to stock volatility (Tables 9B and 9C).

Finally, major episodes in U.S. economic history are associated with greater volatility, such as the Civil War, World War I, the Great Depression, World War II, the OPEC oil shock, and the post-1979 period. The puzzle highlighted by the results in this paper is that stock volatility is not more closely related to other measures of economic volatility. For example, the volatility of inflation and money growth rates is very high during war periods, as is the volatility of industrial production and business failures. Yet the volatility of stock returns is not particularly high during wars. Similarly, there were many 'financial crises' or 'bank panics' during the 19<sup>th</sup> century in the U.S. that caused very high and volatile short-term interest



rates, yet there is no major change in stock volatility.

In short, the evidence in this paper reinforces the argument made by Officer[1973] that the volatility of stock returns from 1929-1940 was unusually high relative to either prior or subsequent experience. For many years macroeconomists have puzzled about the inability of their models to explain the data from the Great Depression. The descriptive results in this paper pose a similar challenge to financial economists. Moreover, based on evidence in Fama and French[1988] and Poterba and Summers[1988], the 1929-1940 period plays a crucial role in the evidence for 'mean reversion' in stock prices. I suspect an analysis of Shiller's[1981a,1981b] variance bounds tests would reveal that the 1929-1940 period is responsible for the inference of 'excess volatility' of stock prices. Indeed, the spirit of the preceding discussion suggests that stock volatility was inexplicably high during this period. I am hesitant to cede all of this unexplained behavior to social psychologists as evidence of fads or bubbles. Nevertheless, there remains a challenge to both theorists and empiricists to explain why this episode was so unusual.

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## APPENDIX

### Data Series Used in This Paper

#### 1. Common Stock Returns, 1857-1986

For 1926-1986, I use the returns including dividends to the value-weighted portfolio of all New York Stock Exchange (NYSE) stocks constructed by the Center for Research in Security Prices (CRSP) at the University of Chicago. For 1871-1925, I use the returns including dividends to the value-weighted portfolio of NYSE stocks constructed by the Cowles Commission[1939, pp. 168-169], as corrected by Wilson and Jones[1987, p. 253, with erratum]. For 1857-1870, Macaulay's[1938, pp. A142-A161] index of railroad stock prices is used to calculate returns, then the regression of the Cowles returns on the Macaulay returns from February 1871 through December 1879,

$$\text{Cowles}_t = .005585 + .999395 \text{Macaulay}_t + u_t, \\ (.000422) (.013594)$$

predicts the level of the Cowles returns from the observed Macaulay returns, where standard errors are in parentheses under the coefficient estimates. This is essentially equivalent to adding a dividend yield of .56 percent per month (6.7 percent per year) to the percent changes in railroad stock prices. The correlation between the Cowles and the Macaulay returns is .99 from 1871-1879.

#### 2. Common Stock Yields, 1871-1986

For 1926-1986, I use the dividend yield, D/P, on the S&P composite index (from Citibase[1978] for 1947-86 and from the Federal Reserve[1976b, Table 12.19, pp. 788-790] for 1926-46). For 1871-1925, I use the yield expectations series from the Cowles Commission[1939, pp. 270-271], adjusted to splice with the S&P series in 1926 by multiplying the Cowles data by the ratio of the Cowles D/P to the S&P D/P for 1926 = .928571.

The earnings yield series, E/P, for the S&P composite index is available monthly for 1954-1986 from Citibase[1978]. This series is available quarterly for 1935-1953 and annually for 1926-1934 in the Federal Reserve[1976b, Table 12.19, pp. 788-790]. To create a monthly series for 1926-1953, I use the regression of the growth rate of E/P on the growth rate of D/P from 1954-1986,

$$\Delta \ln(E/P)_t = .000148 + 1.017220 \Delta \ln(D/P)_t + u_t$$

$$(.001139) \quad (.032186)$$

where standard errors are in parentheses under the coefficient estimates. The correlation between these monthly growth rates is .85 over this period. The E/P ratios are interpolated forward from the beginning of the period using these predicted growth rates, and interpolated backward from the end of the period. The monthly E/P series used in the paper for 1926-1953 is an average of the forward and backward interpolations. For 1871-1925, I use the annual E/P ratio from the Cowles Commission[1939, pp. 404-405]. This is spliced with the S&P series by multiplying the Cowles data by .914428, the ratio of the S&P to the Cowles E/P ratios for 1926. I assume that the "payout ratio" (D/E) is constant within the year, and equal to the ratio of D/P for December divided by E/P. Thus, for 1871-1934 the earnings yield numbers behave like the dividend yield series within each year.

### 3. Short-term Interest Rates, 1857-1986

For 1926-1986, I use the monthly yields on the shortest term U.S. Government security (with no special tax provisions) which matures after the end of the month from the Government Bond File constructed by CRSP. For 1857-1925, I use the 4 to 6 month commercial paper rates in New York from Macaulay[1938, Table 10, pp. A141-A161]. The commercial paper yields are adjusted so the level of the series is comparable to the Treasury yields, using the regression of CRSP yields on Macaulay yields from 1926-1937,

$$CRSP_t = -.000761 + .9737368 \text{ Macaulay}_t + u_t$$

$$(.000085) \quad (.0309330)$$

where standard errors are in parentheses under the coefficient estimates. This is equivalent to subtracting an average risk premium of .076 percent per month (.91 percent per year) from the Macaulay yields to reflect a small default premium in commercial paper. The correlation between the CRSP and the Macaulay yields is .94 for 1926-1937.

### 4. Long-term Interest Rates, 1857-1986

The high-grade corporate bond yield for 1919-1986 is the Moody's Aa bond yield (Federal Reserve[1976a, Table 128, pp. 468-471] for 1919-40, Federal Reserve[1976b, Table 12.12, pp. 720-721] for 1941-47, and Citibase[1978] for

1948-86). For 1857-1918, I use Macaulay's(1938, Table 10, pp. A141-A161) railroad bond yield index, adjusted to splice with the Moody's series using the average ratio of the yields during 1919,  $(RR/Aa) = .964372$ .

The medium-grade corporate bond yield for 1919-1986 is the Moody's Baa bond yield (Federal Reserve[1976a, Table 128, pp. 468-471] for 1919-40, Federal Reserve[1976b, Table 12.12, pp. 720-721] for 1941-47, and Citibase[1978] for 1948-86).

##### 5. Returns to Long-term Corporate Bonds, 1857-1986

The capital gain or loss from holding the bond during the month is estimated from yields assuming that, at the beginning of the month, the bond has a 20-year maturity, a price equal to par, and a coupon equal to the yield, using the conventional bond pricing formula (see Brealey and Myers[1984], pp. 43-45) to calculate beginning and ending prices. The monthly income return is assumed to be one twelfth of the coupon. Since the Moody's yields are averages of the yields within the month, these returns are not comparable to returns based on end-of-month data. To correct for this problem, I estimate a first order moving average process for the returns,

$$R_{bt}^* = \alpha + \epsilon_t - \theta \epsilon_{t-1},$$

then the 'corrected' returns are defined as  $R_{bt} = \alpha + \epsilon_t$ . This correction eliminates the positive autocorrelation at lag one induced by the within month aggregation of yields (see Working[1960]). Note, however, that the corrected returns are not good estimates of actual returns based on end-of-month prices, since their cross correlations with other variables are still affected by time aggregation of the yields. The table below shows sample statistics for 1926-1985 for the corrected high grade bond returns  $R_{ht}$ , the corrected medium grade bond returns  $R_{mt}$  and the returns to corporate bonds from Ibbotson[1986] which use end-of-month yields.



Statistic	Ibbotson	$R_{ht}$	$R_{mt}$
Mean	.0041	.0035	.0041
Std Dev	.0199	.0132	.0197
autocorrelation, lag 1	.15	.00	.04
autocorrelation, lag 2	.00	.09	.10
autocorrelation, lag 3	-.08	-.14	-.23
cross correlation, with Ibbotson lead 1	.15	.04	.03
cross correlation, with Ibbotson current	1.0	.57	.37
cross correlation, with Ibbotson lag 1	.15	.50	.32

The means and standard deviations are similar, but the high and medium grade bond returns are correlated with the lagged value of the Ibbotson bond returns. This is caused by the time-averaged yields used by Moody's. Because the Ibbotson data are not available before 1926, and they only measure returns to high grade bonds, I also use the returns calculated from the various bond yield series.

#### 6. Inflation Rates, 1862-1986

For 1890-1986, I use the Bureau of Labor Statistics Producer Price Index (PPI) inflation rate, not seasonally adjusted. For 1875-1889, I use the inflation rate of Snyder's index of producer prices from Macaulay[1938, Table 27, pp. A255-A270] to predict the PPI inflation rate. I use the regression of PPI inflation on one lead, current and one lag of Snyder's inflation ( $S_t$ ) for 1890-1936,

$$PPI_t = -.001323 + .496811 S_{t+1} + .951674 S_t + .252962 S_{t-1} + u_t$$

(.000560) (.070773) (.072528) (.070877)

to predict PPI inflation for 1875-1889, where standard errors are in parentheses under the coefficient estimates. The correlation between the

predictions from Snyder's inflation rates and the PPI inflation rate is .67 for 1890-1936. For 1862-1875, I use the inflation rate of Wesley Mitchell's price of gold in greenbacks from Macaulay[1938, Table 18, p. A215] to measure PPI inflation.

#### 7. Stock Market Share Trading Volume, 1881-1986

Standard & Poor's[1986, p. 214] reports monthly NYSE share trading volume for 1883-1985.<sup>1</sup> Citibase[1978] contains similar data for 1986. The NYSE provided data from April 1881 through 1882. I measure the number of trading days per month for 1928-1986 from the daily data on the Standard & Poor's composite index in Standard & Poor's[1986, pp. 134-187].

#### 8. Financial Leverage, 1901-1986

Taggart[1986] discusses many estimates of the equity to total capital ratio ( $S/V$ ) for public corporations in the United States for 1900-1979. Holland and Myers[1979] estimate the capital structure of corporations using National Income Accounts data on dividend and net interest payments from non-financial corporations. They capitalize these flows using the S&P dividend yield and the Moody's Baa bond yield, respectively. These data are available annually for 1929-1945, and quarterly for 1946-1986. For 1926, I use the estimate from Ciccolo and Baum[1986], based on the market value of debt, preferred and common stock for a sample of about 50 manufacturing firms. For 1900, 1912, and 1922, I multiply estimates of the book value of  $S/V$  from Goldsmith, Lipsey and Mendelson[1963, Tables III-4 and III-4b, pp. 140-141, 146-147] by the average ratio of these estimates divided by the Holland-Myers estimates for the years 1929, 1933, 1939, and 1945-1958,  $(HM/Goldsmith) = 1.226$ . Thus, I have annual estimates of  $S/V$  for 1900, 1912, 1922, 1926, 1929-1945, and quarterly estimates for 1946-1986.

I create a monthly series  $S/V_t$  using the rates of return to the stock portfolio  $R_{st}$  described above, and the returns to corporate bonds from Ibbotson[1986]  $R_{bt}$ . Before 1926, I estimate corporate bond returns using the yields on high-grade long-term bonds described above. I interpolate forward,

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<sup>1</sup>The New York Stock Exchange was closed during the last 6 months of 1914 due to the outbreak of World War I. For purposes of this paper, I interpolate share volume growth during this period.

$$(S/V)_t^+ = (S_{t-1}(1+R_{st})/[S_{t-1}(1+R_{st}) + B_{t-1}(1+R_{bt})]),$$

and backward,

$$(S/V)_t^- = (S_{t+1}/(1+R_{st+1})/[S_{t+1}/(1+R_{st+1}) + B_{t+1}/(1+R_{bt+1})]),$$

then use the average of these estimates for the monthly leverage estimate,

$$(S/V)_t = ((S/V)_t^+ + (S/V)_t^-)/2.$$

#### 9. Stock Return Volatility, 1926-1986

Following French, Schwert and Stambaugh[1987], I use the daily returns to the Standard & Poor's composite portfolio for 1928-1986 to estimate the standard deviation of monthly stock returns. The estimate of the monthly standard deviation is,

$$\sigma_t = \left[ \frac{N_t}{\sum_{i=1}^{N_t} r_{it}^2} + 2 \frac{N_t-1}{\sum_{i=1}^{N_t-1} r_{it}r_{i+1t}} \right]^{1/2},$$

where  $r_{it}$  is the return to the S&P portfolio on day  $i$  in month  $t$  and there are  $N_t$  trading days in month  $t$ . For 1926-1927 I use a comparable estimator based on the weekly values of the S&P portfolio.

#### 10. Bank Clearings or Debits, 1857-1986

Bank debits measure the flow of financial transactions. For 1857-1918, I use the daily average clearings data from Macaulay[1938, Table 27, pp. A252-A266]. For 1857-1874, I estimate clearings outside of New York City using the average fraction of clearings in New York for 1875-1884 (70.664 percent), so adjusted total clearings are New York clearings divided by .70664. Daily average debits to demand deposit accounts are from Federal Reserve[1976a, Table 51, pp. 234-235] for 1919-1941, Federal Reserve[1976b, Table 5.1B, pp. 334-339] for 1943-1963, Federal Reserve[1976b, Table 5.2B, pp. 342-343] for 1964-70, and various issues of the Federal Reserve Bulletin since 1970. The data are adjusted to reflect increases in the coverage of the sample by the Federal Reserve Board in 1919, 1964 and 1970. For 1964 and 1970, I use the average of the new to old sample values for the year's overlap as a multiple for all prior data (these multiples are 1.120582 in 1964 and 1.107030 in 1970). I use the ratio of the Federal Reserve debits data to Macaulay's clearings data for January 1919 (1.077120) as a multiple for the clearings

data before 1919. To illustrate, the New York clearings data for January 1857 are multiplied by a factor  $(1.077120 * 1.120582 * 1.107030 / .70664) = 1.890901$  to create a consistent series from 1857 through 1986. Because of the Federal Banking Holidays in March 1933, debits data are not reported for that month, so I use the average of February and April debits to estimate the March debits.<sup>2</sup> Also, the Federal Reserve does not report monthly debits for 1942, so I calculate the annual growth rate from 1941 to 1942 and from 1942 to 1943. Next I estimate the monthly debits in 1942 using an average of two estimates: the corresponding monthly debits from 1941 and 1943 adjusted for the respective annual growth rates.

#### 11. Industrial Production, 1889-1986

For 1947-1986, I use the Federal Reserve Board index of industrial production from Citibase[1978]. For 1919-1946, I use the FRB index of industrial production reported in Moore[1961, p. 129], adjusted to the same base as the current index using the average ratio of the Old to New indexes for 1947-1958 (.294633). For 1889-1918, I use Babson's Index of the physical volume of business activity from Moore[1961, p. 130], adjusted to splice with the industrial production data using the average ratio of Babson to adjusted industrial production for 1919-1938 (.0146398).

#### 12. Liabilities of Business Failures, 1875-1986

For 1948-1986, I use the Dun and Bradstreet data on the liabilities of industrial and commercial business failures from Citibase[1978]. For 1894-1947, I use the Dun and Bradstreet monthly data from Moore[1961, p. 98-99], adjusted to reflect increases in coverage by Dun and Bradstreet in June 1934 and January 1939. The data before January 1939 are multiplied by the average ratio of the New to Old series during 1939 (1.086851), and the data before June 1934 are multiplied by the average ratio of the New to Old series from June 1934 through December 1938 (1.589149). For 1875-1893, I estimate monthly data by linear interpolation of quarterly data between the middle month of each quarter.

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<sup>2</sup>Obviously, this overstates March debits, since the holidays were intended to slow down the rate of financial transactions during this period.

### 13. Money Supply, 1867-1986

I use the monetary base (referred to as high-powered money in Friedman and Schwartz[1963]). For 1867-1960, I use data from Friedman and Schwartz[1963, Table B-3, column (1), pp. 799-808] for the base. For 1961-1986, I use the seasonally adjusted monetary base reported by the Federal Reserve Board from Citibase[1978]. These series are spliced together using the average ratio of the respective series during 1960. Thus, the base data since 1960 are multiplied by 1.127538. The Friedman and Schwartz data are reported on a monthly basis beginning in May 1907. From June 1878 through April 1907, I use a monthly monetary base series from the National Bureau of Economic Research (NBER), multiplied by the average ratio of the Friedman and Schwartz series to the NBER series for 1878-1914, 1.006948. These data were provided by Professor Robert Barro. Thus, there are continuous monthly data on growth rates of the base from July 1878 through December 1986.

Table A1

Synopsis of US Economic History -- 1867-1986

<u>Dates</u>	<u>Important Event</u>
7/1857-12/1858	recession
11/1860-1/1861	recession
early 1862 --	convertibility of Union currency into specie suspended (not resumed until January 1, 1879); flexible exchange rates; 'greenback standard'; UK on gold standard during this period
5/1865-12/1867	recession
1869	Open Board of Stock Brokers and Stock and Exchange Board merge to form NYSE
7/1869-12/1870	recession
2/12/1873	law discontinues silver dollar
9/1873	Bank panic
11/1873-3/1879	recession (severe)
2/28/1878	Bland-Allison Act resumes silver dollars
1/1/1879	resumed gold standard/fixed exchange rates with UK
4/1882-5/1885	recession (mild)
5/1884	Bank panic (NY) - no suspension of convertibility
4/1887-4/1888	recession (mild)
8/1890-5/1891	recession (mild)
11/1890	Bank panic
7/14/1890	Sherman Silver Purchase Act (bimetallism)
2/1893-6/1894	recession (severe)
5/4/1893	Bank panic (suspension of convertibility of deposits into currency -- ends in Sept) -- stock market collapse (Erie RR in receivership in late July)
6/1893	President announces will repeal Sherman Silver Act
1/1896-6/1897	recession (mild)
4/1898	declare war on Spain
7/1899-12/1900	recession (mild)
10/1899	Boer War (South Africa)
3/14/1900	Gold Standard Act (killed bimetallism)
11/1899	Bank panic
5/9/1901	Morgan/Harriman fight for North Pacific collapses (more stock sold than issued)

<u>Dates</u>	<u>Important Event</u>
9/1901	President McKinley assassinated
10/1902-8/1904	recession (mild)
6/1907-6/1908	recession (severe)
10/1907	Bank panic (suspension of convertibility of deposits into currency -- lifted in early 1908)
5/30/1908	Aldrich-Vreeland Act - led to Federal Reserve in 1914 created National Monetary Commission
2/1910-1/1912	recession (mild)
2/1913-12/1914	recession
12/23/1913	Federal Reserve Act
7/31/1914	NYSE closed due to World War I (under Aldrich-Vreeland Act) (trading resumed on 12/12/1914)
4/6/1917	US enters World War I
11/1918	World War I Armistice
9/1918-3/1919	recession (mild)
2/1920-7/1921	recession (severe)
early 1920	Fed reverses monetary expansion (raised discount rates in Jan and June)
6/1923-7/1924	recession (mild)
11/1926-11/1927	recession (mild)
10/29/1929	S&P falls to 162 (245 on 10/10)
10/1930-12/1930	first banking crisis
3/1931	second banking crisis
9/1931	UK leaves gold standard
9/1929-3/1933	crash (severe)
1/1933	banking panic
3/1933	National Banking Holiday 3/6-3/13 (US off gold standard)
1/31/1934	US sets official \$33 price for gold
6/1937-6/1938	recession (severe)
8/1939	World War II starts in Europe
12/7/1941	Pearl Harbor
early 1942	prices controls imposed (withdrawn in mid-1946)
5/8/1945	VE day
9/2/1945	VJ day
3/1945-10/1945	recession (mild)

<u>Dates</u>	<u>Important Event</u>
12/1948-10/1949	recession (mild)
6/26/1950	Korean War starts
3/1951	Fed-Treasury accord (abandoned in 1953)
8/1953-5/1954	recession (mild)
9/1957-4/1958	recession (mild)
5/1960-2/1961	recession (mild)
1/23/1962	Cuban missile crisis
11/22/1963	President Kennedy assassinated
1/1970-11/1970	recession (mild)
8/16/1971	Nixon price controls
12/1973-3/1975	recession (mild)
10/6/1979	Federal Reserve announces major policy changes
2/1980-7/1980	recession (mild)
8/1981-11/1982	recession (mild)

Sources: Friedman and Schwartz[1963] and the Wall Street Journal.