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In a provocative recent article, Evans (1984) argues that a policy-induced rise in unanticipated interest rate volatility in 1980-82 substantially and significantly reduced output in the U.S. economy. He concludes that "stabilizing interest rates is probably sensible monetary policy." A second hypothesis examined by Evans is whether increased volatility of money growth has contributed to stagnation. His evidence indicates that unanticipated money growth volatility has no effect on real output. Surprising, even it did have such an effect, his chart of volatility (Figure 1, p. 211) indicates that it would have played no role in the 1980-82 downturn because it was essentially unchanged from 1977-82, equaling roughly its postwar average.

Evans' argument is flawed in a number of ways. First, he offers no justification for the measure of interest rate volatility that he uses and his results for the effect on output are sensitive to the definition of volatility that he uses.[1/] For example, one measure, constructed like Evans' measure of money growth variability (annual average data), indicates that interest rate variability does not matter. Second, Evans' distinction between unanticipated versus anticipated interest rate volatility is shown to be empirically weak. "Anticipated changes in volatility" are shown to have similar effects on output. Third, Evans' measure of money growth volatility is not adequate to test the hypothesis that increased money growth variability has contributed to the 1980-82 stagnation of output.

The literature on the transitory effects of changes in money growth focuses on the effects of short-run (less than one year) changes in money growth on short-run movements in output.[2/] Evans' use of annual data for money growth and output makes it difficult enough to observe short-run changes in either variable. But his use of a moving average standard deviation of annual money growth over three to six years makes it impossible to examine short-run effects of the type posited by those he criticizes (Meltzer 1982 and Friedman 1982). Short-term movements in money growth (whether anticipated or unanticipated) could have temporary effects on output that simply get averaged out using annual money growth data and annual output data.

Finally, Evans' results suggest that the channel of the effect of interest rate volatility on the economy is through an unanticipated decline in aggregate demand. His use of the Barro (1981) model for output, however, suggests that the price level impacts expected from unanticipated reductions in aggregate demand can be tested too using Barro's complementary price equation. This is done in the final section. The implied emphasis on aggregate demand shocks contained in Evans is misplaced. To the extent that risk matters, its effects appear to show up on the supply-side of the economy. In short, a rise in risk does not depress output and prices. Instead, a rise in risk apparently has its dominant effect on aggregate supply so that output declines and prices rise.

To examine these issues, three alternative measures of interest rate variability and an alternative measure of money growth variability are developed below. The money growth measure is closer in spirit to that Evans uses for the interest rate. These measures are then used to conduct some of the tests reported by Evans. The results indicate that (1) it is not possible using Evans' model to disentangle whether only unanticipated interest rate variability matters, (2) Evans' results are sensitive to the measure of variability chosen, (3) one cannot reject the hypothesis (not considered by Evans) that interest rate volatility did reduce output sharply and substantially in 1980-82 but interest rate volatility, in turn, rose because of an increase in the volatility of money growth, and (4) in the model chosen by Evans to examine interest rate volatility effects (Barro (1981)), risk changes have dominant aggregate supply effects. The latter is in sharp contrast to the implied demand shock in Evans, Gertler and Grinols (1982) and Mascaro and Meltzer (1984).

Evans' policy conclusions are not emphasized below because he provides no evidence that the increased volatility of interest rates was a policy choice of the Fed or that the choice of an interest rate targeting procedure would have lessened interest rate volatility over the period 1979-82.[3/] Clearly, however, the results below indicate that the policy actions with respect to M1 growth show a destabilizing influence on interest rates and output in the 1980-82 period. The results suggest that improved monetary control stabilizes both interest rates and output. The optimal or possible procedures for achieving such control are not examined.

Alternative Measures of Interest Rate Volatility

Evans examines the effects of changes in the annual volatility of monthly changes in the Aaa bond yield. Specifically, he defines VR_t to be $[\frac{1}{12} \sum_{i=1}^{12} (\Delta r_i - \overline{\Delta r}_t)^2]^{1/2}$, where Δr is the change in the bond yield in month i of year t and $\overline{\Delta r}_t$ is the average monthly change in year t. No justification is offered as to why the standard deviation of monthly changes is used instead of that for, say, monthly levels. Also, no explanation is offered for the use of the monthly data for changes in interest rates.

The VR measure is suspicious for two reasons. First, its discussion comes quickly after a discussion of VM_t which measures the "unpredictability of money growth" as the six-year moving standard deviation of unanticipated annual money growth. It is this measure which does not vary much in 1980-82. A measure of intrayear variability such as that of quarterly money growth, looks more like Evans' volatility of interest rates (his Figure 2, p. 212). For example, in Chart 1 the volatility of annual money growth (six-year moving standard deviation of annual money growth) is plotted along with the volatility of quarterly money growth (standard deviation of quarterly money growth for the four quarters of money growth in each year). The actual money growth rate is used since there is little difference between it and unanticipated money growth (see Sheehey (1984), for example). Note that, as in Evans' Figure 1 (p. 211), the volatility of annual money growth is not unusual, while that for quarterly money growth is dramatically higher in 1980-82, much like Evans' volatility of changes in interest rates.

In a related fashion, the question arises as to what the volatility of the level of interest rates looks like, and more important, how Evans' conclusions would be affected if the level of interest rates had been used rather than the change in interest rates, or if the standard deviation of annual interest rates had been used rather than monthly data.

Three alternative measures of interest rate volatility are presented here. The first, $VRLEV_t$, is constructed using monthly levels of the Aaa bond yield, instead of changes in it. The second is the standard deviation of the monthly logarithm of the Aaa bond yield within each year, $VRLOG_t$. The third, VRA_t, is the five-year moving standard deviation of the annual average Aaa yield.

The first series is examined because it is the variability of the level of interest rates or rates of return that matter to investors, not the variability of its changes. Since monthly interest rates are highly correlated from month t to t+1 [that is, the covariance of (r_t, r_{t+1}) is "large"], the variance of changes gives a distorted measure of volatility of the level of rates. That is, the square of VR is roughly equal to twice the square of VRLEV less the covariance of (r_t, r_{t-1}). Chart 2 provides a comparison of VR and VRLEV that indicates this distortion. The second measure, using logarithms of the monthly rate, is examined because a given probability of a one-percentage point move up or down in the Aaa bond yield has a greater potential for affecting wealth when the expected bond yield is only 1 percent, than if it is, as recently, 15 percent. The variance of ln r equally weights percentage changes around the mean of the rate within each year, making volatility in the low rate years before 1965, comparable to variations in the high-rate years since then. The standard deviation of the logarithm of interest rates shown in Chart 3 provides such a mean-corrected measure. Stated otherwise, the elasticity of wealth with respect to the interest rate is -1, so that the variance of expected wealth is a function of the variance of the logarithm of the interest rate.[4/] The third measure, VRA, is introduced to provide comparability to Evans' use of the standard deviation of annual money growth to investigate the monetary variability hypotheses.

The mean standard deviation and coefficient of variation of each standard deviation measure and its logarithm are provided in Table 1. This information supports several conclusions that are apparent in Charts 2 and 3. Evans' measure spikes up sharply in 1979-81, so that the standard deviation of VR nearly triples when this period is included. The levels measure, VRLEV, also shows a sharp increase in its standard deviation but its past (1947-78) variability is much greater and it rises less relative to its mean in 1947-78. VRLOG and VRA rise in 1979-81 but not to the extent of the other two measures; moreover, their coefficients of variation change very little over the longer period. The logarithms are given because this is the data used in the real output equation. Of particular importance is the variability of ln VRLOG. Its standard deviation is less than 20 percent of its mean and much smaller than that of the other three measures. Hence, tests of its effect on real output are limited by the fact that this measure of risk shows little variation from 1947-78.

<u>Anticipated Versus Unanticipated Interest Rate Volatility</u>

An important issue in a rational expectations framework is the extent to which anticipated or unanticipated movements in either policy or the remainder of the economic structure matter. Evans' test for effects of money growth and interest rate volatility are conducted using a variant of Barro's (1978, 1981) model for real output. Naturally, he attempts to distinguish these two types of movements in interest rate volatility and he concludes that only unanticipated movements in interest rate volatility affect real GNP.[5/]

Specifically, Evans derives unanticipated movements in the volatility of interest rates from an equation relating the logarithm of VR_t to a constant, time trend and two lagged values of itself. The residual from such an equation is the unanticipated component, EVR_t. Such an equation is given in equation (1) in Table 2.[6/] The second lagged dependent variable and the trend are not significant at conventional levels; when the lagged dependent variable is omitted, the trend remains insignificant ($t = 1.60$). Therefore, equation (2) is also used in the tests below to delineate anticipated/unanticipated movements in interest rate volatility. The measures of interest rate volatility ln VRLEV and ln VRLOG are not significantly related to past values of themselves. Since the equations for real GNP contain a trend, it is not possible to test the anticipated versus unanticipated versions of Evans' hypothesis for these measures of risk.

Using an equation such as (1), Evans generates an unanticipated interest rate volatility series and adds the actual and unanticipated variables to a variant of Barro's real output equation (ln X is the dependent variable) that contains constant, trend, transitory movements in federal expenditures, FEDV, a lagged dependent variable, and unanticipated money growth. Unanticipated money growth is estimated as DMR_t from an equation explaining money growth.

$$\Delta \ln M_t = \underset{(0.0285)}{0.6890} + \underset{(0.0273)}{0.10195}\, FEDV_t + \underset{(0.1070)}{0.7034}\, \Delta \ln M_{t-1}$$

$$+ \underset{(0.0108)}{0.0469} \ln \left[\frac{U_{t-1}}{1-U_{t-1}}\right] - \underset{(0.0104)}{0.0222} \ln \left[\frac{U_{t-2}}{1-U_{t-2}}\right] + DMR_t$$

1947-78, $\bar{R}^2 = 0.676$ S.E. = 0.0131 D-W = 2.03 (1)

The money measure is M1 and U is the unemployment rate of the total labor force.

When the first equation in Table 2, equation (1) above and the ln X_t equations are jointly estimated, Evans finds that EVR_{t-1} is significantly negative in the ln X_t equation; the contemporaneous EVR and lagged anticipated component of ln VR are not. He concludes that unanticipated interest rate volatility one year earlier matters. This is a curious use of the notion of an unanticipated change: typically (for example, in the case of money growth), unanticipated changes in variables that influence decisions affect those decisions immediately, then, due to information or other adjustment costs, with a lag. In this case, the "unanticipated" information does not affect any decision until it is fully known in the next year.

Alternative Measures of Volatility and Real Output

To examine the sensitivity of real output to interest rate volatility, Evans' real GNP equation is estimated with DMR variables obtained from (1) above and (a) EVR_t and EVR_{t-1} variables from the five equations in Table 2, (b) the contemporaneous and lagged predicted components of interest rate volatility in the three equations where these depend upon their past history, (c) the contemporaneous and lagged actual volatility measures, and (d) combinations of (a)-(c). when variables from either are significant.

Table 3 summarizes the effects of adding contemporaneous or lagged information to the real output equation for 1948 to 1978.[7/] The t-statistics for comparable equations estimated through 1981 are given in parenthesis. The t-statistic provides information on the sign of the effect as well as its significance. The coefficient estimates, by themselves, are not comparable so they are omitted. Note, first, that several of the measures have significant negative effects in both periods. Moreover, if the fit of the ln X equation is the criterion for selection, Evans' EVR_{t-1} measure (from Table 2, equation (1)) outperforms all others. The conceptual difficulties associated with the VR measure, however, militate against this conclusion. Nonetheless, the results in Table 3 indicate that the central thrust of Evans' hypothesis is correct. Table 3 reveals that some qualifications appear to be in order, however.[8/] For example, had Evans used annual average data for interest rates to construct his volatility measure (VRA), as he did for money growth, he would have found this measure to be insignificant too.

Evans' Measure of the Volatility of Interest Rate Changes

While Evans' measure of interest rate volatility lacks conceptual justification, it is useful to examine his claim that only unanticipated volatility matters. In the first and second sections of Table 3, several measures of volatility appear significant when added separately. Tests were therefore conducted on the addition of each significant variable, given that another is included. For example, when both the contemporaneous and lagged values of the actual volatility measure are included, neither is statistically significant. The inclusion of the lagged value, however, is significant before and after 1979, while that of the contemporaneous value is not before 1979. Of course, the contemporaneous measure could not be obtained until after (or at the end) of year t, so its insignificance is understandable. The predicted measure can be known, however, using information available at the end of year (t-1) and it is highly significant with either expectations process equation (1) or (2) in Table 2. Theory indicates that a rise in expected volatility of yields should reduce the demand for income streams, *ceteris paribus*. The results in Table 2 support this view.

Moreover, the addition of information on the lagged unanticipated volatility does not add statistically significant information to the real output equation containing this period's predicted volatility. The addition of EVR_{t-1} to equations containing ln $\hat{VR}_t$ results in the four equation estimates shown in Table 4 for the two periods. The top two equations use Evans' ln $\hat{VR}_t$ specification while the bottom two are for the simpler ln $\hat{VR}_t$ specification. In both periods, one can reject the hypothesis that past unanticipated volatility of interest rates affects real GNP when the contemporaneous anticipated volatility is taken into account (and conversely). Thus, Evans' expectations hypothesis does not appear to be supported by the data. One cannot reject the hypothesis that the current period anticipation of interest rate volatility is what matters in affecting current period output.

The Variability of Interest Rate Levels

When the variability of the monthly interest rate is considered, rather than that of monthly changes, the results are similar using either the actual level of interest rates (VRLEV) or the logarithm of the rate (VRLOG). In each case, the variability measure is not significantly related to its own past, so that the anticipated/unanticipated distinction cannot be tested directly. In each case, the lagged level of interest rate volatility significantly affects current real output and in both periods. Suppose that the last year's observed volatility determines expected variability in the current and future periods, then the results for $VRLEV_{t-1}$ and $VRLOG_{t-1}$ in Table 3 are consistent with the view that a permanent rise in risk associated with investment will permanently reduce real GNP.[9/] Of course the results in Table 1 raise some doubt about the rationality of such expectations.

Finally, note that ln $VRLOG_{t-1}$ is insignificant at conventional levels in the pre-1979 period. This is slightly problematical because VRLOG has more appeal on conceptual grounds as an appropriate measure of risk. The effect is only marginally insignificant, however, and on a one-tail test of the hypothesis that the effect is significantly negative, it cannot be rejected (critical $t = 1.71$). No doubt, the principal reason for the small size of the t-statistic is the lack of variability of this measure before 1979.[10/]

Does the Volatility of Money Growth Matter?

As noted earlier (see Chart 1), quarterly money growth volatility increased dramatically in 1980 and 1982. Tests of whether this measure of volatility, VM*, directly affected real output in either the 1948-78 or 1948-81 indicate that it did not. This is in accord with the Evans result for the variability of annual unanticipated money growth.[11/] In contrast to his conclusion, however, Charts 1 and 3 suggest a contemporaneous relationship between the variability of money growth and interest rates. Moreover, such a link would establish the basis for a policy implication from the recent experience.

The interest rate variability equations in Table 2 were reestimated adding the variability of money growth (ln VM*), to examine whether the recent increase in variability of interest rates was related to the increased variability of money growth. The results for the first four measures shown in Table 1 are given in Table 5 for both time periods.[12/]

The fourth pair of equations at the bottom of Table 5 indicates that a rise in the variability of money growth has a positive and significant effect on the variability measure VRLOG. The generally higher levels of volatility of money growth in 1980-83 raised the volatility of interest rates significantly.[13/] The volatility of the level of interest rates (VRLEV) is also significantly positively related to the past increase in the volatility of money growth in both periods. Moreover, the simpler equation (the second set in Table 5) for Evans' measure of interest rate volatility shows a significant positive contemporaneous relation with money growth volatility over the longer period 1947-81.[14/]

These equations indicate that there is a policy link between Federal Reserve actions and the deleterious effects of interest rate variability.[15/] Specifically, policy actions that lower (raise) the variability of money growth apparently can reduce (increase) the volatility of interest rates. Other sources of the variability of interest rates are presumably beyond the control of the Federal Reserve, but policy actions to control the growth rate of money, say at least as well as before 1979, can reduce interest rate variability and real GNP losses associated with it.

For each of the four equations in Table 5 and for each period, anticipated and unanticipated interest rate volatility were added to the real GNP equation. As in Table 3, only the lagged unanticipated change or the contemporaneous anticipated volatility measure is significant for Evans' VR measure. Table 6 provides a comparison of these equations. Judged solely on the basis of the fit of the equations (S.E. for the equation or the size of the t-statistic for the VR measure), lagged unanticipated interest rate volatility provides the best result in the 1947-78 period. In the longer period, however, and for both periods using the second equations in Table 5, the anticipated volatility measure outperforms the lagged unanticipated measure. Also, note that the magnitude of the effect of either measure is essentially the same.

Taking money growth volatility into account in the forecast of ln VR strengthens the result that anticipated volatility matters using Evans' measure of interest rate volatility. When both EVR_{t-1} and ln $\hat{VR}_t$ are entered into the output equation, neither is significant except with the simpler VR expectations process over the 1948-81 period. In that case, ln $\hat{VR}_t$ has a coefficient of -0.020 (t = -2.18), while EVR_{t-1} has an insignificant coefficient, -0.009 (t = -0.90). Thus, in three of the four tests of Evans' measure, neither the anticipated nor unanticipated interest rate volatility hypotheses can be rejected, but in one test, the results reject the unanticipated volatility hypothesis in favor of an anticipated volatility hypothesis.

A similar test of anticipated versus unanticipated interest rate volatility effects on output was conducted using the Table 5 equations for ln $VRLEV_t$ and ln $VRLOG_t$. For both measures, the results indicate that lagged unanticipated interest rate volatility outperforms the actual lagged measure, and each past unanticipated measure has a significant negative effect on output in both periods. These results are given in Table 7. Note that the adjusted $\bar{R}^2$ in all 12 equations in Tables 5 and 6 are essentially the same so it is difficult to differentiate between the variability measures on empirical grounds, although the fit of the equation, as indicated by the standard error, favors the Evans measure using contemporaneous expected volatility and the simpler expectations process for ln VR.

<u>Money Growth and Interest Rate Variability: Supply or Demand Shock?</u>

Evans' analysis of the effect of risk on output, together with previous work on monetary variability by Gertler and Grinols (1982) and Mascaro and Meltzer (1984), suggest that risk affects aggregate demand. In Gertler and Grinols (1982), increased variability of money growth is shown to reduce investment, while in Mascaro and Meltzer (1984), the aggregate demand reductions arise through an increase in money demand. Evans does not directly describe why risk reduces output, but an aggregate demand channel is implicit. If a rise in money growth volatility and/or interest rate volatility results in an unanticipated (or anticipated) reduction in aggregate demand, however, then one would expect, ceteris paribus, to observe a decline in prices (assuming, of course, that the supply curve is not vertical, in which case, no price response would be expected). Increases in perceived risks of future returns, however, have effects on producers. Indeed, purported reductions in investment represent reductions in demand for capital inputs that in the short-run are achieved by reduced utilization of capital, given expected prices of inputs and outputs.[16/] Whether supply is reduced more than demand at unchanged prices is essentially an empirical question.

To test the price level effect of increased interest rate risk, each measure (VR, VRLEV, and VRLOG) was entered into the Barro price equation (1981, pp. 159-67) for 1952-78 and extended to 1952-81. The price level equation is derived from a money demand function where r_{t-1}, the lagged Aaa yield is used as an instrument for the current quarter yield, and G_t, federal government purchases, is included along with current and five lagged values of unanticipated money growth and a trend. The equation is also modified to include another supply factor, the relative price of energy.17/ The price equation is estimated from 1952 to avoid reliance on the Friedman-Schwartz data but to allow for the long lags on DMR. Also, the variability measure is used rather than its logarithm as above. This was done because in both periods and for each variable introduced, this specification generally yielded superior results.18/ Moreover, results using the log level of the variables did not alter the conclusions here for interest rate volatility. The results are given in Table 8. In each case and over both periods, a rise in risk is shown to have a significant positive effect on the price level. No attempt has been made here to test whether it is anticipated or unanticipated volatility that matters. It appears from the results in Table 8 that, while a rise in volatility may depress investment and aggregate demand, the dominant effect is on aggregate supply, so that increased risk raises the price level.19/

Finally, the hypothesis that increased volatility of money growth affects prices was examined in the same way.

These results are also included in Table 8. Again the introduction of VM_t outperformed the use of ln VM_t. In both periods, the fit of the price equation is slightly worse than when the variability of interest rate measures are used. Nonetheless, in both periods VM has positive and significant effects on prices when the interest rate variability measures are excluded. When both VM_t and the lagged interest rate changes are included (the results are not reported), VM_t is not significant in the early period and both variables are significant in the longer period.[20/] In the 1952-78 period, money growth volatility, which changed little, had no appreciable affect on prices, once lagged interest rate volatility is taken into account. Thus, the positive impact of lagged interest rate volatility is robust in the Barro model, but that for money growth volatility is only robust if interest rate volatility is ignored.

The results above suggest that there are really two channels of influence by which a change in the variability of money stock growth affects economic performance. The first is that a change in VM_t influences prices instantaneously, then raises the volatility of interest rates, which, in turn, subsequently influences both prices and output. Whether such a complex chain of effects can be successfully tested with richer data, such as quarterly observations or other periods when money growth exhibited greater volatility, remains an open question. Nonetheless, the evidence suggests that both interest rate volatility, however measured, and money growth volatility reduce the demand for real money balances. These results appear to run directly counter to the Mascaro-Meltzer (1984) hypothesis which emphasized a positive money demand effect of risk, but ignored such supply-side considerations. In the results here, this hypothesis is not directly tested since the Table 8 equations are quasi-reduced-form expressions for prices so that output is allowed to vary. The results only suggest that, net of other changes and given interest rates, a rise in money growth variability reduces money demand.

Summary

Several measures of interest rate volatility have been presented here and all but one indicate that past interest rate volatility significantly reduces real output. These results generally support Evans' recent claim that interest rate volatility has adverse effects on the economy; however, they raise an unresolved question about the theoretical mechanism by which this effect occurs. Whether this effect occurs because of rationally anticipated variability or extrapolative expectations or because of a past unanticipated volatility effect is not clear from the tests here. With Evans' measure, the results here show that one cannot discriminate between the anticipated/unanticipated hypotheses. With the other measures, extrapolative expectations appear to do above as well as the lagged unanticipated variability measure, but the regression-based expectation of interest rate volatility allows for rejection of the hypothesis that anticipated variability affects output.

The analysis of the real output effect also does not discriminate between the channels of an aggregate demand effect, such as whether it occurs due to a rise in money demand, like money growth uncertainty in Mascaro and Meltzer (1984), or through a decline in investment, like money growth uncertainty in Gertler and Grinols (1982). A second feature of the analysis here, however, does shed some light on the mechanism through which risk affects output. Instead of working simply through changes in aggregate demand, it appears that risk has adverse effects on aggregate supply and therefore is positively related to the price level. Moreover, the price level results suggest a direct channel for money growth variability as well as through past interest rate variability.

The evidence presented here suggests that policymakers have reason for concern about interest rate volatility. Unlike the post-war experience prior to 1980 when the variability of quarterly money growth and quarterly interest rates were relatively small and steady, recent increases in the variability of money growth, especially in 1980 and 1982, have resulted in greater variability of interest rates and reduced output. Thus, policymakers can contribute to higher levels of real GNP by reducing risk in the investment environment through steadier control of monetary aggregate growth.

The data upon which the evidence and these conclusions rest differs from that used by Evans (1984). In particular, Evans found that money growth variability had not increased recently and that, had it, it would not affect real output anyway. His measure of money growth variability was a standard deviation of annual money growth (unanticipated). The same insignificant results are shown here to hold for interest rate levels when annual data are used. In principle, what matters for real output and investment decisions is the variability of monetary aggregates that affect real output temporarily, and this is the variability of quarterly money growth. Variability of annual money growth over several years would be expected to have a relatively greater influence on the variability of nominal spending and inflation, but not output. The intrayear variability of interest rate measures used here are, not surprisingly, significant and positively related to the intrayear variability of money growth. Hence, a link exists between Federal Reserve actions and interest rate variability that can usefully be exploited. Such a link (other than announcements) was absent from Evans analysis. This link indicates that improvements in monetary control tend to reduce interest rate variability and raise output. It is not possible from this framework, however, to delineate the monetary control procedure that accomplishes such a reduction in intrayear money growth variability.

The conclusions here lack precision. Little theoretical work exists that would unambiguously delineate the sources of variability of economic variables and the theoretical or empirical effects of such changes in variability. Moreover, the measurement of meaningful concepts of variability remains in a crude state.[21/] The results here are intended to be suggestive and questioning rather than definitive; they await the critical delineations of the economic influences of alternative sources of variance in economic variables and the formation of expectations about such variances that only more developed economic and statistical theory can provide.

FOOTNOTES

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1/ Evans (1984, p. 211) indicates that the criterion for selection of a volatility measure is unpredictability of the interest rate. As a measure of risk, however, the superiority of a measure of unpredictability is not clear, at best. Presumably the risk assessments that matter, in terms of influencing economic decisions, are those that are predictable.

2/ See Poole (1975) for example.

3/ Walsh (1984) shows that a change in the policy rule, in contrast to an announcement, used by the Fed away from interest rate smoothing can lead to greater volatility of both interest rates <u>and</u> the money supply. Risk in his model is wholly financial, however, that is interest rates affect real wealth given a constant expected earnings stream. The most important aspect of a rise in the variance of money growth is that the variance of expected earnings streams rises, especially returns to capital. There is no capital in the Walsh model. Whether his results hold in this broader context is not clear, but is not the central problem of this paper.

4/ Another way of adjusting interest rate variability for differences in the mean return is to use the coefficient of variation of the level of the interest rate which is $VRLEV/\bar{r}_t$, where $\bar{r}_t$ is the mean interest rate over the period for which VRLEV is measured. The results using the coefficient of variation are virtually identical to those for $VRLOG_t$ so they are not discussed below. See Weston and Brigham (1983, pp. 98-99) for a discussion of this measure.

5/ Evans provides little theoretical basis for the effect of interest rate volatility on output, other than to suggest that the Modigliani-Miller theorem (1958) applies to predictable changes in interest rate variability and that such changes, then, could not affect the private allocation of resources or output. This ignores the fact that these changes affect market assessments of risk generally and hence affect the after-tax real rates of return, the desired capital stock, the price level and output.

6/ The results here are estimated using OLS. Evans uses the full-information-maximum-likelihood technique, following Barro (1981, pp. 150-9). Equation 1 is essentially the OLS version of Evans' equations (8), (11) and (14), where these are estimated for the same period (1947-78) jointly with real output and money growth equations that have different structures or time periods. OLS estimates are used here because, first, they are sufficient to demonstrate the issues raised, and second, Kmenta (1971, p. 174-82) and Amemiya (1977) have noted the sensitivity of maximum likelihood estimators to specification errors. Admittedly, however, this choice can be problematical. OLS estimates are not generally consistent if the true model is a simultaneous system; variable selection results based on OLS methods may be inferior.

7/ In the tests reported here, levels of the standard deviations were also examined instead of their logarithms. The results were qualitatively the same, but the significance levels and standard errors of real output equations were slightly lower than when the logarithm of the standard deviations is used.

8/ The t-statistics do not indicate the magnitude of differences in the fit of the equations, however. Using the predicted ln VR_t in either period instead of EVR_{t-1} raises the standard error of the ln X equation in the latter case of about 0.016 by less than 5 percent for the Evans specification and the 0.017 standard error found using the EVR_{t-1} from the simpler ln VR specification by 1.4 percent in the earlier period and 3 percent in the longer period. The worst fit, using ln $VRLOG_{t-1}$, results in a standard error of the output equation of 0.018 in both periods, about 4.5 percent higher than using the EVR_{t-1} from the simpler specification of ln VR_t.

9/ This effect presumably arises through a decline in the desired capital-labor ratio.

10/ Also, the long-run effect of a rise in this measure of volatility is statistically significant at a 95 percent confidence level. This effect is -0.02484 according to the ln $VRLOG_{t-1}$ and ln X_{t-1} coefficients, and its standard error is 0.01207, so that the t-statistic equals the 95 percent critical value.

11/ It is also the result found for velocity in Tatom (1983, pp. 45-7) for the standard deviation of quarterly money growth measured over 12 quarters, instead of four as here.

12/ In the VRA equations not reported in Table 5, four lagged values of ln VM* enter significantly with a positive sum for the 1947-81 period. Over the earlier period, only the first lagged value is significant and equals 0.357 (t = 3.38).

13/ The presence of a significant effect in the 1947-78 period is somewhat surprising since the VM* varied little over that period. The standard deviation of VM over the period was only 0.825 while its mean level was 1.740. Also over the period 1947-81, ln VM_t^* is more significant than lnVM_{t-1}^* in the fourth equation: its coefficient is 0.4270 (t = 2.55) and the Durbin-Watson statistic improves to 1.98. In the earlier period (1947-78), the coefficient on ln VM_t^* is 0.3247 (t = 1.70) which is significant at a 10 percent level. Using the contemporaneous ln VM* in this earlier period has little effect on the D-W statistic 2.02, or the adjusted $\bar{R}_2$, however.

14/ Evans has noted the instability of his ln VR equation after 1978. The out-of-sample errors of equation 1 in Table 1 from 1979-82 average 0.951, almost twice (1.84) the in-sample standard error, all the errors are positive, and the errors in 1980-81 are each more than twice the in-sample standard error. In contrast, none of the errors from the ln VRLOG equation including ln VM exceed 1.5 times the in-sample standard error, 0.764; the out-of-sample mean error and RMSE are 0.747 and 0.764. Similarly, the ln VRLEV equation (including ln VM) shows no significantly large errors until 1982, and the ln VRA measure shows no unusual errors at all and the mean error is 0.0022. Thus, Evans' instability result appears to be a property of his rather unique measure and not of interest rate risk or variability generally. The measure VRLOG appears to be white noise over the period 1947-78 for up to 24 lags; for example, the $\chi^2(12)$ is 15.79. The residuals from the ln VRLOG equation in Table 5 are white noise as well. The $\chi^2(12)$ is 9.50, for example.

15/ The possibility of reverse causation was examined by regressing ln VM_t^* on lagged levels of the logarithm of the interest rate variability measures. No significant lagged effects were found for any of the four measures during the 1947-78 period; the largest t-statistic for one lag was found on ln $VRLOG_{t-1}$ and equalled only 1.57. In the longer period, a lag on ln VRLEV was significant, t = 2.43, so that one-way causation cannot be established. As in several instances here, more conclusive tests to resolve the switching of this causality result will likely require the use of quarterly data.

16/A reduction in desired capacity due to an increase in the variability of demand is a result that has been obtained by Sandmo (1971) and Holthausen (1976) for risk averse firms. DeVaney and Saving (1983) provide a model of the firm in which a rise in variability of demand leads to a rise in price and a decline in expected output relative to capacity. In their model capital is diverted, in a sense, to providing insurance against variability so that output per unit of capital shrinks.

17/The energy price measure is the producer price index for fuel power and related products deflated by the implicit price deflator for business sector output. The price effect of energy price changes arises from a reduction in productivity or potential output, or natural output in Barro's model. When the relative price of energy is included in the output equation above, it is not significant ($t < 1.5$), although the steady-state ($\ln X_t = \ln X_{t-1}$) effect is significantly negative. The inclusion of energy prices also has no effect on the real output results reported above, so it was arbitrarily omitted.

18/The exceptions are that the logarithm specification is better than the level specification for VR_{t-1} over the period 1947-81, and for $VRLEV_{t-1}$, over the period 1947-78.

[19] Another obvious extension of the test of the effects of volatility would be to add the risk measure to Barro's unemployment equation. Attempts to do this, however, failed as no measure was statistically significant over the periods 1947-78 or 1947-81. The absence of a significant effect is not a serious problem, however, since the equation performs relatively poorly anyway and is likely seriously misspecified because it ignores any secular rise in the natural rate of unemployment and shows permanent effects of federal purchases on the unemployment rate.

[20] The exception in the 1952-81 case is for Evans' measure VR which is marginally insignificant ($t = 2.07$, critical value = 2.11) when VM_t is included. VM_t remains significant ($t = 2.95$), however, so there is a complete reversal, where only VR matters from 1947-78, but only VM_t is significant over the longer period.

[21] Bomhoff (1983) provides more sophisticated measures of unanticipated changes in monetary growth uncertainty or variability and its effects using the Kalman-filter. Hein and Veugelers (1983) provide a useful discussion of several mechanistic approaches, including the use of Kalman-filter, to develop expected series for economic variables, and, hence, empirically based measures of anticipated or unanticipated changes in their volatility.

Table 1
ALTERNATIVE MEASURES OF INTEREST RATE VARIABILITY

	1947-78			1947-81		
	Mean	Standard Deviation	Coefficient of Variation	Mean	Standard Deviation	Coefficient of Variation
VR	0.077	0.0523	0.679	0.1138	0.1412	1.241
VRLEV	0.149	0.1122	0.753	0.2011	0.2065	0.974
VRLOG	0.029	0.0182	0.628	0.0322	0.0100	0.621
VRA	0.3900	0.3062	0.785	0.4270	0.3548	0.831
ln VR	-2.8066	0.7437	0.265	-2.6307	0.9264	0.352
ln VRLEV	-2.1781	0.7827	0.359	-2.0167	0.9206	0.456
ln VRLOG	-3.7278	0.6593	0.177	-3.6457	0.6866	0.188
ln VRA	-1.2822	0.8841	0.690	-1.2077	0.9012	0.746

Table 2
INTEREST RATE VOLATILITY EQUATIONS[1/]
(1947-78)

1. $$\ln VR_t = \underset{(0.6308)}{-1.9352} + \underset{(0.0126)}{0.0257}\, t + \underset{(0.1788)}{0.7042} \ln VR_{t-1} - \underset{(0.1781)}{0.2526} \ln VR_{t-2} + EVR_t$$

$\bar{R}^2 = 0.5029$ S.E. = 0.5244 D-W = 2.02

2. $$\ln VR_t = \underset{(0.3897)}{-0.8366} + \underset{(0.1330)}{0.6943} \ln VR_{t-1} + EVR_t$$

$\bar{R}^2 = 0.4583$ S.E. = 0.5474 D-W = 1.78

3. $$\ln VRLEV_t = \underset{(0.2422)}{-2.7896} + \underset{(0.0134)}{0.0395}\, t + EVR_t$$

$\bar{R}^2 = 0.20$ S.E. = 0.7011 D-W = 1.60

4. $$\ln VRLOG_t = \underset{(0.1166)}{-3.7278} + EVR_t$$

S.E. = 0.6593 D-W = 1.68

5. $$\ln VRA_t = \underset{(0.3510)}{-0.9480} + \underset{(0.0121)}{0.0268}\, t + \underset{(0.1700)}{1.0378} \ln VRA_{t-1} - \underset{(0.1690)}{0.4529} \ln VRA_{t-2} + EVR_t$$

$\bar{R}^2 = 0.78$ S.E. = 0.4150 D-W = 2.22

1/ Standard errors are indicated in parentheses.

Table 3
THE EFFECT OF INTEREST RATE VOLATILITY ON OUTPUT: 1948-78
(t-statistics, 1948-81 in parentheses)

		Actual		Predicted		EVR	
1.	ln VR_t (Eq. 1)	-1.38	(-2.64*)	-2.72*	(-3.61*)	0.34	(-0.42)
	ln VR_{t-1} (Eq. 1)	-2.42*	(-3.05*)	-0.51	(-0.48)	-3.22*	(-4.28*)
2.	ln VR_t (Eq. 2)	-1.38	(-2.64*)	-2.42*	(-3.05*)	0.56	(-0.05)
	ln VR_{t-1} (Eq. 2)	-2.42*	(-3.05*)	-0.76	(-0.59)	-2.60*	(-3.40*)
3.	ln $VRLEV_t$	0.05	(-1.09)	---	---	---	---
	ln $VRLEV_{t-1}$	-2.36*	(-3.19*)				
4.	ln $VRLOG_t$	0.37	(-0.73)	---	---	---	---
	ln $VRLOG_{t-1}$	-2.02	(-2.88*)				
5.	ln VRA_t	-1.25	(-0.95)	-0.43	(0.23)	-1.55	(-1.93)
	ln VRA_{t-1}	-0.73	(0.04)	-1.18	(-0.45)	0.27	(0.64)

*Critical t-statistic (5 percent significance) is 2.06 for the period 1948-78 and 2.05 for the period 1948-81.

Table 4

TESTS OF EVANS' ANTICIPATED VERSUS UNANTICIPATED VOLATILITY EFFECTS[1/]

$\ln VR_t = f(t, \ln VR_{t-1}, \ln VR_{t-2})$:

1948-78

$$\ln X_t = \underset{(2.93)}{2.125} + \underset{(2.32)}{0.0109}\, t + \underset{(5.52)}{0.667} \ln X_{t-1} + \underset{(4.18)}{1.1042}\, DMR_t$$

$$+ \underset{(1.61)}{0.5013}\, DMR_{t-1} + \underset{(0.48)}{0.0118} \ln VR_t - \underset{(-1.56)}{0.0312}\, EVR_{t-1}$$

$\bar{R}^2 = 0.9971$ S.E. = 0.0174 D-W = 1.94

1948-81

$$\ln X_t = \underset{(3.10)}{1.989} + \underset{(2.51)}{0.0103}\, t + \underset{(6.45)}{0.686} \ln X_{t-1} + \underset{(4.52)}{1.0710}\, DMR_t$$

$$+ \underset{(1.46)}{0.0410}\, DMR_{t-1} + \underset{(0.23)}{0.0037} \ln VR_t - \underset{(-1.88)}{0.0281}\, EVR_{t-1}$$

$\bar{R}^2 = 0.9979$ S.E. = 0.0160 D-W = 1.92

1948-78

$$\ln X_t = \underset{(3.06)}{2.392} + \underset{(3.02)}{0.0138}\, t + \underset{(4.76)}{0.612} \ln X_{t-1} + \underset{(3.76)}{0.9969}\, DMR_t$$

$$+ \underset{(2.27)}{0.6897}\, DMR_{t-1} - \underset{(-0.77)}{0.0085} \ln VR_t - \underset{(-1.14)}{0.0120}\, EVR_{t-1}$$

$\bar{R}^2 = 0.9971$ S.E. = 0.0174 D-W = 1.94

$\ln VR_t = f(\ln VR_{t-1})$:

1948-81

$$\ln X_t = \underset{(3.18)}{2.2152} + \underset{(3.14)}{0.0127}\, t + \underset{(5.63)}{0.6414} \ln X_{t-1} + \underset{(4.07)}{1.0365}\, DMR_t$$

$$+ \underset{(2.11)}{0.5879}\, DMR_{t-1} + \underset{(-1.14)}{0.0082} \ln VR_t - \underset{(-1.73)}{0.0136}\, EVR_{t-1}$$

$\bar{R}^2 = 0.9980$ S.E. = 0.0169 D-W = 1.89

1/ t-statistics are given in parentheses.

Table 5

THE VOLATILITY OF MONEY GROWTH AND INTEREST RATES[1/]

1. (1947-78)

$$\ln VR_t = \underset{(-3.28)}{-2.1105} + \underset{(2.07)}{0.0258}\, t + \underset{(3.43)}{0.6345} \ln VR_{t-1} - \underset{(-1.14)}{0.2050} \ln VR_{t-2} + \underset{(1.28)}{0.2087} \ln VM^*_t$$

$\bar{R}^2 = 0.51$ S.E. = 0.5184 D-W = 2.06

(1947-81)

$$\ln VR_t = \underset{(-3.54)}{-2.1405} + \underset{(2.70)}{0.0315}\, t + \underset{(4.13)}{0.7004} \ln VR_{t-1} - \underset{(-1.41)}{0.2477} \ln VR_{t-2} + \underset{(1.91)}{0.2838} \ln VM^*_t$$

$\bar{R}^2 = 0.69$ S.E. = 0.5138 D-W = 2.09

2. (1947-78)

$$\ln VR_t = \underset{(-2.51)}{-1.0345} + \underset{(4.90)}{0.6574} \ln VR_{t-1} + \underset{(1.35)}{0.2224} \ln VM^*_t$$

$\bar{R}^2 = 0.47$ S.E. = 0.5401 D-W = 1.89

(1947-81)

$$\ln VR_t = \underset{(-2.07)}{-0.7542} + \underset{(6.42)}{0.7564} \ln VR_{t-1} + \underset{(2.22)}{0.3441} \ln VM^*_t$$

$\bar{R}^2 = 0.64$ S.E. = 0.5572 D-W = 1.89

3. (1947-78)

$$\ln VRLEV_t = \underset{(-11.90)}{-3.0422} + \underset{(3.18)}{0.0400}\, t + \underset{(2.27)}{0.4247} \ln VM^*_{t-1}$$

$\bar{R}^2 = 0.30$ S.E. = 0.6570 D-W = 1.80

(1947-81)

$$\ln VRLEV_t = \underset{(-13.02)}{-3.1936} + \underset{(4.61)}{0.0527}\, t + \underset{(2.53)}{0.4333} \ln VM^*_{t-1}$$

$\bar{R}^2 = 0.45$ S.E. = 0.6806 D-W = 1.63

4. (1947-78)

$$VRLOG_t = \underset{(-27.76)}{-3.9030} + \underset{(2.03)}{0.3632} \ln VM^*_{t-1}$$

$\bar{R}^2 = 0.09$ S.E. = 0.6283 D-W = 1.80

(1947-81)

$$\ln VRLOG_t = \underset{(-27.61)}{-3.8372} + \underset{(2.24)}{0.3642} \ln VM^*_{t-1}$$

$\bar{R}^2 = 0.11$ S.E. = 0.6491 D-W = 1.64

[1/] t-statistics are given in parentheses.

Table 6
THE EFFECT OF ANTICIPATED OR UNANTICIPATED INTEREST RATE VARIABILTY (TABLE 5) ON OUTPUT 1/

	Anticipations from Equation 1, Table 5				Anticipations from Equation 2, Table 5			
	1947-78		1948-81		1947-78		1948-81	
Constant	2.239 (3.48)	2.006 (3.04)	2.323 (3.98)	1.962 (3.17)	2.528 (4.10)	2.080 (3.06)	2.607 (4.56)	2.036 (3.20)
Trend	0.014 (3.90)	0.011 (2.81)	0.014 (4.40)	0.010 (2.89)	0.016 (4.48)	0.011 (2.82)	0.016 (4.93)	0.011 (2.92)
$\ln X_{t-1}$	0.626 (6.04)	0.681 (6.34)	0.614 (6.49)	0.688 (6.85)	0.578 (5.80)	0.669 (6.04)	0.567 (6.11)	0.676 (6.54)
DMR_t	0.946 (3.84)	0.995 (4.01)	0.949 (4.10)	1.012 (4.21)	0.915 (3.81)	0.998 (3.86)	0.919 (4.04)	1.027 (4.08)
DMR_{t-1}	0.922 (3.82)	0.628 (2.46)	0.931 (4.02)	0.584 (2.31)	1.045 (4.37)	0.711 (2.75)	1.062 (4.61)	0.681 (2.67)
$\ln VR_t$	-0.030 (-3.62)	---	-0.026 (-4.38)	---	-0.030 (-3.76)	---	-0.027 (-4.51)	---
EVR_{t-1} 2/	---	-0.027 (-3.69)	---	-0.028 (-4.14)	---	-0.024 (-3.34)	---	-0.025 (-3.78)
$\bar{R}^2$	0.998	0.998	0.998	0.998	0.998	0.998	0.998	0.998
S.E.	0.0165	0.0164	0.0160	0.0162	0.0163	0.0170	0.0157	0.0168
D.W.	1.83	1.84	1.82	1.88	1.92	1.78	1.91	1.79

1/ t-statistics are given in parentheses.

2/ EVR_{t-1} is the lagged residual from the interest rate volatility equation given at the top of the column.

Table 7
THE EFFECT OF ANTICIPATED OR UNANTICIPATED INTEREST RATE VARIABILTY (TABLE 5) ON OUTPUT 1/

	Anticipations from Equation 3, Table 5		Anticipations from Equation 4, Table 5	
	1947-78	1948-81	1947-78	1948-81
Constant	2.394 (3.43)	2.325 (3.67)	2.439 (3.34)	2.316 (3.49)
Trend	0.013 (3.23)	0.012 (3.41)	0.013 (3.13)	0.012 (3.28)
ln X_{t-1}	0.618 (5.43)	0.629 (6.11)	0.610 (5.13)	0.630 (5.83)
DMR_t	0.753 (2.92)	0.771 (3.16)	0.736 (2.75)	0.757 (2.97)
DMR_{t-1}	0.762 (2.79)	0.735 (2.86)	0.784 (2.75)	0.748 (2.77)
EVR_{t-1} 2/	-0.015 (-2.67)	-0.016 (-3.53)	-0.013 (-2.18)	-0.015 (-3.02)
$\bar{R}^2$	0.997	0.998	0.997	0.998
S.E.	0.0180	0.0172	0.0187	0.0180
D.W.	1.66	1.68	1.61	1.63

1/ t-statistics are given in parenthses.

2/ EVR_{t-1} is the lagged residual from the interest rate volatility equation given at the top of the column.

THE EFFECT OF INTEREST RATE VOLATILITY ON PRICES[1]
(1952-78; 1952-81)

Dependent Variable: [ln P - ln M]

Independent Variable	1952-78				1952-81			
Constant	-0.974	-0.971	-0.996	-1.103	-0.912	-0.906	-0.973	-1.107
	(-9.79)	(-9.43)	(-9.56)	(-9.56)	(-7.74)	(-9.17)	(-9.55)	(-10.81)
DMR_t	-0.928	-0.723	-0.771	-0.768	-0.854	-0.715	-0.771	-0.751
	(-6.76)	(-5.37)	(-5.62)	(-5.20)	(-5.43)	(-5.37)	(-5.45)	(-5.32)
DMR_{t-1}	-0.881	-0.838	-0.862	-0.996	-0.852	-0.762	-0.785	-0.984
	(-6.33)	(-5.72)	(-5.80)	(-6.31)	(-5.40)	(-5.53)	(-5.36)	(-6.74)
DMR_{t-2}	-0.857	-1.077	-1.052	-1.080	-0.815	-0.983	-0.974	-1.102
	(-5.88)	(-7.66)	(-7.32)	(-6.94)	(-5.34)	(-7.84)	(-7.28)	(-7.86)
DMR_{t-3}	-1.354	-1.320	-1.278	-1.424	-1.199	-1.264	-1.235	-1.455
	(-9.36)	(-8.91)	(-8.44)	(-8.23)	(-7.32)	(-9.01)	(-8.25)	(-9.02)
DMR_{t-4}	-1.275	-1.203	-1.162	-1.134	-1.264	-1.261	-1.234	-1.160
	(-9.37)	(-8.76)	(-8.27)	(-7.45)	(-8.22)	(-9.58)	(-8.76)	(-8.10)
DMR_{t-5}	-0.585	-0.598	-0.636	-0.565	-0.681	-0.650	-0.725	-0.608
	(-4.49)	(-4.47)	(-4.69)	(-3.72)	(-4.52)	(-5.04)	(-5.41)	(-4.29)
t	-0.008	-0.010	-0.010	-0.011	-0.008	-0.010	-0.010	-0.012
	(-6.67)	(-10.73)	(-10.21)	(-10.46)	(-6.55)	(-11.65)	(-11.50)	(-13.45)
$\ln G_t$	0.051	0.049	0.053	0.076	0.038	0.036	0.048	0.077
	(2.39)	(5.05)	(2.38)	(3.08)	(1.50)	(1.67)	(2.15)	(3.47)
R_{t-1}	0.846	1.939	2.014	2.389	1.206	1.770	2.977	2.656
	(1.58)	(5.05)	(5.18)	(5.69)	(2.19)	(5.10)	(3.62)	(7.62)
$\ln p^e_t$	0.051	0.036	0.036	0.041	0.044	0.040	0.045	0.040
	(4.95)	(3.86)	(3.74)	(3.82)	(5.09)	(5.33)	(5.71)	(4.96)
VR_{t-1}	0.198	---	---	---	0.090	---	---	---
	(3.45)				(2.82)			
$VRLEV_{t-1}$	---	0.048	---	---	---	0.054	---	---
		(3.21)				(4.18)		
$VRLOG_{t-1}$	---	---	0.244	---	---	---	0.298	---
			(3.02)				(3.62)	
VM_t	---	---	---	0.005	---	---	---	0.005
				(2.40)				(3.65)
$\bar{R}^2$	0.98	0.98	0.98	0.98	0.97	0.98	0.98	0.98
S.E.	0.0069	0.0071	0.0073	0.0078	0.0084	0.0072	0.0077	0.0076
D.W.	2.02	2.07	2.05	2.03	1.85	1.98	1.93	2.01

1/ t-statistics are given in parentheses.

CHART 1
THE VOLATILITY OF MONEY GROWTH

CHART 2
THE VARIABILITY OF MONTHLY LEVELS AND CHANGES IN THE AAA BOND YIELD

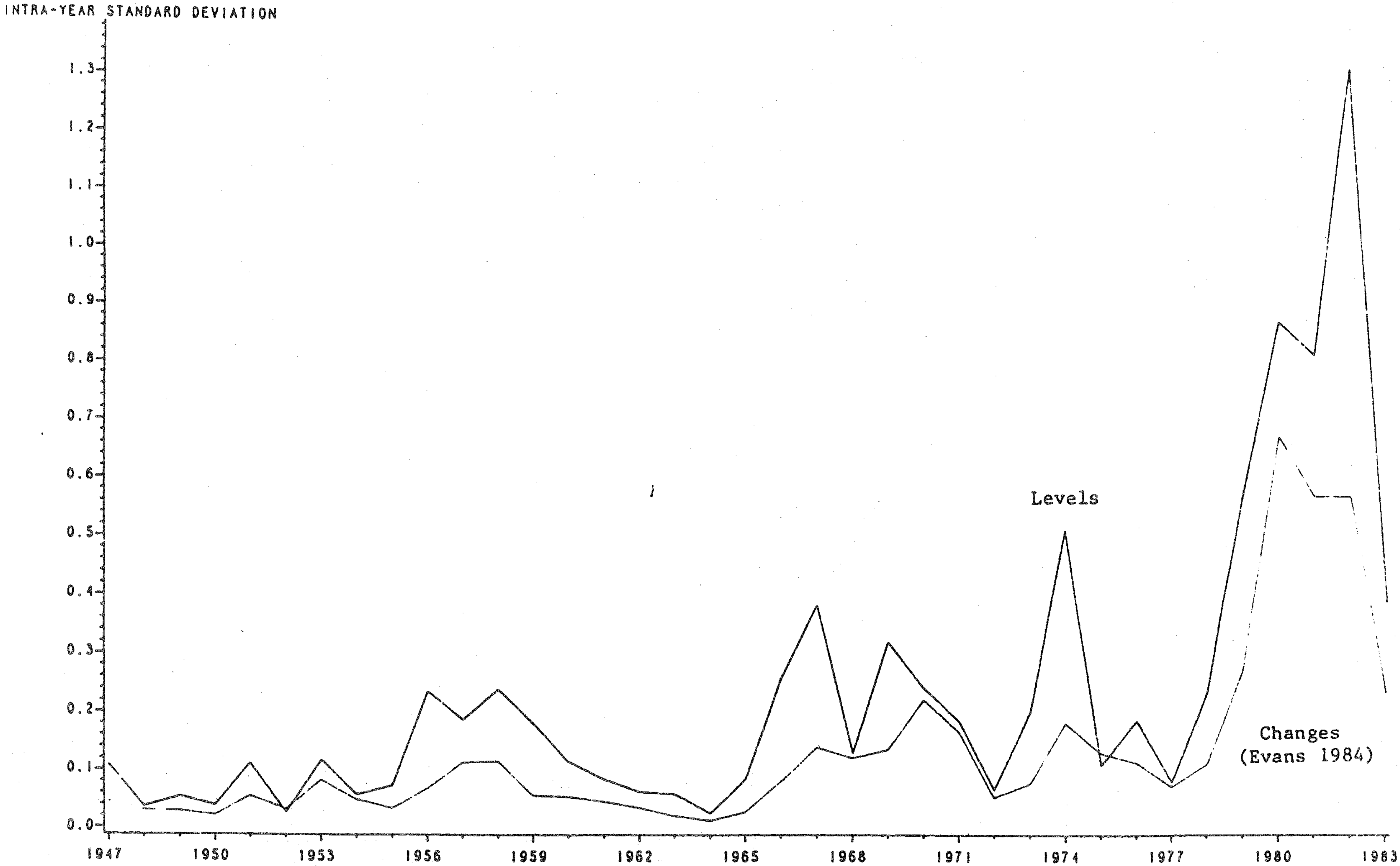
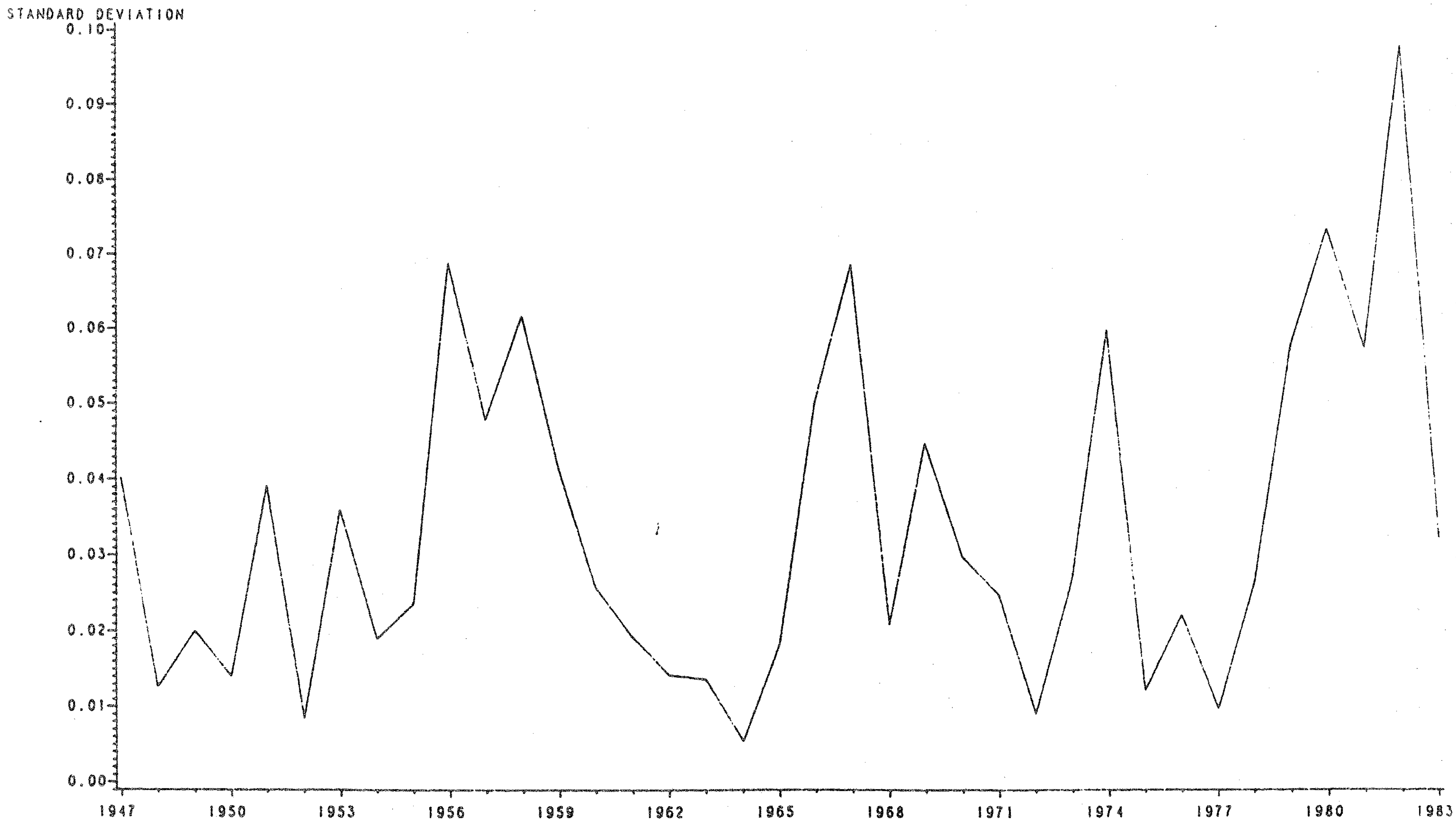


CHART 3
THE VARIABILITY OF THE LOGARITHM OF MONTHLY AAA BOND YIELDS



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