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SHORT TERM INTEREST RATES AND INFLATION

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Short Term Interest Rates and Inflation

By

Nicholas Barcia

A dissertation submitted to the Graduate Faculty in Economics in partial fulfillment of the requirements for the degree of Doctor of Philosophy, The City University of New York.

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CHAPTER I INTRODUCTION

One of the most controversial and studied relationships in economics is the relationship between nominal rates of interest and the anticipated rate of inflation, commonly referred to as the Fisher relationship.

The Fisher equation is a mathematical relationship which states that the nominal interest rate should be equal to the real rate of interest, i.e. the marginal product of capital, plus the anticipated rate of inflation. Mathematically, this is expressed as

$$(1) \quad i_t = a_0 + b_1 \hat{P}_t$$

where i_t = nominal interest rate at time t

a_0 = real interest rate

$\hat{P}_t$ = inflation rate expected at time t-1 for time t.

This relationship, named after its originator, says that b_1, the partial derivative of i_t with respect to $\hat{P}_t$, should be equal to unity.

The theoretical reason for this is that with expected inflation, lenders will require an inflation premium so as to preserve the purchasing power of their nominal balances. With an inflation rate of $\hat{P}_t$, nominal balances must grow at the rate of $\hat{P}_t$ to preserve real balances. Over and above this, a real rate of return, measured in purchasing power, is required. Borrowers would be willing to pay the higher nominal rate of interest because of the decrease in the real value of the principal. Hence, the Fisher equation.

The interest rate mentioned is a rate of return on Loaned, nominal cash balances. It is measured as the change in the price of a pure discount bond, such as a treasury bill, or an as expected holding period rate of return on a corporate bond. Mathematically, for treasury bills, the rate of return is

$$(2) \quad ROR_t = (\hat{BP}_{t+1} - BP_t)/BP_t$$

where BP_t = bond price at time t

$\hat{BP}_{t+1}$ = anticipated bond price at time t+1

For a corporate bond, the expected holding period rate of return is mathematically measured as

$$(3) \quad HPR = (\hat{BP}_{t+1} - BP_t + C_t)/BP_t$$

where C_t = interest payment at time t

We will be concerned only with treasury bills in this paper for two reasons: (1) treasury bills are sold as pure discount bonds and have no coupon. The selling price reflects the anticipated nominal rate of return.

Corporate bonds pay a coupon, so the selling price does not by itself reflect the holding period rate of return. While the coupon is reflected in holding period return calculations, the timing of once or twice yearly coupons may introduce a new wrinkle into the problem. This would not be a problem with treasury bills.

2) Corporate bonds carry a default risk premium which would raise the nominal yield and result in another coefficient to estimate.

For these reasons, we will constrain our analysis to treasury bills.

The expected inflation rate is the percentage change in a price index expected to occur over a particular time period.

How is this expected inflation rate formed? It is in the interest of borrowers and lenders to get as accurate a prediction as possible since the actual value will determine the reduction in the purchasing power of nominal balances held. It is not the purpose of this paper to explore the formation of inflation expectations; however, we could hardly ignore this issue. The rational expectations school states that the inflation rate is forecasted by looking at all relevant economic variables and using this information to forecast the expected inflation rate. Under this assumption, expectations could never be incorrect systematically, as any systematic error would become part of the forecasting process. In other terms, this simply says that there can be no serial correlation in a time series of inflation forecast errors. The adaptive expectations school states that the change in the expected inflation rate is a positive fraction of last periods forecast error. If adaptive expectations is the correct formulation, the expected inflation rate is a distributed lag function of past values of the inflation rate, with weights declining geometrically to zero. With adaptive expectations, interest rate adjustment to a new, higher inflation rate would take place over a number of periods, while under rational expectations, adjustment would tend to be quicker, and hence more efficient.

The above analysis has explicitly omitted any discussion of the effect of income taxes on the analysis. While the issue is not an unimportant one, it is not the purpose of this study to explore the relationships in the presence of income taxes, and so this issue will be ignored in this analysis.

There is very little empirical evidence to support the theory that the coefficient of the expected rate of inflation should be equal to unity, even though the relationship is treated as gospel in textbooks. As early as 1930, Irving Fisher himself noted that this is the case. He noted that, even in the absence of tax considerations, the coefficient of expected inflation is considerably less than unity. He states, "When prices are rising, the rate of interest tends to be high, but not so high as it should be to compensate for the rise; and when prices are falling, the rate of interest tends to be low, but not so low as to compensate for the fall." Fisher concludes that "Men are unwilling or unable to adjust at all accurately and promptly the many rate of interest to the changing price level".[1]

The problem is to determine if the coefficient of anticipated inflation is equal to unity or not, and if so, why is there little empirical evidence to support the hypothesis? If the relationship is not correct, what is the correct relationship?

The literature on this subject varies greatly in approach and conclusion. Eugene Fama (1975), in a study of short term interest rates and inflation, finds that the capital markets are indeed efficient in the sense that a rise in interest rates is accompanied by a rise in the inflation rate on a one to one basis, i.e. the interest rate accurately reflects all relevant information and there is no extra information content in the values of past error terms. This statement about information and error terms is the rational expectations result familiar to most economists.

Market efficiency requires that in setting the price of an n month treasury bill at time t-1 for time t, the market correctly uses all available information in assessing the underlying distribution of the relevant variable. Fama's model uses short term interest rates, i.e. the price of treasury bills maturing in one to six months as measures of the short term interest rate.

Fama's model assumes the real rate of interest to be constant. The real rate of interest on a bond is defined as the nominal rate plus the rate of change of purchasing power of nominal cash balances, expressed mathematically as

$$r_t = R_t + \dot{P}_t$$

The rate of change of purchasing power of nominal cash balances is measured as

$$\left[\frac{1}{P_t} - \frac{1}{P_{t-1}}\right] \Big/ \frac{1}{P_{t-1}} = \frac{P_{t-1}}{P_t} - 1 ,$$

where P_t is the price level, as measured by the CPI.

If the real rate is constant, then the market's expectation of $\dot{P}_t$ can be measured as

(4) $E(\dot{P}_t) = E(r_t) - R_t$

So a constant expected real return implies that all variation through time in R_t is a reflection of variation in the expected rate of change in the purchasing power of nominal cash balances.

Fama then estimates the following two equations:

(5) $\dot{P}_t = a_0 + a_1 R_t + e_t$

(6) $\dot{P}_t = a_0 + a_1 R_t + a_2 \dot{P}_{t-1} + e_t$

If the coefficients are consistent with his hypothesis, the value of a which would be expected a priori is - 1.0. The coefficient of the lagged rate of change of purchasing power, a_2, should be equal to zero. A non zero coefficient would imply that information contained in $\dot{P}_{t-1}$ is relevant, which would violate the efficiency assumption.

Fama's theory is, in general, borne out by his statistical results. Estimates of equation (5) generally give a value for a_1 which is not significantly different from unity in absolute value. Estimates of equation (6) give values of a_2 which are not significantly different from zero. This leads Fama to conclude that interest rates on n month treasury bills are the best predictors of rates of change of purchasing power and that the market is indeed efficient in the sense that no extra information is contained in lagged values of the rate of change of purchasing power.

The sole exception to these conclusions are the results for five and six month treasury bills. The estimated values for a_1 are significantly different from unity in absolute value. Fama says some results just won't turn out that well in even the best models. In concluding, he blames the failure of others to obtain his results on poor commodity price data. This is due to the fact that most studies use pre-1953 price data. Prior to 1953, many items in the CPI were not sampled monthly, and the index was not that reliable a measure of the price level.

In a follow up study by Charles Nelson and G. William Schwert (1977), Fama's results are criticized as inconclusive. They maintain that while Fama's results are reproducible, the statistical tests used are not powerful enough to test the joint hypothesis of constancy of the real rate and market efficiency in setting money interest rates. They argue that observing the ex post real rate is equivalent to observing the ex ante real rate with a forecasting error, or

$$r_t = \hat{r}_t + v_t$$

Since Fama's estimates of (5) and (6) actually observe the expost real rate of interest, substitution of the above equation into (5) gives

$$\dot{P}_t = \hat{r}_t + a_1 R_t + (e_t + V_t)$$

The residual term in this equation is a linear combination of two error terms. The relationship between the exante real rate forecast error and e_t may weaken the ability of Fama's results to test the joint hypothesis of constancy of the real rate and market efficiency.

Neither of these papers consider the method of inflation forecasting.

Some studies have used actual price forecast data, obtained from surveys, to investigate the interest rate inflation relationship. Joseph Livingston, a financial columnist, has twice yearly since 1946 surveyed a group of government, business, and labor economists on their expectations of future values of selected economic variables, including the consumer price index.[2] From this data set can be constructed expected rates of change in the price level, which can then be related to nominal interest rates. William Gibson, in a 1972 study using the Livingston data set, has estimated an interest rate-inflation relationship of the following form:

$$(7) \quad i_t = a_0 + a_1\hat{P}_t$$

where i_t = nominal interest rate

$\hat{P}_t$ = expected rate of change of the price level

This study does not go into depth in terms of theory, but simply seeks to quantify the relationship. The results obtained lend support to the hypothesis that the real rate of interest is not affected by price expectations within six months. He also finds that expectations have a significantly stronger effect on interest rates before

1959. In general, he finds the value of a_1 to be very close to unity for short term treasury bills, and lower for longer term treasury bills. This may be due to increased uncertainty as the time horizon lengthens.

The issue of the exact formulation of the expected inflation-interest rate relationship has been explored in depth by Thomas Sargent (1972,1973). In his 1972 paper, Sargent uses an income-expenditures model to study the relationship between nominal interest rates and anticipated inflation. Sargent shows that while an increase in anticipated inflation will eventually cause the nominal interest rate to rise by the full amount of the increase, the response of the interest rate is generally distributed over time, the length of time depending on a lag distribution. The more potent is monetary policy relative to fiscal policy, the shorter will be the resulting lag distribution and the more adequate the Fisher equation will be in its original form. During the period of adjustment, the perceived (ex post) real rate of interest will have been affected. Sargent concludes the paper by stating "the tendency . . . [is] . . . for anticipated inflation to affect interest rates via a distributed lag, one that may very well be very long".

In Sargent's 1973 study of interest rates and prices in the long run, he notes that if the lag distribution is long enough, the expected inflation rate more clearly resembles the level of prices than it does the current rate of inflation. Sargent questions why the anticipations of inflation are so slow to adjust. Sargent's tests lead him to state "It is difficult to accept Fisher's explanation of the Gibson paradox and to maintain that extraordinary long lags are rational". Within the context of bivariate models, interest rates and inflation appear to influence each other. This result implies that any theory which postulates one way effects, i.e. inflation rates affect interest rates and not vice versa, would be inadequate. Sargent concludes that "In general, there is no reason to expect a regression of interest rates against current and lagged rates of inflation to reveal very much about the expectations of inflation held by the public".

It would seem that the results of Sargent's two papers contradict each other, but this is not completely the case. His 1972 paper makes the correction between anticipated inflation and monetary policy. Noting the Gibson paradox, Sargent simply states that when lagged distributions from the effect of monetary policy are introduced, anticipated inflation will affect interest rates via a very long lag.

In his 1973 paper, he notes that the interest rate-inflation relationship is not a one way causal relationship. Interest rates and inflation rates affect each other and in turn are each affected by other variables. Simply looking at a Fisher equation with long lags on the right side should say very little about expectations of inflation.

On balance, both papers would seem to support the idea that in order to adequately look at such relationships, a multivariate relationship may be much more accurate.

The historical record shows that the Fisher equation does not seem to hold, at least looking at the long run. Summers (1980), using decadal averages of quarterly data, looks at interest rates and inflation rates back to 1860.

A regression of the average interest rate per decade against the ten year inflation rate gives the following results:

$$R_t = 4.24 + .12 \dot{P}_t$$

$$(.73) \quad (.14) \qquad \text{RBAR**2} = -.03$$

No clear relationship between inflation and nominal interest rates emerges. In five decades, the real rate of interest was negative. These were the periods with the most rapid inflation rates. Conversely, the real rate is highest in deflationary decades. This would occur if interest rates underadjusted for expected inflation, or if expected inflation substantially underpredicts actual inflation. Over the long run, it seems that less than one eighth of changes in inflation rates are incorporated into nominal interest rates. The variance of the real rate far exceeds the variance of the nominal return. If the Fisher relationship held, nominal rates would vary, while real rates would remain relatively constant. This relationship might be stronger in the short run than in the long run. Summers states that interest rates have never responded to inflation in a way that the theory might suggest. In concluding, Summers notes "The overall conclusion that comes from reviewing this evidence is that at no time have inflation premiums been fully incorporated into nominal interest rates".

In an attempt to get a full handle on the interest rate-inflation relationship, Maurice Levi and John Makin (1979) estimate what could be called a modified Fisher equation. The main thrust of their argument is that nominal interest rates should contain a full inflation premium when the relationship is correctly specified.

In theory as porposed by Fisher, the coefficient of anticipated inflation should be equal to unity. It is also assumed that the ex ante real rate of interest is constant. The main thrust of Levi and Makin is that the ex ante real rate of interest is not constant, and that failure to control for the factor is biasing the coefficient value away from unity. Levi and Makin recognize the need, while testing this relationship to control for changes in employment and output, and in the level of uncertainty about inflation which are likely to arise when the level of inflation changes. Failure to control for these factors will bias any results obtained.

The purpose of this paper is to investigate the causal factors in the interest rate-inflation relationship, using an approach similar to that of Levi and Makin in the sense of omitted variables, but different in the estimation of the systems of equations below, for the United States in the 1960's and 1970's.

FOOTNOTES

[1]Fisher, Irving. 1930. The Theory of Interest. New York: Macmillan.

[2]For a list of survey respondents, see Gibson (1972).

CHAPTER II THE MODEL

Levi and Makin begin by discussing the relationships which they believe will affect the real rate of interest. The first is called the Phillips Effect. They believe that an increase in the level of inflation will have an effect on the real rate of interest. This will work as follows: an increase in the rate of inflation due to, say, an increase in the rate of growth of the money supply, will cause an increase in the rate of growth of money wages. This will cause a decrease in the real wage rate and hence unemployment will fall (or employment will rise). With higher real production, this raises savings and, for a given investment schedule, lowers the real rate of interest. This requires that workers not fully comprehend the increase in inflation. If workers do fully anticipate the rise in inflation, a sufficient condition for this to work as stated is for the elasticity of money wages with respect to inflation be less than unity so that the real wage falls. This may arise from a contractual obligation or some risk sharing agreement (such as an incomplete cost of living adjustment). This negative relationship will bias downward the coefficient of anticipated inflation in the Fisher equation.

Another effect spoken of is called the Friedman effect. In his Nobel lecture, Milton Friedman noted two effects:

1. Higher levels of inflation are associated with higher volatility in the actual and anticipated rates of inflation.
2. Due to the institutional rigidities of long term contracts and government price fixing, higher volatility of inflation will be associated with a "reduction in the capacity of the price support system to guide economic activity."

This loss of efficiency could produce a reduction in productivity. The reasoning for this is as follows: firms, when evaluating investment proposals, will calculate the project's Net Present Value, using a desired rate of return in the NPV calculation. NPV is the difference between the discounted benefits and costs associated with a particular investment proposal.

$$NPV = \sum Bt/(1 + i)^t - \sum Ct/(1 + i)^t$$

The investment proposals are then ranked, highest NPV first, second highest second, etc. A project whose NPV is positive will be accepted, while a negative NPV will be rejected.

As increased uncertainty about the inflation rate drives up the cost of funds, apart from an inflation premium, fewer investments will be undertaken, as some proposals which previously had a positive NPV no have a negative NPV and will be rejected as no longer profitable. Ceteribus paribus, this means a lower investment schedule.[1]

The first effect will cause an increase in savings, while the second causes a decrease in investment. In terms of sources and uses of funds, an increase in savings will result in a lower real rate of interest as will a decrease in investment. Both of these will result in a misspecification in estimating (1).

The measure of the inflation rate used by Levi and Makin arises from survey data collected by Joseph Livingston. From these data, anticipated rates of inflation are constructed. It should be noted that this is not a random sample, but a sample whose members could be said to be very well informed, at least much more than average. The method by which respondents arrive at their forecasts is not noted. These data are collected twice each calendar year, in April and October, and reported in June and December the same year. These data have come under criticism by J. A. Carlson (1977), who argued that the difference between collection and publication dates and subsequent adjustment by Livingston has influenced results obtained by those such as Gibson, and hence Levi and Makin use Livingston data as prepared by Carlson.[2]

To measure the dispersion of inflation rate expectations, Levi and Makin calculate the standard deviation of the implied rates of inflation, which are based upon the forecasts of the Consumer Price Index. This is calculated as any standard deviation would be.

When the variance of nominal shocks is large, there will be a high degree of variation in the measured rate of inflation which will lead to greater uncertainty as to the anticipated rate of inflation. Conversely, when the variance of nominal shocks is small, there will be less uncertainty about anticipated inflation. This is to be distinguished from high variation in inflation which is known, for this would not lead to increased uncertainty.

It is important to note that this standard deviation is a measure of the distribution of inflation expectations at a point in time, not an historical standard deviation. It is this standard deviation which is used to measure the disperson in inflation expectations.

To measure output effects on rates of interest, the rate of growth of real gross national product is used. The interest rates used are the three month treasury bill rate and the four to six month commercial paper rate.

This leads Levi and Makin to estimate a modified Fisher equation of the form

(3) $i_t = b_0 + b_1\hat{P}_t + b_2Y_t + b_3S_t + e_t$

where i_t = nominal interest rate

$\hat{F}_t$ = anticipated rate of inflation

Y_t = rate of growth of real G.N.P.

S_t = standard deviation of inflation expectations

e_t = residual term

Levi and Makin estimate this model for the period 1950-1970, and for the period 1947-1975 using OLS. They estimate (3) using only $\hat{P}_t$ as an explanatory variable, using $\hat{P}_t$ and Y_t, and using P_t, Y_t, and S_t. Their results are shown below in Table 1.

Levi and Makin's results support their hypothesis that after correctly controlling for factors which affect the real rate of interest, nominal rates of interest will rise on a one to one basis with increases in anticipated rate of inflation.

The results obtained are interesting, but deserve some clarification. Looking at the estimates of the simple equation, they show a coefficient of anticipated inflation (henceforth referred to as b_1) of .88 for the period 1950-1970, using the three month T bill rate.

This value is not significantly different from unity.

The value of b_1 for the four to six month commercial paper rate is .50, also not significantly different from unity. For the period 1947-1975, the corresponding values are .64 and .68. Both of these values are significantly different from unity.

Addition of real income to the equation raises the value of b_1 for the period 1950-1970 for both the three month t bill rate and the four to six month commercial paper rate by approximately .05-.07. Again, both these values are not significantly different from unity. The values of b_1 for the period 1947-1975 are not changed at all by the inclusion of real income as an explanatory variable. The inclusion of the standard deviation of the anticipated inflation rate raises the values obtained for the period 1950-1970 to 1.00 and 1.04, while again not affecting the values for the period 1947-1975. The R**2 obtained rises with the inclusion of each new explanatory variable, ranging from .44 in the simple Fisher equation to .72 in the full model. The Durbin-Watson statistic is very low, ranging from .52 to 1.31, suggesting the possibility of omitted variables. It is interesting to note that while the value of b_1 rises as the two explanatory variables are added, the value of b_1 in the original equation is not significantly different from unity. While the low Durein-Watson statistic for this result (t bill and commercial paper), this does raise some questions as to whether or not anticipated inflation is fully incorporated into nominal interest rates without controlling for movements in the real rate of interest. This is really two separate questions:

1. Is the real rate of interest constant?
2. Are inflation premiums incorporated into nominal interest rates?

Upon looking at these results, one becomes aware that a discrepancy exists among the results of the different equations. For the period 1950-1970, their results are self explanatory -- the value of b_1 rises with the inclusion of additional explanatory variables until, in the "correct" model, as proposed by Levi and Makin, it's value is equal to unity. However, for the period 1947-1975, not only is the value of b_1 very significantly different from unity, but the inclusion of additional explanatory variables does not raise the value of b_1 at all. In addition, the Durbin-Watson statistic is not appreciably changed by the additional explanatory variables. This suggests that the results may be sample specific, as well as the possibility of specification bias. This casts strong reservations on the model as described in the paper. Nevertheless, the results do support the original hypothesis to some extent.

I have done some additional work on the model as specified above. However, I was not able to re-estimate the model in the exact specification above. The main differences between my estimates and those of Levi and Makin are differences in variable formulation. Levi and Makin use survey data to calculate their anticipated inflation rate. Not having access to the Livingston data, I was forced to construct my own inflation forecast. In these estimates, the anticipated inflation rate which pertains to the relevant three month Treasury Bill is the inflation rate which is anticipated to occur over the life of the Treasury Bill, i.e. for the three month Treasury Bill auction rate, the relevant inflation rate is the three month inflation rate. This inflation rate is calculated as an autoregressive forecast, the three month anticipated inflation rate a function of lagged values of the actual three month inflation rate. The length of the lag, for purely arbitrary reasons, is twelve three month periods, or three years.

The growth rate of real income is harder to proxy. Information on real income is available on a quarterly basis (every three months), while I am using monthly data. To capture the effects of changes in real income, the employment rate is used. Defining U as the unemployment rate, the employment rate is defined as E = 1 - U/100. During a downturn, the anticipated inflation rate will be falling, while during an upturn, the anticipated inflation rate will be rising. The problem with using the employment rate is that the same employment rate will be generated at two different stages of the business cycle. However, the same change in the employment rate will not be generated at more than one stage in the business cycle. The change in the employment rate will be positive in an upturn and negative in a downturn, having the same sign as the rate of growth of real output. For this reason, I use the change in the employment rate as a proxy for the rate of growth of real output.

Levi and Makin control for the effect of increased volatility of anticipated inflation on real interest rates by including the standard deviation of the inflation rate, given by the price level forecasts in the Livingston data. Not having the Livingston data, I constructed an historical standard deviation of inflation rates. It is calculated by comparing the three month inflation rate for a lag of twelve periods to the actual inflation rate which occured over the same three year period. It is calculated as any standard deviation would be. Ideally, we would want the standard deviation of inflation expectations at a point in time, but this information is essentially unreversable, so I use this standard deviation to capture the effects of increased volatility of inflation on real interest rates.

A final variable which I use in my estimates is a measure of financial risk. As Friedman noted, an increase in the level of inflation is associated with an increase in the volatility of the inflation rate. There is much more variation in inflation at, say, a ten percent average level of inflation than there is at a two percent level. The inflation rate may change without a corresponding change in the standard deviation of inflation. Likewise, the standard may change without a corresponding change in the inflation rate. Both of these scenarios are esasily imaginable. However, it is also easily imaginable that both could change at the same time. This will also have an effect on the real interest rate unlike the effect of either variable changing by itself. This effect will be captured in a variable which is equal to the product of the anticipated inflation rate and the standard deviation of the inflation rate.

A comment on my interest rate variable is in order at this point. The rate of interest used in the estimates below is the rate of discount on new three month treasury bills. This discount rate is expressed as a percentage reduction from the face value of a three month treasury bill, and is not equal to a bond equivalent yield. The yield to maturity will be higher than the discount rate, the difference being one of degree, i.e. the higher the discount rate, the greater the difference between the discount and the yield. The formula to change a discount on a three month treasury bill into an annualized yield to maturity is

$$\text{Yield} = [1 + .25(\frac{365d}{360 - 90(d)})]^4 - 1.0$$

where d = discount rate.[3]

I have estimated a modified Fisher equation in the same manner as Levi and Makin, the sole difference in equations being the variables above. Due to data differences, their original results are not replicated, but extended to other time periods. The reason for picking this sample period is relatively simple; the 1960's was a period of high rates of economic growth, characterized by relatively low rates of inflation and a long period of stability. The United States economy in the 1960's experienced one of the longest periods of sustained growth ever recorded, as well as one of the most stable. The 1970's, on the other hand, were characterized by economic instability. We had two oil shocks, two recessions, and, in general, a long period of economic instability. Two very different periods, economically speaking. For these reasons, I estimated the model for those two periods. The equations are estimated using ordinary least squares, in the same manner as Levi and Makin. The equation estimated is the following:

$$4) \quad i_t = b_0 + b_1 P_t + b_2 E_t + b_3 S_t + b_4 R_t + e_t$$

where I_t = three month treasury bill rate

P_t = anticipated inflation rate at time t-1 for t

E_t = change in employment rate

S_t = standard deviation of inflation rate

R_t = risk variable

e_t = residual term

A priori, this residual term would be expected to satisfy the usual assumptions. However, this may not be the case as will be discussed later. Estimates of this equation are shown below in Table 2.

These equations were also estimated using six month T-bills at auction rates. The construction of variables in the six month estimates is the same, with all relevant numbers doubled. For example, we now use the six month anticipated inflation rate, with twelve six month periods used in the forecast. Twelve six month periods were also used in calculating the standard deviation of the six month inflation rate. Results for six month T-bills are shown below in Table 3.

The results obtained below are mixed. Estimates of the equation for the 1960's are not bad, by historical comparison, but in every case the coefficient of anticipated inflation is significantly different from unity. For three month treasury bills (see Table 2), the value of b_1 is approximately .75. When S or E is added to the equation, the value of b_1 rises by approximately .04. Addition of the risk variable results in a complete swamping of b_1. It's value goes down and becomes not significantly different from zero. For six month treasury bills, (See Table 3), the results have more variation in them. The coefficient of anticipated inflation ranges in value from .68 to .825. In no cases is the value of b_1 not significantly different from unity. Table 3, equ. 1, which is an unmodified Fisher equation, has the highest value of b_1. The addition of S, E, or risk seems to lower the value of b_1, the opposite of the predicted result.

Results for the 1970's, shown for three month treasury bills in Table (2) and six month bills in Table (3), show striking contrast from results obtained for the 1960's. The value of b_1 for three month bills is approximately .6. The addition of the extra variables doesn't seem to have much effect until all are added. In equations (11) and (12) in Table (2), the value of b_1 is equal to 1.06 and 1.04, respectively, not significantly different from unity in either case. For six month bills, the coefficients differ in value, but for equations (11) and (12) in Table (3), the values of b_1 are .847 and .856, respectively. Neither value is significantly different from unity.

One possible interpretation of these results is that during the 1970's, nominal rates of interest adjusted fully for changes in anticipated inflation, while adjusting less than fully during the 1960's. The 1960's was a period of relatively low and stable inflation. It may be that adjusting completely for changes in anticipated inflation may not have been worth the trouble due to the fact that the inflation rate was so low. During the 1970's, with a higher inflation rate, incomplete adjustment of nominal interest rates would have been more costly, and hence adjustment was more complete.

The coefficient of S is, with the exception of Table (3), equ. (11), positive. It may be that when risk is included, to take account of the interrelationship between S and P, that it captures all of the caution that Friedman spoke of. It may also be that an increase in S during the 1960's would induce the public to believe that interest rates would go down, while during the 1970's, an increase in S would go up due to an increase in the risk premium.

Also note the intercepts during the 1970's. In any equation with risk included, the intercept is not significantly different from zero. During the 1970's, the oil shock caused the marginal product of capital, approximately equal to the real rate of interest to fall. It may be that in this model, OLS is unable to distinguish between a very low intercept and a zero intercept.

It seems that when attempting to control for variables which affect the real rate, the coefficient of anticipated inflation is not significantly different from unity, at least in the model as described above. It may be that the costs of adjustment made adjusting prohibitive during the 1960's due to low inflation, a condition which did not exist in the 1970's.

These results would seem to indicate that when correctly controlling for variables which affect the ex ante real rate, nominal interest rates adjust on a per unit basis with changes in anticipated inflation. This can be seen by the coefficient of anticipated inflation, which is not significantly different from unity. However, there are many things wrong with them.

Levi and Makin use price level forecasts from the Livingston survey of price forecasts. Respondents of this survey include business, financial, government, and academic economists, who, as Livingston puts it, "Are in strategic positions to influence decisions of businessmen. This is not a random sample. It is a sample of individuals who can best be described as well informed. These individuals would have a much better than average understanding of the workings of the economy, of sophisticated economic relationships and arguments, and the effects of current economic relationships and arguments, and the effects of current economic conditions on the future values of economic variables. Simply put, a very atypical group. The true relationship depends on the interaction of all individuals in the economy, not the actions of a select few. The group includes members whose opinions carry much more weight than those of the ordinary price level forecaster. Also, these individuals would typically have control over a much larger amount of assets and as a group can have a much larger effect on markets where such expectations would have effects.

All in all, a very well informed, atypical group of individuals who could be termed "important."

Also, these are not market-tested expectations; what people think may not be the same as the way they behave.

Absolutely no discussion of the method of price forecasting is undertaken in Levi and Makin. How the respondents arrive at their price level forecasts is completely unknown. This is not an unimportant question, although the fact that the respondents as a group are more well informed than average would lead one to conclude that their forecasting methods were some degree better than average, or at least not naive forecasts. However, the exact methods are unknown.

While it would seem to be safe to say that the respondents forecasts are not the result of dart board throws, the methods are probably somewhere towards rational expectations, with the method of forecasting increasing in sophistication in later years of the survey.

Another criticism of the model is the relationship between the periodic inflation rate and the nominal interest rate. It seems that the inflation rate which corresponds to a particular interest rate is the inflation rate which is expected to occur over the life of the treasury bill.

There is one big error in using this as the anticipated rate of inflation. It implicitly assumes that every treasury bill which is purchased is held to maturity. This is the only reason why the inflation rate which is expected to occur over the life of the treasury bill would be the relevant rate of inflation. Not all treasury bills are held to maturity, whether maturity is three months, three years, or thirty years. To use the inflation rate as calculated, one would need to know the rate of inflation expected by market participants who purchased three month treasury bills and held them to maturity. The percentage of investors holding treasury bills to maturity is unknown, but certainly less than one hundred percent. This is a serious flaw.

Another major problem with the models above is one of the logic contained in them. There is no statistical theory to support the model. The main thrust of the model is that certain variables affect the real rate, but this is not tested statistically. The testing is done implicitly, by incorporating certain arguments into a modified Fisher equation, with the statistical results "proving" the theory, but this is not tested directly. The economic theory foundation is ad hoc, with certain relationships postulated and estimated additively in a new equation. This is not a flaw, but it should be noted the equation estimated is not, in the truest sense, a reduced form. This is a major criticism.

Another problem in the above models is one of contemporaneousness. The variables used are all for time in the model. This can lead to problems. Levi and Makin use the rate of growth of real income to measure what is called the Phillips effect. They use the rate of growth which occurs over the life of the treasury bill in question. At the time of the treasury bill auction, this variable is unknown. If anything, the ex ante real rate of interest would be affected by the anticipated rate of growth of real income, not the actual, which is unknown at the time. I used the change in the employment rate to proxy the Phillips effect, and this variable fails for the same reason. The variables, used to measure the dispersion of inflation expectations, also has problems. As is well known, the standard deviation is a useful tool only if the underlying distribution is normal. The survey respondents are drawn from individuals who have access to better information and certainly more knowledge than does the general population. Also, the sample is small, relative to the forecasting population in general. The sample could hardly be called representative of the underlying population with any degree of accuracy. The standard deviation may not be a good measure of the dispersion of inflation expectations for the simple fact that the dispersion it is measuring may not be representative of the underlying dispersion in price expectations in the economy, and so S as measured by Levi and Makin, may not be the correct variable for the model.

A more serious problem with both models is one of the dynamic nature of the undelying model. Both the model of Levi and Makin and of myself are estimated without any lagged values of explanatory variables. This implies that adjustment is completed every period and takes only one period. Inflation expectations are formulated, changes in real income are noted, the variation in inflation forecasts is accounted for, and nominal interest rates are adjusted fully and completely every period. This implies not only that nominal interest rates are adjusted, but it also implies that the effects of the explanatory variables on the real rate of interest occur within one period. Indeed, the possibility of multiperiod adjustment is not even entertained, much less explored or studied. Many recent papers, as well as many old ones, have postulated that these effects take place over a period of time, not within a single period. One would be hard pressed to imagine that the effects of variation in inflation forecasts occur within a single time period. It is a well known fact that there are lags of varying length between investment planning and investment implementation. Indeed, a change in investment plans occurring in the current time period will have effects on real income and real interest rates in future time periods. The correct relationship may, in fact, be a dynamic one with many lags of the explanatory variables. It is to these problems that we now address ourselves.

Footnotes

[1] See any book on corporate finance. The author is aware that other decision rules exist.

[2] The forecasting methods by which respondents arrive at their predictions is not revealed.

[3] These rates move together. In a regression of YTM on the discount rate, we obtain the following results for the 1960's:

YTM = -.0012 + 1.073 * discount

(30.002) (1124.45) R**2 = .9999

and the following for the 1970's,

YTM = -.0031 + 1.108 * discount

(29.56) (692.03) R**2 = .9998.

The equations estimated in this paper are not, strictly speaking, Fisher equations in the sense of I. Fisher, but are Fisher equations in the sense that we examine an interest rate-inflation relationship.

CHAPTER III The Model Using Vector Autoregression Estimator

In order to get a better handle on the solutions to the above problems, we will now use the vector autoregression approach to economic modelling. A vector autoregression (henceforth referred to as a VAR) is a set of random difference equations applied to a vector of economic time series whose dynamic interrelationship is the focal point of interest. In a VAR as suggested by Sims (1980), each time series is regressed on its own past values and the past values of the other time series in the vector. These regressions form the forecasting model. Since only lagged values of these time series are included as independent variables, no outside forecasted variables are required in solving the model dynamically.

The reason for using the VAR method is relatively straight-forward. The VAR method enables us to take account of the dynamics of the model the effects of the independent variables on the dependent variable may not (and, in all probability, will not) occur in a single period. The speed of adjustment by individuals as units and as a whole is unknown. There is a large precedent for lag structures in an economic model. The issue of the proper lag length for anticipated inflation is a well known case. Some work has suggested that the lag length is so long as to be better represented by a distributed lag on the price level. Sargent (1972), states that "while it is true that eventually we should expect an increase in anticipated inflation to drive the nominal rate of interest upward by the entire amount of the increase, it may take a very long time for this adjustment to occur . . . During this period of time, the perceived real rate of interest will generally have been affected."

An argument is made that the impact of a change in anticipated inflation upon nominal rates of interest ought to be derived as a reduced form based on the structural parameters of a macroeconomic model. This approach validates the proposition that the correct form of the Fisher equation may not be as Fisher postulated, but one with additional explanatory variables.

The VAR systems estimated below are not, strictly speaking, the reduced forms of a general equilibrium macroeconomic model, although Levi's and Makin's are. However, this may not violate the reduced form requirement.

The equations reported below are vector autoregression estimates of the modified Fisher equations estimated above, with some changes.

The index of industrial production has been subtituted for the change in the employment rate. While the employment rate is intuitively appealing, there are some problems with using it as an explanatory variable. The denominator in the employment rate is the number of people in the labor force. If some individuals were to exit the labor force, the employment rate would rise with no corresponding change in employment or production. If the reverse should occur, the employment rate would fall, again with no change in employment or production. These problems reduce reliability in using the employment rate as an explanatory variable. These problems do not exist if we substitute the index of industrial production as an explanatory variable. When production rises, so does the index and vice versa. There are no problems with labor force participation.

Anticipated inflation is generated with a lag structure of past inflation rates as well as lagged values of industrial production. Standard deviation of past inflation rates, nominal rates of interest, and the risk variable. The anticipated rate of inflation we are interested in in this section is the instantaneous rate of inflation, i.e. the monthly inflation rate at an annualized rate. When an investor purchases a treasury bill, the rate of inflation which is of interest is the instantaneous rate of inflation, since the investor is under no obligation to hold the treasury bill to maturity. Of course, some investors do hold treasury bills to maturity, but the proportion which behave in that manner is unknown. Formulating the anticipated inflation variable in the above manner allows for investors to hold to maturity or to sell prior to maturity.

All other variables are constructed as noted above. This set of variables is then estimated via a vector autoregression of the following form:

$$i_t = a_0 + b_1 t + \hat{\sum_{t=1}} a_{1,\ t-i}\, S_{t-i} + \hat{\sum_{t=1}} a_{2,\ t-i}\, \hat{P}_{t-i} + \hat{\sum_{t=1}} a_{3,\ t-i}\, R_{t-i} + \hat{\sum_{t=1}} a_{4,\ t-i}\, IP_{t-i} + \hat{\sum_{t=1}} a_{5,\ t-i}\, i_{t-i} + e_t$$

where S_t = standard deviation of inflation rate

$\hat{P}_t$ = anticipated inflation rate

R_e = risk measure

IP_t = industrial production

i_t = three month t-bill rate

e_t = residual term

for the 1960's and 1970's for eight, ten, and twelve lags of each explanatory variable. (Although in a VAR, each variable is regressed on all other variables in the vector, the equation we are most interested in has the above form).

A vector autoregression is a system of equations where each endogenous variable is regressed on all other endogenous variables and exogenous variables in the model. Each variable will be a linear (assumed) function of past values of all other endogenous variables (as well as any known exogenous variables) in the model. The actual inflation rate will then be a function of past values of the other variables in the model. For expectations to be "rational" in the sense of Sargent and Wallace (1975), the anticipated rate of inflation must be the expected value of the inflation rate generated by the inflation rate equation in the VAR system. In the model described above, the actual rate of inflation will be a function of past values of *S*, IP, three month treasury bill rate, and risk. The other criteria which must be met is that the inflation forecast error, $\dot{P}_t - \hat{\dot{P}}_t$ must consist solely of error terms (or linear combinations thereof). These error terms must not be serially correlated or be related to any variables through any functional form. Non validity of these restrictions results in non rational expectations.

The model we have is one consisting of anticipated inflation and its effects, not actual inflation and its effects. In this regard, anticipated inflation is generated through the equation for actual inflation in the VAR system. This anticipated rate of inflation is then used to estimate the VAR system which measures the effect of anticipated inflation on nominal rates of interest. This new system, with the anticipated of inflation replacing the actual rate, is our set of variables which is estimated in a vector autoregression.

The VAR results which are of particular interest are those which are estimated with the three month treasury bill as the independent variable. There are three sets of VARS for the 1960's and three sets for the 1970's, consisting of eight, ten, and twelve lagged periods each. The sum of the coefficients as well as summary statistics for each equation are listed below in Tables 4 and 5. The results are very interesting, and will be summarized here, with a more extensive analysis to follow.

For the most part, the results for the 1960's show very little in the way of what could be called "conclusive" results. For all three lagged structures, the sum of the coefficients on lagged expectations of inflation are not significantly different from zero. Indeed, the only interesting coefficient is the sum of the lagged coefficients on three month treasury bills. These are the only consistently significant coefficients for the 1960's. The coefficients on all other lagged variables are not significantly different from zero for any of the lagged structures, with the sole exception of industrial production for eight lagged values of the independent variables. A result like this might lead us to the conclusion that we would be unable to reject the null hypothesis that nominal rates of interest are exogenously determined and solely a function of own past values, in much the same way as Litterman and Weiss (1983) find they cannot reject their own null hypothesis that nominal rates of interest are exogenously determined and solely a function of own past values, in much the same way as Litterman and Weiss (1983) find they cannot reject their own null hypothesis that ex ante real rates of interest are exogenously determined and solely a function of their own past values.

One must be careful when interpreting the sums of coefficients in this model. While it is correct to state that a variable is significant due to a very low significance level, one cannot compare the sums to a value other than zero. These sums are reported in order that we may examine the signs of the sums in order to assess the direction of impact of each variable on the dependent variable.

The results for the 1970's are not consistent with the results of the 1960's. The sum of the lagged coefficients on anticipated inflation are .355, .3317, and .322 for eight, ten, and twelve lags, respectively, remarkably consistent across different lag lengths, and significantly different from zero except for the twelve lag case. The values for lagged nominal rates of interest are lower than in the 1960's, being .766, .777, and .917 for eight, ten, and twelve lags, respectively. Industrial production is significant for eight and ten lags, but not for twelve lags. The standard deviation of inflation rates is significant for eight and ten lags, but not for twelve lags. The most significant variable (economically, not statistically), is risk, which is significant variable (economically, not statistically), is risk, which is significant for all three lagged structrues. The sum of coefficient values are -5.306, -5.3783, and -4.516 for eight, ten, and twelve lags, respectively, relatively consistent across lag structures. A comparison across time periods shows very different results for the two time periods. None of the predicted relationships show up during the 1960's, while all show up during the 1970's. It may be that these relationships do not show up unless inflation reaches some noticeable level which was attained in the 1970's but was not attained in the 1960's. Certainly the level of inflation was higher in the 1970's than it was in the 1960's.

We now turn our attention to a simulation of the above estimated equations. The purpose of estimating a simulation is to test the model's reaction to a surprise in one of the variables. It is done in order to see how the model behaves, i.e. the interaction of all the variables. In estimating a particular equation, the coefficients are generally partial derivitives, enabling us to see the effect of a change in one variable on another holding other variables constant. This is certainly useful, but a simulation allows us to observe how the entire model reacts to a change in one of the variables. This differs from the single equation in that all variables are allowed to vary, not just one. This allows any and all interactions to have an effect on the variable by simulating for a number of periods, we can observe the evolution of the change in the variables as the effect of the surprise works its way through the model. This is an alternative method of looking at the moving average representation of the vector without obtaining the moving average explicitly.

What we have done is to apply a one standard deviation shock to the above models, and see what values the variables take on over a twenty month period. All values are scaled to zero, i.e. assuming a jump off point of zero, a shock will cause the variables to take on values around zero. It is these values we are interested in, for different orders of causality. Specifying the order of causality is very important. For example, if one was looking at stock prices and GNP, the direction of causality runs both ways. If GNP were to rise, this would have a positive effect on stock prices. If a particular stock's price were to rise, this would have a positive effect on GNP through wealth effects, although the effect of GNP on a stock's price would be much stronger than the effect of a stock's price on GNP. It is this type of causality which must be specific prior to the simulation. We will look at different orders of causality among the variables in the next section when we look at the simulation results from the VAR system above.

The results of the simulation did not vary much with changes in the length of the lag of the estimating model;

only the results of the simulation from estimating the model with a twelve period lag will be reported here. The results, reported here, can be seen graphically below in Tables (8) - (12).

With $\hat{P}$ first, a shock in $\hat{P}$ resulted in a relatively varied tracing in the 1960's. $\hat{P}$ rises at first, and then oscillates around zero for the twenty periods, the effects dampening in later periods. The effect on S and risk is generally positive, with downturns at approximately the thirteenth month. The effect on nominal interest rates is an initial upswing which lasts twelve periods before becoming a downswing, with the effect dampening in later periods. When S is first, the effect on anticipated inflation is generally negative, with some positive values at periods five to ten, inclusive.

The effect on S is an increase for thirteen periods, turning down in period fourteen, roughly the same behavior as that of risk. The effect on nominal interest rates is an initial decrease for nine periods, which then turns down, and up again in period sixteen. When risk is first, the effect on interest rates is generally negative, with some positive values in early periods. The effect on S is an initial increase, followed by a decrease in period twelve, similar to risk. The effect on interest rates is mixed, with an initial increase, followed by a decrease in period four, increase in period seven, and decrease in period fourteen. A shock in interest rates seems to lead to gyrations around zero in all variables, with interest rates rising at first and then falling. When IP is first, this causes gyrations in $\hat{P}$, S, and risk. Interest rates rise at first and then fall in period sixteen.

IP rises and stays up as the effect dampens.

When this same simulation was done for the 1970's, the results are more conclusive, and in accordance with what was predicted earlier.

A shock in $\hat{P}$ caused anticipated inflation to gyrate around zero for the twenty periods, with the effect dampening in later periods. S rose at first, fell, and then rose again, as did risk. The effect on nominal interest rates was much more pronounced, and positive. Interest rates rose and stayed up for twenty periods, and in later periods were almost all positive, with some negative values as the effect of the shock wore off. An increase in S resulted in an oscillating anticipated inflation rate. S rose, fell, then rose again, as did risk, with the general tendency an increase in both S and risk. Nominal interest rates were unambiguously lower due to a shock in S. This is the result we would expect if S were acting on ex ante real rates in the way that was predicted.

When risk is first, the anticipated inflation rate is generally lower. Both S and risk vary around zero. Nominal interest rates are ambiguously lower, with no values above zero. When nominal rates are first, anticipated inflation is generally higher, with interest rates rising and then falling in period nineteen. A shock in industrial production results in nominal interest rates rising, although the values interest rates take are very small.

These results are interesting, and seem to conform with the results of the VAR estimation. The effects we are looking for show up in the 1970's very strongly, but not as strongly in the 1960's. During the 1960's, the effect of a shock in S or risk would, on balance, seem to be negative, but not that strong. A shock in risk causes interest rates to vary around zero, with neither positive nor negative effects seeming to dominate. A shock in S causes interest rates to rise and then fall, but not to vary much around zero. There is only one change in direction. Surprises in anticipated inflation cause interest rates to jump up, and then fall as the effects of the shock dampen in later periods. Shocks in interest rates seem to cause rises in interest rates which are positive, dampening in later periods.

The 1970's show the results we are looking for more strongly. The effect of a surprise in S on interest rates is unambiguously negative. When risk is first, the effect of a surprise in risk on nominal interest rates is also unambiguously negative. The effect of a surprise in anticipated inflation is positive, with some variation around zero in later periods as the effect of the shock dampens. A shock in interest rates causes anticipated inflation to rise, with some values negative, but the overall effect is positive. An interest rate surprise causes interest rates to unambiguously rise, with some negative values at the very end of the period.

A look at the decomposition of variance yields some interesting comparisons (see Tables 13 and 14). In the 1960's, a shock in a particular variable results in most of the variance of results manifesting itself in variation in that particular variable; for example, a shock in P results in most of the variation coming in predicted values of anticipated inflation. When the surprise is in P, S, or risk, there is little corresponding variation in nominal interest rates. When the surprise is in IP, the variation in nominal interest rises; it seems that surprises in nominal variables have little effect on nominal interest rate variation in the 1960's. However, a surprise in industrial production seems to have a much larger effect on variation in nominal rates of interest than does a surprise on any of the other variables for that period.

In the 1970's, this is not the case. The effect of a surprise on any of the three nominal variables on variation in nominal interest rates is much larger than in the 1960's. The effect of a surprise in S or risk on variation in nominal interest rates is ten to fifteen times as large in the 1970's as it is in the 1960's. Indeed, the largest variation in variables other than themselves is on nominal interest rates in the 1970's. A surprise in anticipated inflation causes three to four times as much variation in nominal interest rates in the 1970's as it does in the 1960's. A shock in IP in the 1970's causes approximately four times as much variation in anticipated inflation than it does in the 1960's. Indeed, in the 1970's, for shocks to risk, the resulting variation in nominal interest rates is larger than resulting variation in risk itself.

A shock to IP in the 1970's results in the most variation being in IP itself, with very little corresponding variation in nominal interest rates.

These results support the VAR results obtained above. The effects we looked for showed up much more strongly in the 1970's than they did in the 1960's. Indeed, the results of the 1960's would lead us to be unable to reject the null hypothesis that nominal rates of interest (at least the three month treasury bill rate) are exogenous, i.e. a function of its own past values, the sum of the lagged coefficients being not significantly different from unity for the period.

During the 1970's, the sum of the coefficients on lagged interest rates is in all cases lower than the corresponding value for the 1960's. In addition, the coefficients on the other variables in the model are generally significant for the 1970's, while not significant for the 1960's.

The results of the simulation also support what was predicted. In the 1960's, the sign of the values predicted a priori for interest rates do not conclusively support what was predicted. For the 1970's, however, the results of the simulation are much more clear. Values of nominal interest rates due to surprises in S and risk are unambiguously negative, which is as predicted. Values for nominal interest rates due to surprises in industrial production are not as predicted, but a look at the decomposition of variance shows that surprises in IP manifest themselves mainly in increased variability in industrial production. Indeed, a surprise in IP causes two to five times as much variation in risk as it does in nominal interest rates. This fact does not rescue the a priori expectations, but it does lead one to at least entertain the notion that the relationship may not be that strong in the 1970's.

Up to now, what we have essentially been doing is testing a theory implicitly. It was originally postulated that certain variables would affect the non constant ex ante real rate of interest. This would bias the coefficient of anticipated inflation in any Fisher equation which treated the ex ante real rate as constant. Then we looked for the effects of these variables in a modified Fisher equation. This is a theory which is testable explicitly. We can generate an ex ante real rate by forecasting an anticipated inflation rate and subtracting it from the nominal interest rate, thereby giving us an ex ante real rate of interest. We can then test the theory directly. This is done in the next section.

CHAPTER IV

ESTIMATION USING THE EX ANTE REAL RATE OF INTEREST

In this section, we will look at the question of constancy of the ex ante real rate of interest. In Irving Fisher's original work, it was assumed that the ex ante real rate was not affected by any factors, and hence constant in any estimate of the Fisher equation.

In their 1983 paper, Robert Litterman and Laurence Weiss test for exogeneity of the real rate in a Var model similar to, but not the same as, the Var model used in this paper. In their model, which uses past values of money, prices, and industrial production, the test for exogeneity is

$$E(r_{t+1}/r_{t-s}, s \geq 0) = E(r_{t+1}/r_{t-s}, m_{t-s}, P_{t-s}, y_{t-s}, s \geq 0)$$

This questions if the expected value of the ex ante real rate given the past series of ex ante real rates is equal to the expected value of the ex ante real rate given the past series of ex ante real rates, money, prices, and income. Equivalence between the two would be interpreted as exogeneity in ex ante real rates since there would be no additional information in the series of past values of money, prices, and income which would be useful for predicting values of r_{t+1}. Statistically, this would manifest itself in beta coefficients of the past values of money, income, and prices which were not significantly different from zero. Litterman and Weiss found that the ex ante real rate failed to reflect any systematic influence from money, income, or prices, given the past series of ex ante real rates. They find that the hypothesis that the ex ante real rate is exogenous cannot be rejected in either a monthly or quarterly model. They further state that this result casts strong doubt on Keynesian money-interest-output link, since exogeneity of the ex ante real rate means that monetary policy cannot affect output by altering perceptions of the ex ante real rate, as Keynesians believe.

There are published results contrary to the findings of Litterman and Weiss. In a 1984 paper by John Huizinga and Frederick Mishkin, it is found that the evidence against constancy of the real real rate is very strong. It is found that for six of seven assets measured, the ex ante real rate is not constant. Constancy is rejected for three month treasury bills, six month bills, twelve month bills, intermediate term bills, long term corporate bonds, and common stock. Constancy cannot be rejected for long term treasury bonds. It is also found that the ex ante real rates are significantly different across these assets, with the obvious exception of long term treasury bonds.

The sample period used in this study is January, 1959 to October 1979; this sample being very close to the sample used in this paper.

The statistical methodology used in Huizinga and Mishkin is different from the methodology used here, their's being an Ols model and ours being a Var model.

In order to test the real rate theory directly, it is necessary to generate an ex ante real rate of interest. This is done by subtracting the anticipated rate of inflation, derived as described earlier, from the nominal rate of interest. This ex ante real rate of interest is then estimated as a function of the explanatory variables S, IP, Risk, a constant term, and a time trend for the 1960's and 1970's, in the same manner as described above, for eight, ten, and twelve lags. The model is then simulated as described above. These results are reported below in Table 6-7.

The results of estimating this model are very interesting. For the 1960's, the sum of the coefficients on lagged values of the ex ante real rate of interest are significant for ten lags, but not for eight and twelve lags. This would cast at least preliminary doubt on exogeneity of the ex ante real rate of interest. The sum of the coefficients of lagged values of industrial production is significant for eight, ten, and twelve lags. Risk is also significant for eight, ten, and twelve lags.

S is not significant for any lag length.

The 1970's show much stronger results. All variables are significantly different from zero for all lag lengths. The sum of the lagged coefficients on ex ante real rates of interest are in all cases significantly different from zero, casting doubt on exogeneity of ex ante real rates for the 1970's as well as the 1960's. Industrial production is also significant, leading to the conclusion that real factors can and do affect the ex ante real rate of interest. S and risk are also significantly different from zero for all three lag lengths. The constant term is significant for eight, ten, and twelve lags, while the time trend variable is not significant for any lag length. This would cast doubts on the time significant movement in ex ante real rates found by Huizinga and Mishkin.

The results of the simulation would seem to bear out what was predicted, although much more strongly in the 1970's than in the 1960's, as is the case with the equations estimated using the nominal rate of interest. The results for the 1960's are actually quite weak. These results are shown below in Tables 15-18.

During the 1960's, a surprise in risk seems to have little effect on the ex ante real rate of interest (XRR), with values being positive and negative, although in later periods the values seem to be more on the negative side.

Risk and S are both positive at first, and then turn negative, Risk in the twelfth period and S in the thirteenth. IP falls sharply, tapering off in later periods.

In response to a surprise in S, XRR takes on mainly negative values, although very small in size. Risk also takes on very small values, positive and negative. S responds by jumping up and tapering off in later periods, but always positive. IP responds in much the same manner.

The response of XRR to surprises in IP is generally positive, with some negative values. S and risk both respond positively, as does IP.

A surprise in XRR generates a rise in XRR which tapers off in mid range. The results of the other variables are mixed.

The 1970's show much stronger results. A surprise in risk results in an unambiguous decline in XRR. Risk and S are higher, and IP is also higher, although some negative values are obtained.

A surprise in S generates a decline in XRR, with S and risk generally higher, IP mixed.

Surprises in IP generate mixed results in early periods, but a downturn occurs in mid range.

A look at the decomposition of variance yields some concordant results (see Table 19-20). Surprises in risk generate slightly more variation in XRR in the 1970's than in the 1960's. Surprises in S generate seven to ten times as much variation in XRR in the 1970's than in the 1960's. Surprises in IP generate variability in the 1960's which is higher in early periods than in later periods. In the 1970's, the reverse is true, with more variation in XRR due to surprises in IP coming later in the simulation period. Surprises in XRR cause much more variation in own values in the 1970's than they do in the 1960's.

CHAPTER V CONCLUSIONS

The results we have obtained have shed some light on the interest rate-inflation rate relationship during the 1960's and 1970's. It was found, contrary to Levi and Makin, but in accordance with much of the literature, that nominal interest rates do not adjust on a one to one basis for changes in anticipated inflation. During the 60's, interest rates hardly adjusted for changes in anticipated inflation, while during the 1970's, changes in anticipated inflation were significant in explaining changes in interest rates, but not to the degree that was hoped for. In the 1960's, for example, we would be unable to reject exogeneity of nominal interest rates. In the 1970's, we can very easily reject the hypothesis of exogeneity.

We can also reject exogeneity for ex ante real rates for both the 1960's and 1970's, with ex ante real rates significantly affected by industrial production and risk both in the 1960's and the 1970's, contrary to the findings of Litterman and Weiss.

There would seem to be a dichotomy in the model between the 1960's and 1970's. When the standard deviation is regressed against nominal interest rates in the 1960's, the sum of the coefficients is negative, although not significantly different from zero, while positive and significant in the 1970's. Risk is positive in the 1960's and negative in the 1970's. Industrial production is negative in the 1960's and positive in the 1970's.

The dichotomy also appears for ex ante real rates of interest, although to a lesser degree. The standard deviation is positive in the 1960's and negative in the 1970's. Risk is positive in both periods. Industrial production is negative in both periods, and significant for all lag lengths. Lagged values of ex ante real rates explain a significant amount of current ex ante real rates, although to a stronger degree in the 1970's than in the 1960's.

In looking at simulation results for nominal interest rates, a surprise in anticipated inflation in both periods tends to raise nominal interest rates. In the 1960's, a surprise in the standard deviation or risk lowers nominal rates, but very weakly. In the 1970's the results are unambiguous: a surprise in the standard deviation or risk lowers nominal rates.

The variables also tend to be much more sensitive to shocks in the 1970's than they do in the 1960's. Effects seem to manifest themselves mostly in increased variation in own values in the 1960's and in other values in the 1970's. Shocks have relatively little effect on variation in nominal rates in the 1960's and much more in the 1970's.

Indeed, in many cases, the resulting variation from a shock in a variable on nominal rates is ten to fifteen times as large in the 1970's as it is in the 1960's. The sole exception is industrial production, which has a larger effect on nominal rates in the 1960's than in the 1970's.

Simulation using the ex ante real rate shows the same general results. Responses of ex ante real rates to surprises in the 1960's are relatively weak. In the 1970's, shocks in the standard deviation or risk cause very strong declines in ex ante real rates. This model is also much more sensitive in the 1970's than in the 1960's, with surprises causing more variation in own values in the 1960's and in other values in the 1970's.

It would appear that in the 1960's, nominal variables have less effect on both nominal and ex ante real rates, while real variables such as industrial production have a greater effect. In the 1970's, just the reverse is true, with nominal variables having greater effect and real variables having less effect.

The results would seem to shown that what we have are two separate periods in the U.S. economy with two distinct modes of interest rate reaction to other variables in the model.

One broad conclusion which can be reached is that in a period of stable prices, such as the 60's, shocks do not have a great effect on interest rates, while the opposite is true in a period of unstable prices, such as the 70's. This is supported by the apparent exogeneity of nominal interest rates in the 60's. When the inflation rate is low, surprises in inflation are discounted relatively quickly, which is not the case when the inflation rate is relatively high. Further research is warranted.

CHAPTER VI POLICY IMPLICATIONS

One result which is apparent is that inflation premiums are never fully incorporated into nominal interest rates even on a pre-tax basis, a result which has been obtained by many others. It also seems that even after accounting for this incomplete adjustment, anticipated inflation lags behind changes in actual inflation. This manifests itself in very high ex post real rates of interest during times of falling inflation rates and very low (sometimes negative) ex-post real rates of interest during times of rising inflation rates. This has very serious implications for government borrowing. By selling long term bonds when the inflation rate is falling or when a policy aimed at reducing the inflation rate is about to be implemented, the government is looking itself into paying a very high real rate of interest on borrowed funds if the inflation rate falls or if the policy is effective. This makes it relatively harder to repay such debts. It also adds to the credibility problem. By selling long term bonds, the public might have reduced faith in the government's ability to pay the implicitly higher real rate of interest and the increased probability of rising rates of inflation in order to reduce the real rate paid on the debt issued.

When inflation is relatively low, simulation results would seem to indicate that a change in the inflation rate is not seen to have such effect on other nominal variables in the mode. This is a condition which could be exploited by a central bank which desires to exploit the trade-offs along a short-run Phillips curve. With a relatively low inflation rate, an expansionist monetary policy would have a larger output effect than if the inflation rate was relatively higher. This is shown in the simulation by comparing the response of Industrial Production to changes in anticipated inflation in the 1960's to that of the 1970's.

It would seem that a central bank should be concerned with the reaction of variables in the system to changes in, say, the rate of growth of the money supply, with the main concern being what type of variables will be affected most, nominal or real. The results of the simulation show that with higher rates of inflation, changes in nominal variables such as the anticipated rate of inflation, due to a change in the rate of growth of the money supply, would have a more pronounced effect on nominal variables, while the greater effect would be on real variables if the rate of inflation were low. This would give a central bank an information advantage in knowing where the major effects of surprises will show up.

TABLE I

Estimates From Levi's and Makin's Model

$$i_t = \beta_o + \beta_1 \hat{P}_t + \beta_2 \dot{Y}_t + \beta_3 S_t + e_t$$

	1950-1970		1947-1975	
	3 month Treasury Bills	4-6 mo. Finance Paper	3 month Treasury Bills	4-6 mo. Finance Paper
Estimates from Fisher Equation				
β_0	2.07 (7.85)	2.44 (8.62)	2.38 (11.35)	2.74 (12.28)
β_1	0.88 (5.85)	0.90 (5.58)	0.64 (8.61)	0.68 (8.57)
R^2	0.46	0.44	0.57	0.57
D-W	0.52	0.48	0.74	0.74
Estimates from Fisher Equation with Phillips Effect				
β_0	2.51 (8.96)	2.99 (10.48)	2.79 (11.68)	3.27 (13.33)
β_1	0.93 (6.76)	0.97 (6.86)	0.64 (9.20)	0.67 (9.51)
β_2	-0.13 (-3.04)	-0.17 (-3.78)	-0.12 (-3.01)	-0.15 (-3.75)
R^2	0.56	0.59	0.64	0.66
D-W	0.91	0.89	0.86	0.87

TABLE I (contd.)

	1950-1970		1947-1975	
	3 month Treasury Bills	4-6 mo. Finance Paper	3 month Treasury Bills	4-6 mo. Finance Paper
Estimates from Fisher Equation with Phillips Effect and Friedman Effect				
β_0	3.57 (9.95)	4.04 (10.85)	3.53 (11.28)	4.03 (12.66)
β_1	1.00 (8.44)	1.04 (8.42)	0.62 (9.71)	0.66 (10.08)
β_2	-0.13 (-3.41)	-0.16 (-4.21)	-0.14 (-3.76)	-0.17 (-4.58)
β_3	-1.01 (-3.97)	-0.99 (-3.76)	-0.42 (-3.30)	-0.44 (-3.38)
R^2	0.69	0.70	0.70	0.72
D-W	1.31	1.27	1.02	1.04

"t" statistics are below coefficient estimates.

TABLE 2

Own Estimate of Levi and Makin Model Using Three Month Rate

$$i_t = a_0 + a_1\hat{P}_t + a_2E_t + a_3S_i + A_4\text{Risk} + e_t$$

Period 1960:1 - 1969:12

	a_0	a_1	a_2	a_3	a_4	R^2
1)	.0052	.716				.76
	(19.9)	(20.2)				
2)	.0067	.762		-.57		.788
	(10.5)	(19.3)		(2.47)		
3)	.005	.736	.251			.812
	(20.3)	(22.6)	(4.9)			
4)	.0057	.751	.223	-.21		.816
	(8.57)	(20.3)	(4.2)	(.905)		
5)	.0089	.251		-1.26	148.75	.794
	(6.7)	(.949)		(3.0)	(1.96)	
6)	.0079	.21	.235	-.922	154.64	.82
	(6.3)	(.89)	(4.3)	(2.3)	(2.1)	

Period 1970:1 - 1979:12

	a_0	a_1	a_2	a_3	a_4	R^2
7)	.0051	.559				.72
	(8.3)	(17.68)				
8)	.0064	.641		-.479		.769
	(10.17)	(18.8)		(4.6)		
9)	.005	.57	.116			.73
	(8.2)	(18.1)	(2.3)			
10)	.0062	.646	.019	-.456		.77
	(9.9)	(19.1)	(1.95)	(4.4)		
11)	-.0002	1.06		.631	-66.01	.81
	(.14)	(11.9)		(2.64)	(5.5)	
12)	.0004	1.04	.0215	.601	-63.87	.811
	(.02)	(11.28)	(.406)	(2.41)	(4.5)	

TABLE 3
Own Estimate of Levi and Makin Model Using Six Month Rate

$$i_t = a_0 + a_1\hat{P}_t + a_2E_t + a_3S_t + a_4Risk_t + e_t$$

	a_0	a_1	a_2	a_3	a_4	R^2
	Period 1960:1 - 1969:12					
1)	.009	.825				.855
	(19.86)	(26.4)				
2)	.0129	.68		-.96E-18		.77
	(9.76)	(10.7)		(2.89)		
3)	.0094	.819	in.111			.86
	(20.0)	(26.4)	(1.98)			
4)	.0127	.683	.084	-.908E-18		.779
	(9.53)	(10.7)	(1.18)	(2.71)		
5)	.0126	.696		-.409E-18	-.58E-16	.77
	(9.0)	(10.3)		(0.51)	(0.76)	
6)	.0122	.708	.104	-.8E-19	-.85E-16	.78
	(8.62)	(10.5)	(1.42)	(0.97)	(1.08)	
	Period 1970:1 - 1979:12					
	a_0	a_1	a_2	a_3	a_4	R^2
7)	.01334	.492				.643
	(9.79)	(14.31)				
8)	.0139	.498		-.06		.63
	(7.6)	(13.4)		(0.4)		
9)	.0134	.494	-.016			.63
	(9.39)	(13.99)	(0.24)			
10)	.0139	.5	-.019	-.065		.63
	(7.49)	(13.0)	(.28)	(.42)		
11)	.0035	.847		.871	-29.7	.65
	(.73)	(5.5)		(2.07)	(2.37)	
12)	.0032	.856	-.0322	.877	-30.15	.65
	(.67)	(5.5)	(.47)	(2.08)	(2.39)	

TABLE IV

Vector Autoregression Results

Dependent Variable: Nominal Interest Rate

Period	Lag Length	Variable	Sum of Coefficients	Significance Level
1970-79	8	$\hat{P}$	.355	.0039
		I3	.766	.138E-16
		IP	.634E-03	.155E-04
		S	.4463	.0054
		Risk	-5.306	.301E-04
		$R^2 = .984$	$\bar{R}^2 = .976$	DW = 1.99
	10	$\hat{P}$	.3317	.026
		I3	.777	.14E-12
		IP	.685E-03	.10E-02
		S	.468	.028
		Risk	-5.3783	.46E-04
		$R^2 = .98$	$\bar{R}^2 = .97$	DW = 1.97
	12	$\hat{P}$	.322	.0843
		I3	.917	.39E-09
		IP	.00049	.13
		S	.3795	.13
		Risk	-4.516	.98E-03
		$R^2 = .987$	$\bar{R}^2 = .975$	DW = 1.95

TABLE V

Vector Autoregression Results

Dependent Variable: Nominal Interest Rate

Period	Lag Length	Variable	Sum of Coefficients	Significance Level
1960-69	8	$\hat{P}$	.0829	.139
		I3	.88	.00-
		IP	.000298	.0908
		S	-.01406	.937
		Risk	.965	.408
		$R^2 = .99$	$\bar{R}^2 = .984$	DW = 2.03
	10	$\hat{P}$	.044	.177
		I3	.8935	.138E-16
		IP	-.000398	.166
		S	-.02284	.965
		Risk	1.68	.497
		$R^2 = .99$	$\bar{R}^2 = .984$	DW = 2.11
	12	$\hat{P}$	.0712	.372
		I3	.9301	.457E-14
		IP	-.0003847	.41
		S	-.01922	.948
		Risk	1.038	.67
		$R^2 = .992$	$\bar{R}^2 = .983$	DW = 2.20

TABLE VI

Vector Autoregression Results

Dependent Variable: Ex Ante Real Rate

Period	Lag Length	Variable	Sum of Coefficients	Significance Level
1960-69	8	XRR	.4936	.1129
		IP	-.000621	.00326
		S	.0315	.0953
		Risk	15.216	.0316
		$R^2 = .528$	$\bar{R}^2 = .348$	DW = 2.03
	10	XRR	.4163	.0304
		IP	-.000591	.363E-05
		S	.0423	.1572
		Risk	17.452	.00483
		$R^2 = .6566$	$\bar{R}^2 = .476$	DW = 2.29
	12	XRR	.3486	.177
		IP	-.000929	.11E-06
		S	.363	.114
		Risk	30.11	.00747
		$R^2 = .7305$	$\bar{R}^2 = .541$	DW = 2.179

TABLE VII

Vector Autoregression Results

Dependent Variable: Ex Ante Real Rate

Period	Lag Length	Variable	Sum of Coefficients	Significance Level
1970-79	8	XRR	.3788	.00351
		IP	-.00193	.119E-04
		S	-.49066	.597E-04
		Risk	2.6057	.115E-02
		R^2 = .726	$\bar{R}^2$ = .621	DW = 2.35
	10	XRR	.4341	.756E-03
		IP	-.00183	.43E-05
		S	-1.166	.159E-04
		Risk	8.69	.88E-05
		R^2 = .7966	$\bar{R}^2$ = .689	DW = 1.88
	12	XRR	.39742	.00452
		IP	-.00817	.48E-07
		S	-.6977	.22E-04
		Risk	4.714	.23E-05
		R^2 = .86	$\bar{R}^2$ = .762	DW = 1.90

TABLE VIII

Response of Nominal Interest Rate to Shocks in Anticipated Inflation

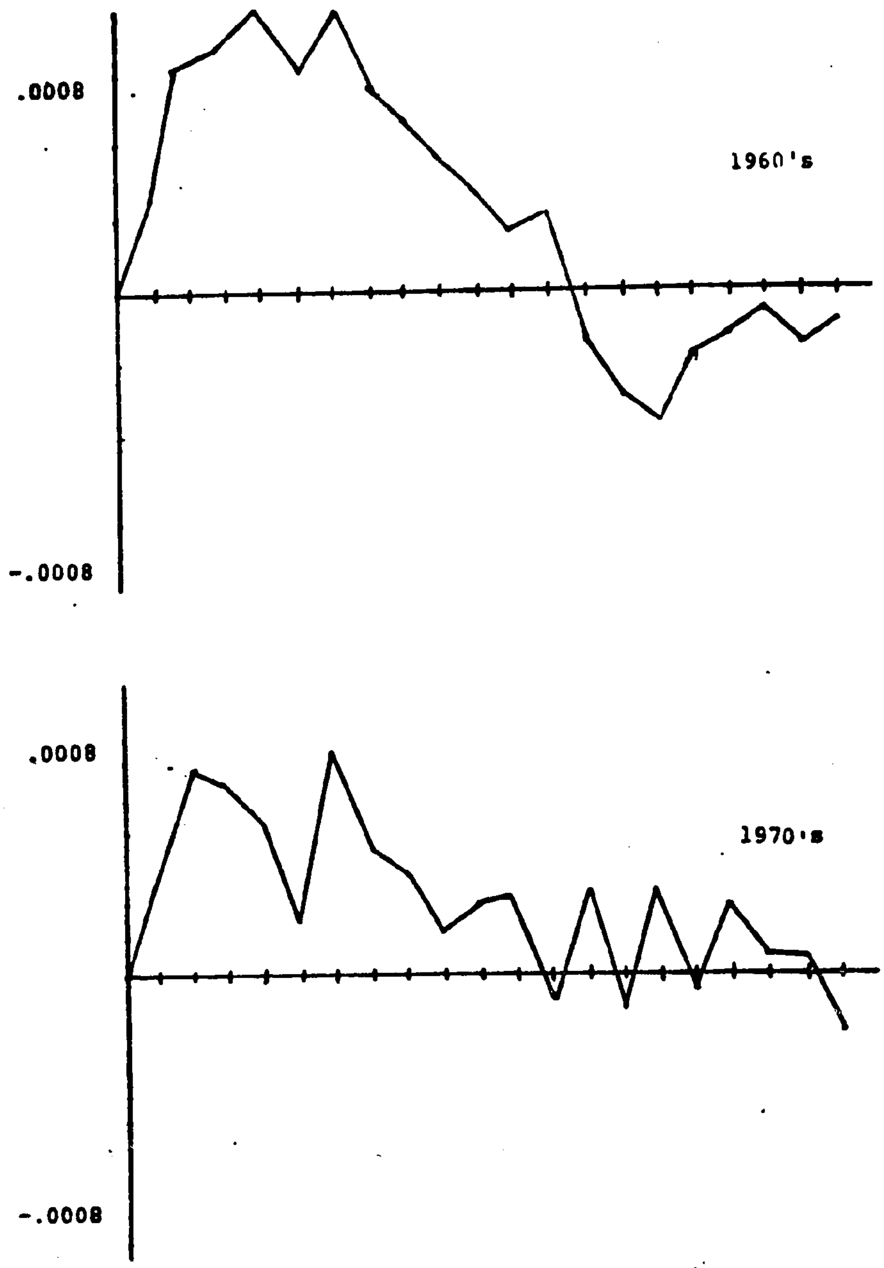


TABLE IX

Response of Nominal Interest Rate to Shock in Risk

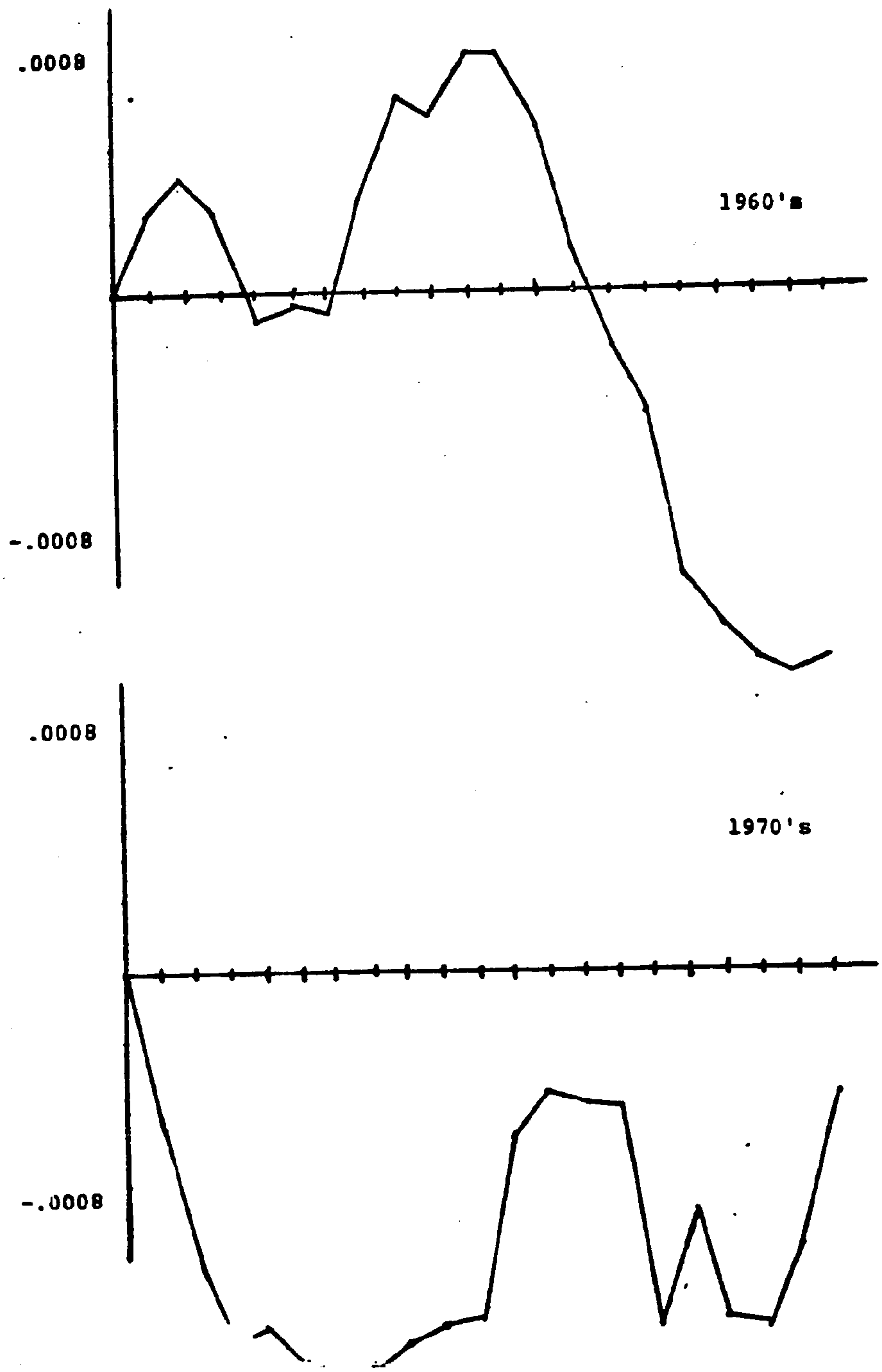


Table X

Response of Nominal Interest Rate to Shock in S

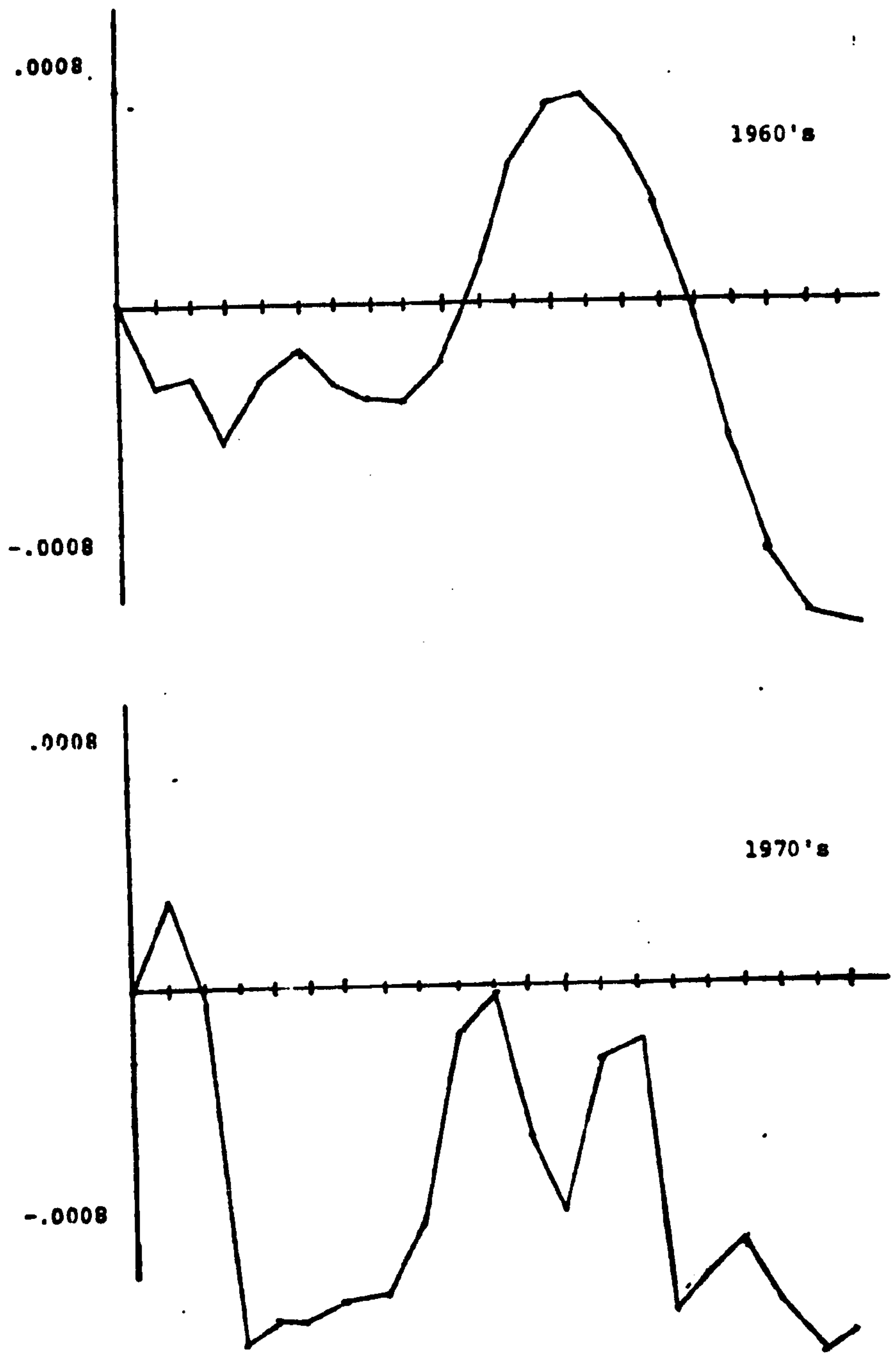


Table XI

Response of Nominal Interest Rate to Shock in Nominal Interest Rate

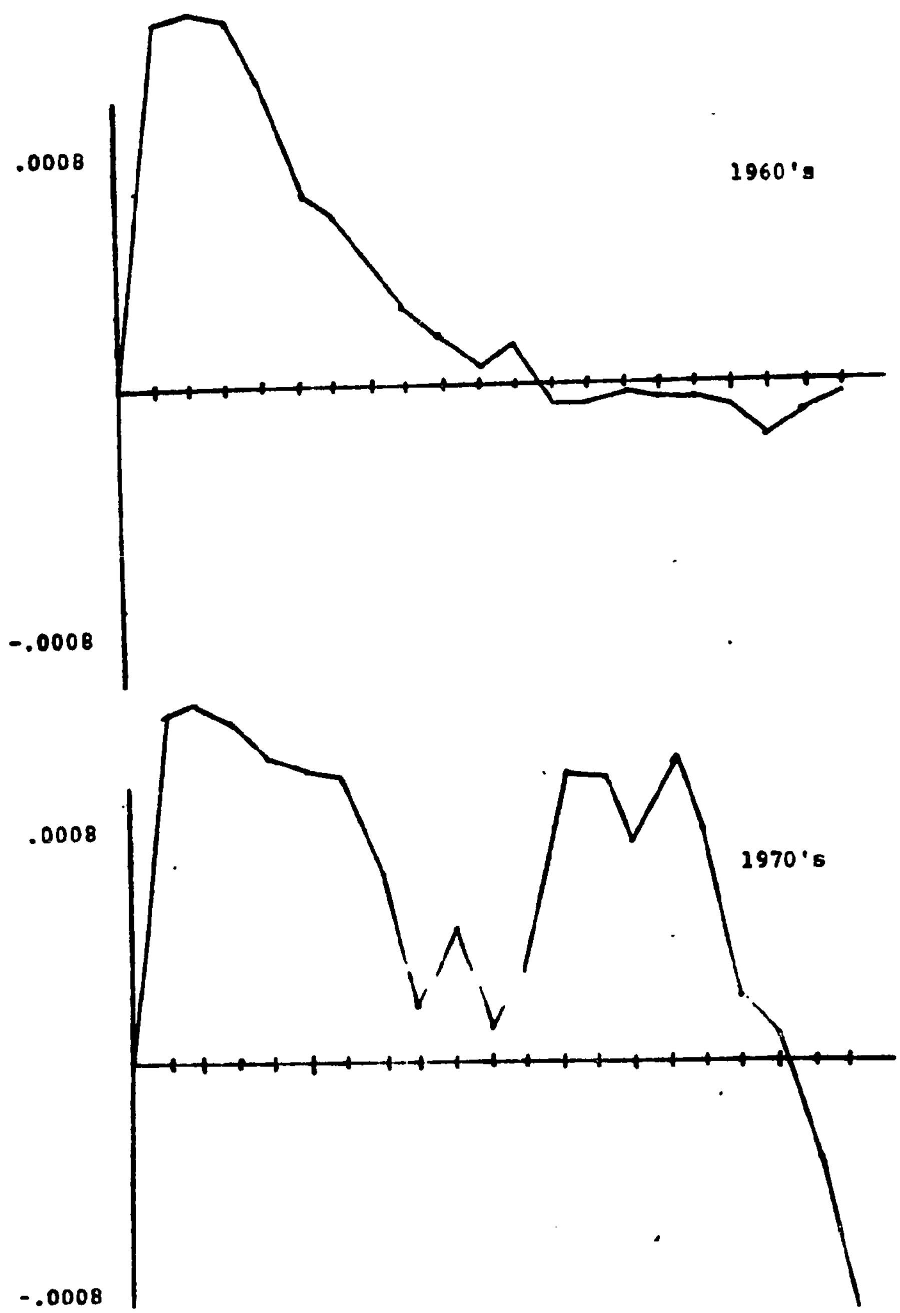


Table XII

Response of Nominal Interest Rate to Shock in Industrial Production

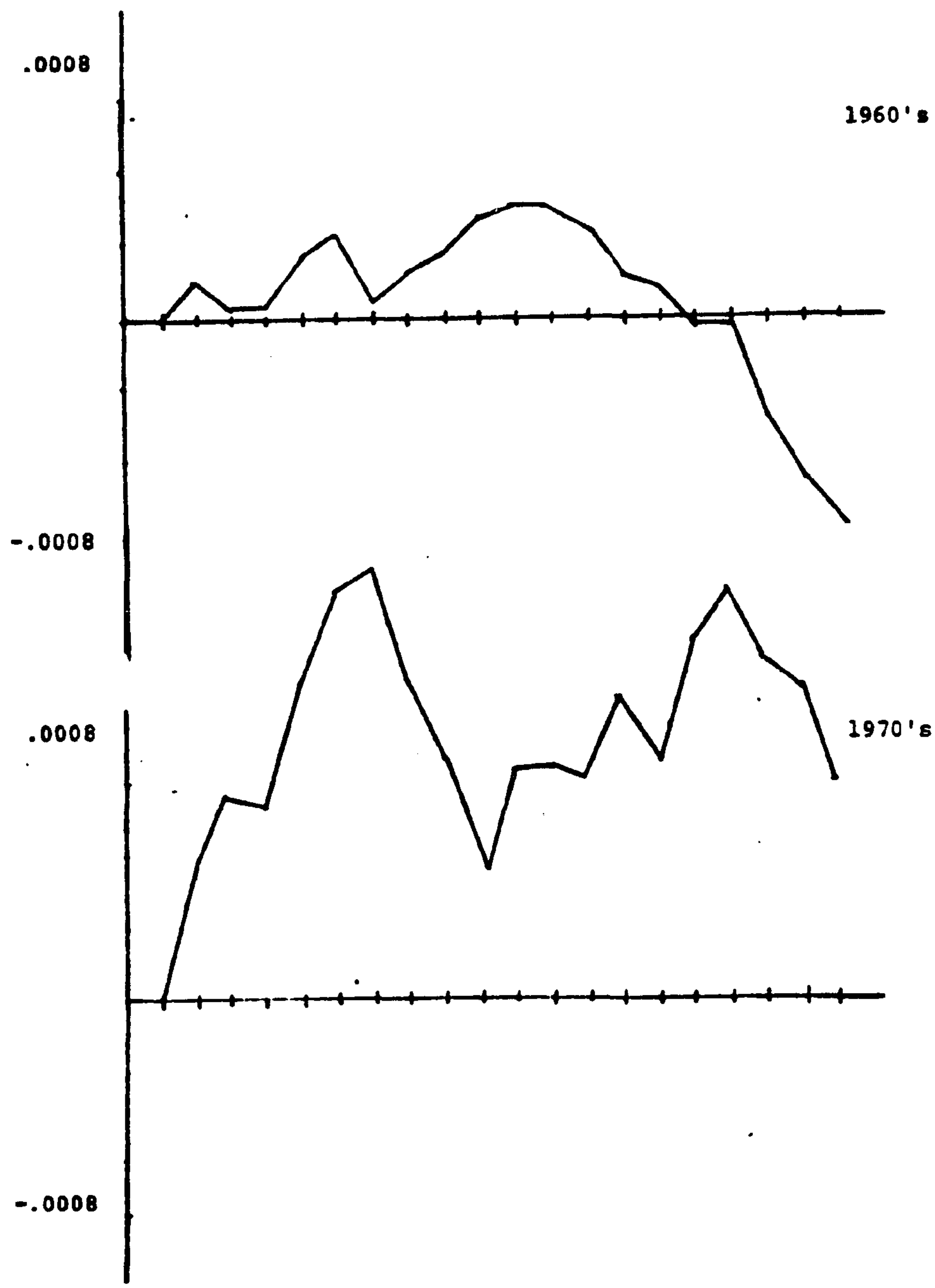


TABLE XIII

Decomposition of Variance -- Nominal Interest Rate

1960's

	$\hat{P}$	S	Risk	13	IP
			$\hat{P}$		
5	68.71	5.47	8.77	4.56	12.40
10	60.71	8.35	10.55	5.22	15.15
15	47.07	9.50	22.98	6.62	13.81
20	39.93	16.98	24.72	6.07	12.27
			S		
5	6.78	88.84	2.08	0.32	1.95
10	4.69	77.04	10.10	0.85	7.30
15	6.89	68.62	10.86	1.03	12.59
20	13.12	60.59	13.06	2.20	11.01
			Risk		
5	55.39	8.01	20.28	3.54	12.75
10	44.73	19.65	18.66	3.34	13.59
15	36.75	17.54	28.32	3.95	13.42
20	32.54	25.19	27.35	3.48	11.42
			13		
5	22.85	3.27	2.64	70.61	0.61
10	27.40	4.27	11.44	54.67	2.19
15	24.75	11.50	15.24	44.77	3.71
20	12.49	17.38	43.74	22.11	4.26
			IP		
5	2.28	0.11	5.11	15.20	77.26
10	3.26	0.58	6.22	12.58	77.33
15	14.36	1.44	6.51	11.11	66.56
20	21.86	5.50	7.47	9.73	55.41

TABLE XIV

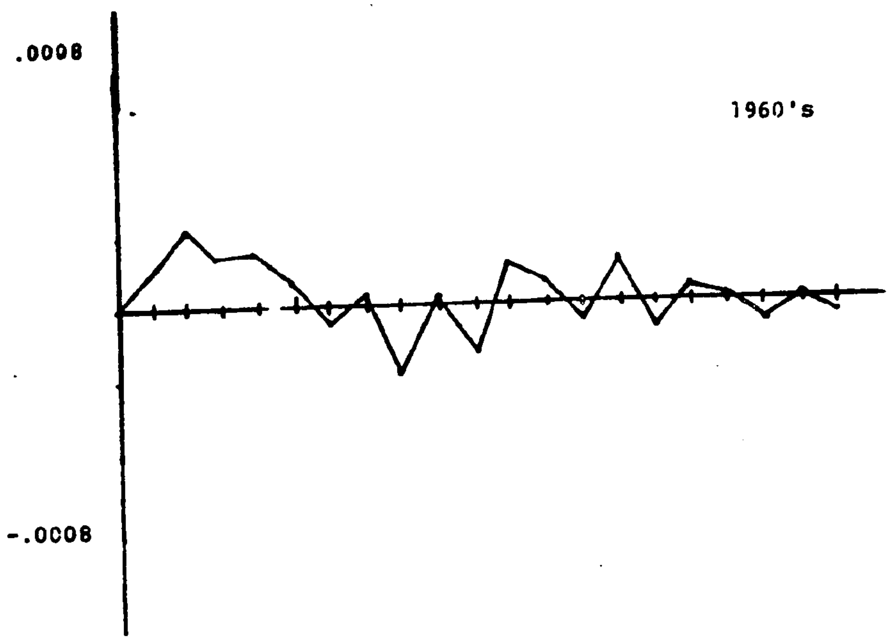
Decomposition of Variance -- Nominal Interest Rate

1970's

	$\hat{P}$	S	Risk	13	IP
			$\hat{P}$		
5	44.80	3.89	18.79	8.5	23.99
10	26.96	16.86	18.19	17.63	20.34
15	19.32	16.04	21.88	20.75	21.98
20	17.30	19.02	21.33	18.87	23.45
			S		
5	3.35	69.38	10.09	16.77	.39
10	3.73	45.21	17.03	32.02	2.00
15	3.46	43.55	16.68	33.19	3.09
20	3.61	44.39	16.38	32.21	3.38
			Risk		
5	5.95	62.31	14.83	14.56	2.3
10	5.94	39.64	19.46	31.67	3.27
15	5.25	39.48	18.03	31.97	5.25
20	5.47	39.5	17.42	31.01	6.56
			13		
5	2.95	15.94	26.02	49.93	5.13
10	2.95	14.12	40.79	31.00	11.11
15	2.83	14.88	37.61	31.35	13.30
20	2.40	19.16	34.80	27.23	10.38
			IP		
5	1.13	.308	8.65	1.37	88.51
10	1.02	1.07	13.51	6.43	77.94
15	.95	8.22	12.49	5.79	72.53
20	2.08	26.38	14.41	12.98	44.12

Table XV

Response of Ex Ante Real Rate to Shock in S



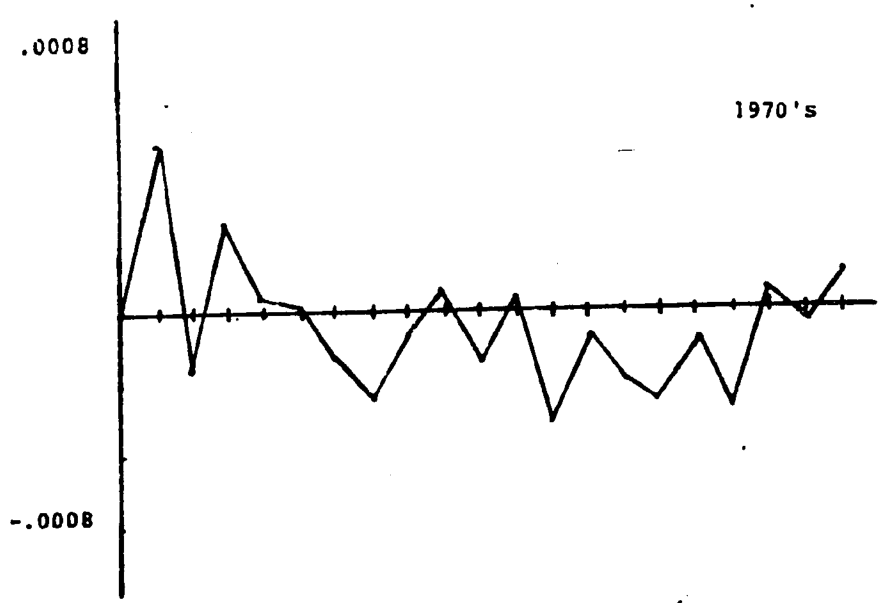
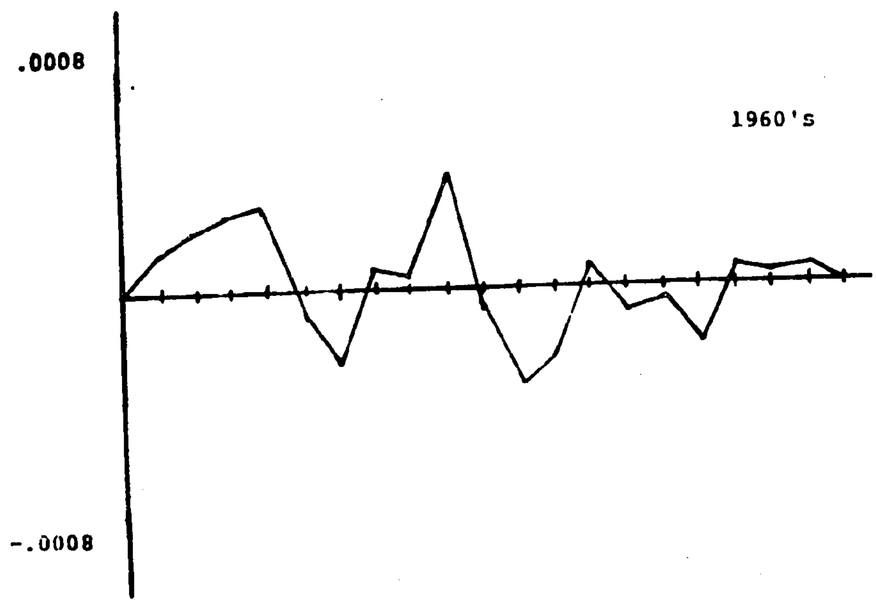


Table XVI

Response of Ex Ante Real Rate to Shock in Industrial Production



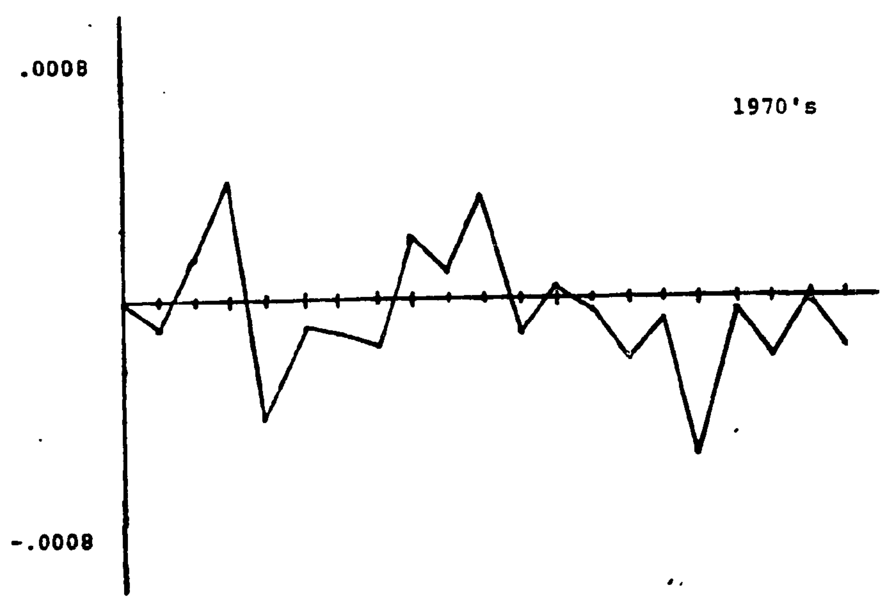
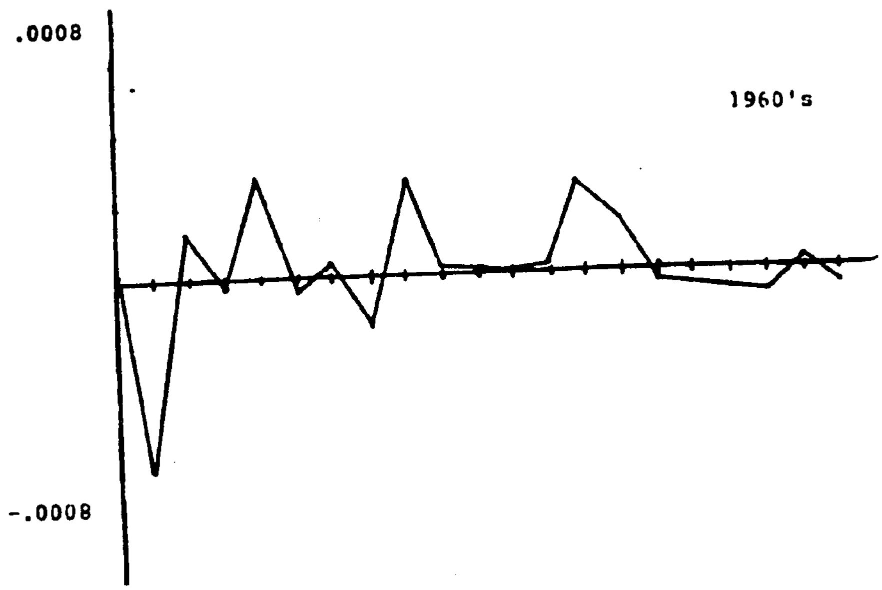


Table XVII

Response of Ex Ante Real Rate to Shock in Risk



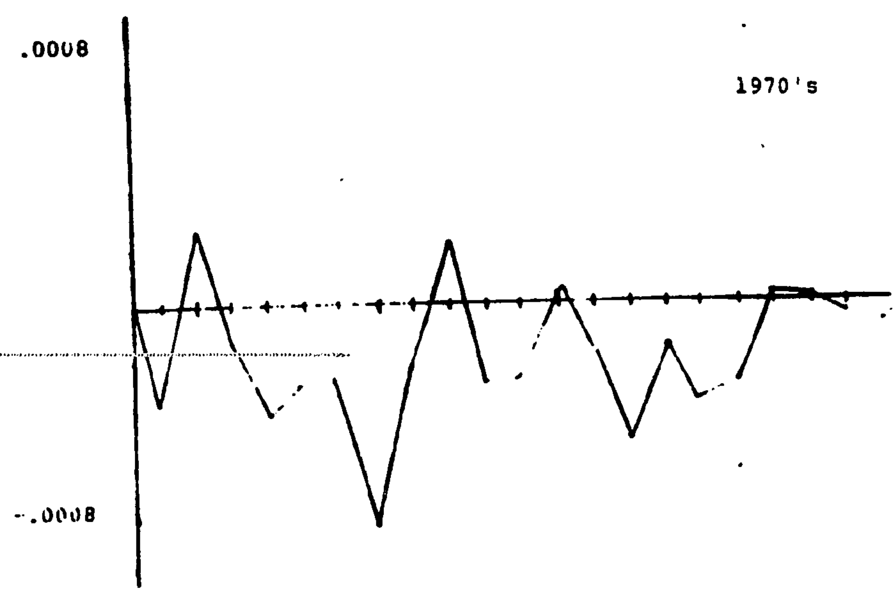
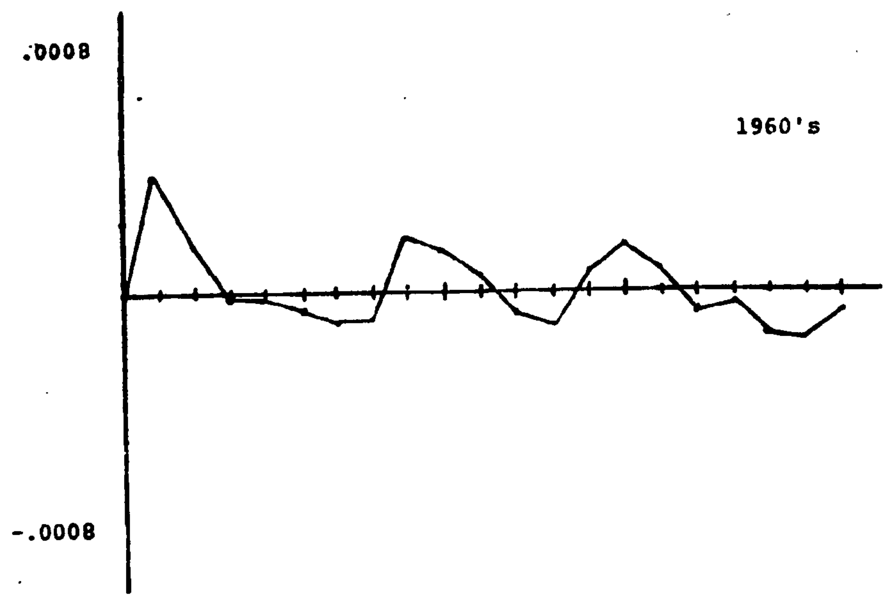


Table XVIII

Response of Ex Ante Real Rate to Shock in Ex Ante Real Rate



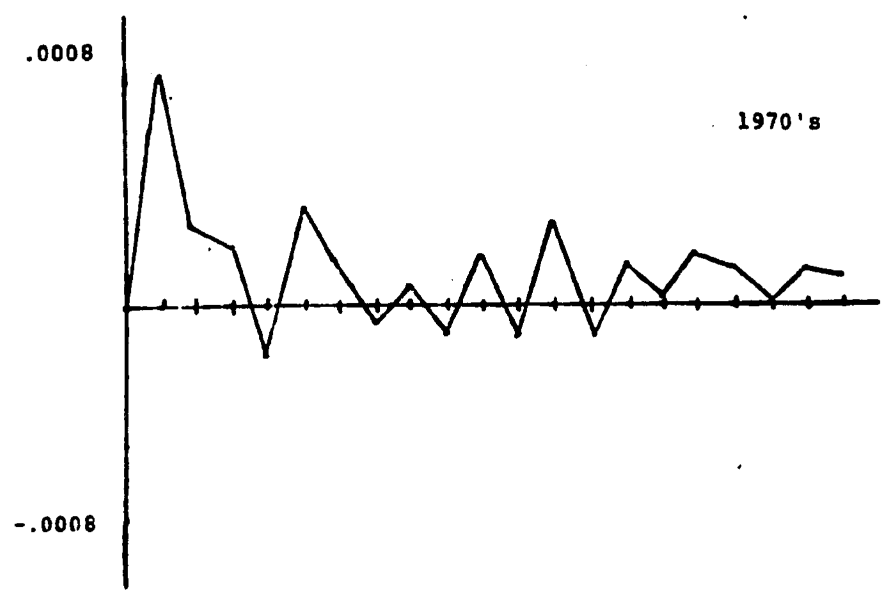


TABLE XIX

Decomposition of Variance - Ex Ante Real Rate

1960's

	Risk	Risk S	IP	XPR
		Risk		
5	85.82	1.77	7.24	5.16
10	66.12	6.75	16.20	10.90
15	55.82	7.35	25.70	11.11
20	63.32	5.91	22.47	8.29
		S		
5	22.53	75.8	0.95	0.64
10	20.50	70.23	7.83	1.42
15	20.72	59.95	17.71	1.60
20	39.39	43.81	14.99	1.79
		IP		
5	0.31	0.62	94.63	4.42
10	1.62	1.84	92.78	3.74
15	15.52	4.79	76.62	3.04
20	28.46	5.18	63.49	2.84
		XRR		
5	50.37	12.99	18.86	17.76
10	41.74	14.45	26.15	17.64
15	39.40	15.06	28.56	16.96
20	37.48	14.73	28.85	18.92

TABLE XX

Decomposition of Variance - Ex Ante Real Rate

1970's

	Risk	Risk S	IP	XPR
5	69.22	20.60	6.29	3.87
10	63.48	18.23	7.58	10.70
15	64.79	16.67	7.82	10.69
20	62.32	16.25	8.59	12.82
		S		
5	65.54	26.97	3.75	3.72
10	63.12	23.04	4.45	9.37
15	64.25	21.47	4.39	9.85
20	63.06	21.21	4.25	11.46
		IP		
5	1.04	1.01	96.31	1.62
10	0.93	1.73	89.27	8.05
15	2.76	3.87	78.63	14.72
20	29.63	14.21	45.14	10.99
		XRR		
5	20.21	21.66	18.65	39.45
10	36.52	17.77	17.96	27.73
15	37.51	21.02	16.10	25.36
20	35.91	20.49	20.41	23.18

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