THE EFFECT OF INFLATION ON INTEREST RATES

by

Paul Wesley Calvert

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Paul Wesley Calvert

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ABSTRACT

This thesis addresses the effect of expected inflation on interest rates, and in so doing attempts to replicate the findings of John Makin. In order to obtain an unbiased estimate of the effect of expected inflation on interest rates, other variables, such as inflation uncertainty, Federal budget deficits, the state of the business cycle and Federal Reserve policy, were included in the model. The model is a reduced form, modified IS-LM macroeconomic model with a money sub-model to separate expected from unexpected monetary policy.

The regressions showed that a 1% change in expected inflation causes about a .915% change in short-term Treasury Bill yields; however, the results depend on the sample period and heteroscedasticity correction employed. The point estimate of .915 for the expected inflation coefficient is similar to what many researchers have estimated. The coefficients for inflation uncertainty, the Federal budget deficits, and the business cycle were not significant.

The attempt to replicate the results of John Makin was not successful. The R^2 and coefficients for expected inflation and inflation uncertainty were different; however, the coefficients for unexpected monetary policy and the intercept term were quite similar.

CHAPTER 1

INTRODUCTION AND REVIEW OF THEORETICAL LITERATURE

The recent high and volatile interest rates experienced in the U.S. have raised new questions about the causes of interest rate movements. Understanding how interest rates are determined is important to both the public and private sectors. It is important to the public sector so policy makers can better understand the expected costs, benefits, and effectiveness of various fiscal and monetary policies. Understanding of interest rate movements is also helpful to business planners, especially in capital intensive industries. The purpose of this paper is to contribute to the understanding of the effects of inflation and other variables on interest rates.

This paper is divided into five chapters. The first chapter contains the introduction and the review of theoretical literature, while the second chapter covers the empirical literature. Chapter 3 presents the model, with the estimation results and hypothesis testing shown in Chapter 4. The conclusion is in Chapter 5.

One of the earlier investigations of the determinants of interest rates was performed by Irving Fisher. Many of the theories developed in his book, The Theory of Interest, are still widely respected today and are used as a standard framework to compare more modern theories.

One interpretation of Fisher is that the rate of interest is the price of current goods compared to future goods. Anything that affects time preference or the future value of goods may have an effect on interest rates. Fisher went into great detail explaining factors which influence people to borrow or lend, but here his conclusions will only briefly be summarized.

The variables Fisher identified that affect how people decide to borrow or lend are the size, time-path, and risk of their incomes, and personal characteristics such as self-control, habit, etc. (Fisher, 1930, pp. 72, 73 and 77). The individual is assumed to construct the "maximum total desirability" (Fisher, 1930, p. 122) income stream by borrowing or lending. The person who has the smaller, faster increasing, less risky income stream is more likely to be a borrower; the person with the larger, decreasing, more risky income stream is more likely to be a lender.

Fisher acknowledged that there is another factor in the demand for loanable funds, for investment purposes, that affects the interest rate. "If, then, I am asked to which school I belong.., time preference or productivity--I answer 'to both'" (Fisher, 1930, p. 182). The market will equate personal time preference to the marginal return to capital; both are determinants of interest rates.

The interest rates discussed here have been real, as opposed to nominal rates. Fisher wrote that the figure "expressing the rate of interest in terms of money does depend upon the monetary standard employed" (Fisher, 1930, p. 36). If the value, in terms of goods, of the currency stays constant, then the real and nominal interest rates

will be the same. When the value of the currency is not stable, "the rate of interest takes the appreciation and depreciation into account to some extent, but only slightly and, in general, indirectly" (Fisher, 1930, p. 43). Thus, according to Fisher, inflation has a positive, but less than a one-for-one, effect on nominal interest rates. This also implies that inflation would have a negative effect on real rates. This relationship between inflation (p), real (r), and nominal rates (i), i=r+p, has become known as the Fisher equation and is the starting point for most researchers studying interest rates.

Much later Mundell (1963) and Tobin (1965) suggested another relationship between the real interest rate and the inflation rate. Tobin argued that an increase in inflation increases the real cost of holding money, encouraging households to hold a smaller share of their wealth in money and a larger share in real capital. This increased real investment pushes down the marginal product of capital until a new equilibrium, with a lower real rate, is reached.

Mundell's hypothesis was based on the fact that a rise in the rate of inflation more quickly reduces the real value of the share of the individuals' wealth held in cash. Individuals are then assumed to raise their rate of saving to obtain a new cash to tangible asset ratio. This increase in saving will increase the capital stock and reduce the real rate of interest. The Mundell-Tobin effect wouldn't have a large effect on interest rates since few people store their wealth in cash. In modern economies, cash is used as a short-term financial instrument rather than a store of value.

In 1975, Michael Darby extended the Fisher hypothesis to include taxes. The tax rules employed by Darby are a crude simplification of the U.S. tax code. He assumes proportional income taxes on nominal interest income at rate t, and allows interest payments to be deductible. The real after-tax costs and receipts (r*) of a loan are then $r^*=i(1-t)-p$. Under this tax system if p rises by one percentage point, the nominal interest rate must increase by $1/(1-t)$ percentage points to keep the after-tax real rate constant. The required nominal return must increase by more than the inflation rate because the inflation component of the interest rate is taxed.

The Darby article is notable because of its introduction of taxes into the analysis of the determinants of interest rates. One difference in Darby's paper as compared to Fisher's work is that Darby assumes the after tax real rate to be constant where Fisher reported finding a negative correlation between the real rate and the rate of inflation. The negative correlation between the real rate and inflation would reduce Darby's estimate of di/dp by $(\partial r/\partial p)/(1-t)$.

In 1976 and 1982, Gandolfi made improvements in the Darby hypothesis by including capital gains taxes and the elasticity of the supply and demand for loanable funds. Gandolfi's model assumes that the demand for loans is a decreasing function of the real after-tax cost of the loan, and that the supply of money for loans is an increasing function of the real after-tax return to savers [$r^*=(1-t)i-p$]. Business people will invest in new capital until the after-tax return, [$(1-t)r_b$], is equal to the after-tax real cost of debt financing, [$(1-t)i-(1-k)p$].

The term [(1-t)i-(1-k)p], or rearranged [i-ti-p+kp], is the nominal interest rate i, less the effect of lower taxes paid due to the interest deduction ti, less the rate at which the financed asset will appreciate in nominal terms p, plus the effect of capital gains taxes on the inflation induced nominal gains kp.

In equilibrium, savings will equal investment at the market clearing interest rate. To isolate the effect of a change in the inflation rate on the nominal interest rate, the total derivative of savings (S) with respect to inflation must be set equal to the total derivative of investment (I) with respect to inflation.

(A) $S(r^*) = I(r_b)$

$r^* = (1-t)i-p \quad (1-t)r_b = (1-t)i-(1-k)p$

$$\frac{dS}{dp} = \frac{dI}{dp}$$

$$\frac{\partial S}{\partial r^*}\frac{dr^*}{dp} = \frac{\partial I}{\partial r_b}\frac{dr_b}{dp}$$

$$\frac{dr^*}{dp} = (1-t)\frac{di}{dp} - 1 \qquad \frac{dr_b}{dp} = \frac{di}{dp} - \frac{1-k}{1-t}$$

$$\frac{\partial S}{\partial r^*}\left[(1-t)\frac{di}{dp} - 1\right] = \frac{\partial I}{\partial r_b}\left[\frac{di}{dp} - \left(\frac{1-k}{1-t}\right)\right]$$

$$\frac{di}{dp} = \frac{\frac{\partial S}{\partial r^*} - \frac{\partial I}{\partial r_b}\left(\frac{1-k}{1-t}\right)}{\frac{\partial S}{\partial r^*}(1-t) - \frac{\partial I}{\partial r_b}}$$

According to this equation, the true di/dp will be between (1-k)/(1-t) and 1/(1-t). If the capital gains tax is zero, and if the supply of savings is perfectly inelastic or elastic, then the Darby Effect [di/dp=1/(1-t)] will occur. The Darby Effect will also occur

if there is a perfectly inelastic or elastic demand for funds. The Fisher Effect (di/dp=1) will occur if the capital gains tax is equal to the income tax rate and zero.

A more complete investigation into the affect of inflation on interest rates was undertaken by Feldstein, Green, and Sheshinski (1983). They included in their analysis personal and corporate income taxes, personal capital gains taxes, the decision of firms to issue debt versus equity, the increasing cost of capital to individual firms, the depreciation laws that base depreciation expense on historic rather than economic replacement cost, and the market's demand for debt relative to capital. All of these variables have the potential to affect interest rates and will be covered briefly.

The firm's decision to issue debt or equity is important when tax laws are designed for an economy with little or no inflation. As inflation rises, the relative after-tax cost of different types of capital changes, and the firm will, subject to the substitutability of debt and equity in investors' portfolios, find the debt to equity ratio that minimizes the firm's cost of capital. Thus the effect of inflation and taxes on interest rates depends also on how inflation and taxes affect alternative investments and how investors substitute among them.

The depreciation laws are important to consider when studying the effect of inflation on interest rates. When depreciation is based on historic cost, and the value of the currency increases or decreases, the present value of the future deductions increases or decreases. In effect, the depreciation laws may subsidize or tax investment.

All of these effects were accounted for by the authors when they constructed their estimate for di/dp. As it turns out, if the firm finds it advantageous to change its debt to equity ratio, a very complex expression emerges. However, if the firm keeps its debt-equity ratio constant, the expression reduces greatly to (1-g)/(1-t), where t is the corporate tax rate and g is a cost, proportional to p, that is incurred if inflation reduces the real value of future tax deductions. The authors estimated that the term g is about .20 in the U.S. during the early 1980's, but would change as the depreciation laws are changed.

The effect of inflation on nominal interest rates is about 20 percent smaller with this analysis than that found by Gandolphi; however, they are not inconsistent. The analysis by Feldstein et al. was of a broader scope and would therefore be expected to produce a more complex, and hopefully more accurate, conclusion.

A General Equilibrium model was used by Levi and Makin (1978) to study the Fisher hypothesis. They claimed that "the Fisher equation ought to be viewed as a reduced-form relationship derivable from a simple general equilibrium model" (Levi and Makin, 1978). The macro-economic model they employed had commodity, money, and labor markets. The system of equations that represent these three markets are differentiated and expressed in elasticity form. The relationship $i=(r^*+p)/(1-t)$ of the real after-tax (r^*) rate, tax rate (t), and inflation rate (p) was substituted in for the interest rate. The effect of inflation on nominal interest rates is given by

$$\frac{di}{dp} = \frac{1}{(1-t) + \dfrac{E_{li}([1-Ewp] - Esm)}{(i/r^*)\ Enr^*([1-Ewp] + 1)}}$$

The term Eli is the elasticity of demand for money with respect to the interest rate and Ewp is the short run elasticity of wages with respect to prices. Ewp will normally be approximately 1, but in the short run may be somewhat smaller because of rigidities caused by labor contracting. The elasticity of saving with respect to money, Esm, is assumed to be close to 0 over a long period of time since changes in the nominal supply of money will not have a lasting real effect on people's behavior. Over a short time span this elasticity may be negative because as new money is put into the hands of individuals, they may feel wealthier and, at least temporarily, save less. The after-tax real interest rate is r*, and Enr* is the elasticity of investment with respect to the real after-tax interest rate.

For almost all values of Ewp the Darby [1/(1-t)] effect is an overstatement of di/dp. For (1-Ewp)=0, di/dp < 1/(1-t), for (1-Ewp)<0 $di/dp \lessgtr 1/(1-t)$ as $(1-Ewp) \gtreqless Esm$. The authors gave crude estimates for the parameters included in their estimate of di/dp and found this to range from .857 to over 1.33, a range which includes many of the empirical findings. The authors also noted that as people and institutions learn to contract for labor in a way to keep Ewp closer to 1, the response of interest rates to inflation will change over time.

The analytical approach in Levi and Makin's paper was first used by Robert Mundel, but was extended here to include the labor market and the tax aspects of Darby's paper. This model suggests some of the dynamics of interest rate movements not previously discussed in such detail. The

results of this model also suggest, since people don't instantaneously adjust to financial shocks, that empirical results might not fully support the theories of Fisher or Darby.

Summary of Theoretical Literature on the Effect of Inflation on Nominal Interest Rates

Fisher (1930) hypothesized that the nominal interest rate should take into account the appreciation or depreciation of the currency used to repay a loan, and reported finding a less than one-for-one change in the nominal interest rate for a change in the inflation rate. Darby (1975) incorporated taxes into the Fisher equation and showed that if the after-tax real rate were held constant, the nominal rate would vary $1/(1-t)$ times the inflation rate. Gandolphi (1976, 1982) pointed out that Darby's assumption of a constant real rate was really an unrealistic constraint of either an infinitely elastic or inelastic demand curve or a perfectly elastic or inelastic supply curve for loanable funds. In Gandolphi's analysis this constraint was relaxed and it was shown, with the inclusion of a capital gains tax, to produce an estimate of di/dp that could range from $(1-k)/(1-t)$ to $1/(1-t)$. Felstein et al. (1983) further broadened the scope of analysis to include corporate income taxes, the decision of firms to issue debt vs. equity, the increasing cost of debt to firms, depreciation laws, and the market's demand for debt relative to equity. One of the results of their analysis was an extremely complex equation to describe the effect of inflation on nominal interest rates. The assumption of a constant debt to equity ratio for firms greatly simplified the equation to $(1-g)/(1-t)$ where g is proportional to inflation and represents the cost associated with the

reduced value of future depreciation deductions. Finally, Levi and Makin (1978) pointed out that the empirical results of researchers wouldn't match the theoretical models since they were attempting to model a dynamic process with a static model.

Other Considerations in Modeling Interest Rate Determination

Other variables that affect real interest rates that have been used in empirical studies include government expenditures, government debt, inflation uncertainty, proxies to measure the demand for private investment demand, monetary policy, and supply shocks.

Government expenditures are occasionally included in reduced form IS-LM interest rate models because they are considered to be an exogenous determinant of income and therefore interest rates.

Government debt or deficits are used in some models because they may affect interest rates, possibly through several channels. One channel is that government debt increases the demand for loanable funds in the capital markets. In order to maintain equilibrium, the interest rate must be higher.

Another way that deficits could affect interest rates is that the Federal Reserve may react to political pressure against high interest rates caused by the deficit. The political pressure begins when the representatives of capital dependent industries lobby Washington for a reduction in interest rates. While politicians have no direct influence on rates, the Federal Reserve Board may not be totally politically insensitive. The Board may then increase, or be expected to increase,

the money supply to try to stabilize rising interest rates. The effects of monetary policy on interest rates is described below.

The variance of inflation forecasts has been included in some models as a proxy for inflation uncertainty. Researchers who have included this variable into their analysis suggest that greater possibility of higher inflation will cause suppliers of loanable funds to demand a higher return to compensate for the additional risk. Inflation risk is not easy to measure, so instead of using the market's true distribution of expected inflation, a proxy made of the distribution of inflation forecasts is usually used. The distribution of inflation forecasts from different forecasters is not the distribution of the market's expected inflation, but it does seem likely that the two would be correlated.

Occasionally some measure of economic activity is used, such as the difference between current and a past average of unemployment or GNP growth. One theory behind these variables is that as capacity becomes a constraining factor of production, business people will be more likely to borrow to finance more capacity. Another theory, but with opposite implications for interest rates, on why this type of variable should be included is that as GNP (income) rises above its long-term trend, people will save more, pushing interest rates lower, for when their income is lower.

Measures of the money supply have been used in most studies of interest rates. The reason for using it is if the money supply is changed the loan market will face a shift in supply, which may cause a change in the interest rate. The effect of monetary policy on interest

rates may depend not only on the actual policy, but on the expected policy also (Mishkin, 1982). If people base their actions on their expectations and their expectations prove incorrect, the resulting effect could be to change the real interest rate.

A proxy for aggregate supply shock is used in a model by Wilcox. His theory is that if a country experiences a change in the supply of an important import, such as oil, the marginal return to capital in general will be lower. The decrease in the marginal return to capital will discourage investment and thus cause a downward pressure on interest rates.

In conclusion, these theories together suggest that expected inflation (Fisher, 1930); taxes (Darby, 1975); the elasticity of supply and demand for funds (Gandolphi, 1976, 1982) and other variables (Feldstein et al., 1983); government deficits; inflation uncertainty (Makin, 1983); expected and actual monetary policy (Mishkin, 1982); and supply shocks (Wilcox, 1983) may be determinants of interest rates. The estimation of the effect of the variables on interest rates is difficult to measure because people don't immediately adjust to financial shocks (Levi and Makin, 1973) and their expectations aren't always correct (Mishkin, 1982).

CHAPTER 2

REVIEW OF EMPIRICAL LITERATURE

One of the early empirical studies on the effect of inflation on interest rates was done by Irving Fisher. In The Theory of Interest, Fisher made the distinction between real and nominal interest rates. Real interest rates were dependent upon many things including, according to him, institutional influences, laws, politics, banking practices, and government finance, all of which he thought were worthy of study but were not within the scope of one book. The empirical work in The Theory of Interest centered on the effects of inflation on interest rates. According to Fisher's findings, which were based mostly on data in the U.S. from 1870-1927, nominal interest rates are slightly responsive to current price changes, but very responsive to lagged price changes. The cumulative effect on interest rates to a 1% change inflation was about .8, or .9%, which indicates a change in the real rate of .1 or .2% in the opposite direction of the change in inflation. Fisher said,

> We have found evidence, general and specific, that price changes do, generally and perceptibly, affect the interest rate in the direction indicated by a priori theory. But since forethought is imperfect, the effects are smaller than the theory requires and lag behind price movements, in some periods, very greatly (Fisher, 1930).

Lawrence Summers extended the investigation of the effect of inflation on interest rates to the period 1860-1980. One of the methods used to test the Fisher hypothesis (meaning a one-for-one increase in

interest rates for inflation) was to average inflation rates over the period of a decade and compare that with the decade long average interest rate. According to Summers, "No clear relationship between inflation and nominal interest rates emerges" (Summers, 1982). For the period 1860-1940, he found no support for the Fisher effect. Regressions of 3-month Treasury Bill yields on inflation for the period 1948 to 1980 yielded different results. The inflation coefficient was always positive and significant, but ranged from .29 to .86, depending on which subperiod and sample frequency was used. The results rejected the hypothesis that di/dp=1 in 15 of 20 regressions.

In 1976, Thomas Cargill tried to estimate the effect of inflation on interest rates, but he emphasized the 50's and 60's. Cargill used two regression equations, i=a+bp, and i=a+bp+cX+dM, where i is the 3-month, 9-12 month, 3-5 year, or long-term government security, a is a constant, p is the Livingston survey average of expected inflation for 6 or 12 months into the future, and X and M are the percentage change in real GNP and real money supply, respectively.

The inflation coefficients from the first model for the 50's were .64 and .67, and marginally significantly different from 0 for the shorter maturities but not significantly different from 0 for the longer two maturities. For the 60's the inflation coefficients are always significantly different from 0, even at the 1% level, and their size ranged from .79 for the long-term rate to 1.18 for the 3-month rate. The second model produced coefficients for the inflation variable that are very small, .01 to .21, and not significant for the 50's, but much

larger, .80 to 1.08, and very significant for the 60's. Similar results have been found by Gibson.

There are two major criticisms of Cargill's regressions. The first is the exclusion in the first equation of independent variables other than expected inflation. Leaving important variables out of an estimated equation will probably give biased estimates of the remaining coefficients. The second problem is the use of the 12-month expected inflation series in the regressions of the longer term interest rates may have caused some problems in interpreting the results. Theoretically each expected cash receipt from the securities should be discounted by the expected price index at the time of payment to measure the effect of inflation on interest rates.

This leaves only the regressions of the second equation with the shorter-term maturities as least biased. These regressions show the interesting results of considerable difference between the effect of inflation on interest rates in the 50's and 60's.

Research was undertaken by Carlson in the 70's that included an estimation of the expected real interest rate. He subtracted the Livingston survey expected inflation rates from the return on 12-month Treasury Bills. The results from 1953 to 1975 showed that this estimate of the real rate varied from 0 to 4.5%. "The most notable declines in nominal interest rates occur in 1953-54, 1957-58, 1960, 1966-67, 1969-70, and 1974-75. All of these, with the possible exception of 1966-67, are associated with recessions" (Carlson, 1977). These results suggest that some measure of the performance of the economy should be used in

regressions on nominal interest rates to account for changes in the real rate.

Vito Tanzi (1980) believed that the real rate is variable and correlated with economic activity. Because of this, he included a variable to control for effects of the business cycle on the real rate when he did regressions with the nominal rate. The variable he used that would be correlated with the economy was the GNP gap, which is the difference between the logs of actual and potential GNP.

The introduction of this economic activity variable into the Fisher equation gave sharply higher $\bar{R}^2$ and the coefficients for the inflation variables sharply increased to close to 1. The estimates for expected inflation were the subsequently observed, distributed lag, adaptive, extrapolative, and a couple of less well-known types. The coefficients on the various expected inflation proxies and the GNP gap were all significant at the 1% level.

In conclusion, Tanzi said that since all the coefficients on the expected inflation proxies were significantly less than 1/(1-t) (estimated to be 1.47), individuals have been able to "see through the money veil,... however, they have failed to see through the fiscal veil and thus have suffered from fiscal illusion" (Tanzi, 1980).

One interpretation of this statement is that Tanzi thinks that as the inflation coefficient approaches one, the market must be adjusting the nominal rate upward as Fisher's theory would suggest, and when the coefficient exceeds one, the market is adjusting the nominal rate upward as Darby's theory would suggest. It should be noted that a coefficient

of less than one could still be consistent with the tax effect suggested by Darby.

John Makin developed a model to explain 3-month Treasury Bill rates using a regression equation which includes variables for expected inflation, surprise money growth, inflation uncertainty, and fiscal deficits. The expected inflation proxy came from the Livingston survey data, as did the inflation uncertainty variable. Surprise money growth was defined to be the residuals from an ARMA (0,8) model of M1 growth.

After estimation of the regression parameters, it was found that the error structure was not well represented by an ARMA (1,0). Estimation of a transfer function showed that an ARMA (1,1) model was needed to leave white noise residuals.

The regression results show the coefficient for inflation to be highly significant and slightly greater than unity, the coefficient for surprise money growth was very significant and negative, the coefficient for inflation uncertainty was negative and occasionally significant depending on the subperiod estimated, and lastly the coefficient for the deficit was very small and not significant. The author argues that the procyclical movement of interest rates, together with the countercyclical cyclical movement of fiscal deficits, will lead to a downwardly biased coefficient for the deficit. He further suggests that exports may be used to measure the shocks on aggregate demand to interest rates. The effect of exports on interest rates is larger than that of deficits, but is still not significant.

Some of the main contributions of the Makin article are the use of the residuals from a money model for the money supply variable, the

search for the actual error process rather than assume random or AR-1 errors, and the inclusion of variables for inflationary risk and fiscal deficits. These and other ideas are incorporated in a model in this paper that will be estimated and presented in later chapters.

A different approach was taken by Mishkin to determine what influences real interest rates. He regressed the expost real rate of 3-month Treasury Bills on real GNP growth, GNP gap, unemployment, expost inflation, the investment to capital ratio, and various measures of money supply growth. The null hypotheses that the coefficients for the GNP growth, the GNP gap, the unemployment rate, and the investment to capital ratio were all equal to zero were not rejected. The only significant variables were the inflation rate and the money growth rates, and the money variable became insignificant when lagged inflation was included in the regression. The author does point out that the real variables may actually be correlated with the real rate, but that the statistical tests he used were not powerful enough.

These results of Mishkin's on the significance of economic activity variables are in contrast to the results reported by Tanzi. Perhaps part of the difference is the use of expost real rates as the dependent variable in Mishkin's regressions.

A model introducing supply shocks was designed by Wilcox in 1983. The supply shock variable is defined as the deviation from the 1952-79 mean of a ratio of the implicit price deflator for imports to the GNP deflator. The idea behind the supply variable was that a change in the price of an important import, like oil, could change the returns to capital and therefore cause changes in the interest rate.

Other variables were included to control for changes in the money supply, expected inflation and exogenous demand. This last variable was defined as the deviations from the 1952-79 mean of the sum of real federal government defense expenditures and real exports, normalized by natural real output.

The supply variable was significant, and its inclusion keeps the relationship between inflation and interest rates stable during the 50's and 60's. Earlier, Cargill reported the different reltionship between inflation and interest rates during the 50's and the 60's, but he didn't include any variables to account for the effect of the world economy on U.S. interest rates. As the U.S. economy continues to grow slower than the world economy, and therefore becomes relatively smaller, it seems reasonable that international markets will continue to have a greater effect on U.S. interest rates.

Robert Ayanian (1983) used the tax-free status of municipal bonds to test the theory that interest rates should vary at rate 1/(1-t) times the change in the rate of inflation. Ayanian noted that one problem previous researchers had in trying to prove this theory was the difficulty in observing the expected real interest or inflation rate. Both of these together should be observable as the nominal return on municipal bonds, he argued.

For the period 1952-79, taxable bond yields were regressed on tax-free municipals. The resulting coefficients imply a 1% change in the tax-exempt yields would result in a 1.63% change in taxable yields, indicating a marginal tax bracket of 38.7% -- proof, the author says, of the Darby effect.

The regression reported by Ayanian is interesting but does not necessarily prove the Darby effect. This regression does suggest that people respond to after-tax rates but the Darby hypothesis held that the derivative of (r+p)/(1-t) with respect to p is (0+1)/(1-t).

Joe Peek (1982) claimed that "the common conclusion that the empirical evidence did not support the tax-adjusted Fisher hypothesis was due to the use of an inappropriate null hypothesis." Peek then proposed several new ways to test the hypothesis that taxes are important in the determinance of interest rates.

Four models are used in Peek's testing:

(A) $i_t = a/(1-tax)+b(M'_t-P'_t)+cG'_t+dZ'_t+eP'_t$

(B) $i_t = a+b(M_t-P_t)+cG_t+dZ_t+eP_t$

(C) i_t = model (A) plus extra term $qFIT(B_t)$

(D) i_t = model (B) plus extra term $qFIT(A_t)$

Where i_t is the 6- or 12-month Treasury Bill yield, tax is the average marginal tax rate, M_t is the log of the money supply less the log of real output, G_t is the log of real government expenditures less the log of natural real output, Z_t is the percentage change in output the preceding time period, and P_t is the expected inflation rate from either the Livingston survey, an extrapolative or a rational expectations model of expected inflation. The ' marks in model A means that variable was transformed by dividing by (1-tax).

The first test is to see which model, (A) or (B), has the lower sum of squared residuals. In all six models (2 interest rates by 3 inflation proxies), the SSR was smaller for the tax-adjusted model. As a second test, the regression equations were estimated for the 1959-76

period and used to forecast rates for the 1976-79 period. The root mean squared errors were smaller in all instances in the tax-adjusted models.

As a last test, regressions (C) and (D) were estimated, where $FIT(A_t)$ and $FIT(B_t)$ are the predicted rates from models (A) and (B), respectively. Model (D) is used to test the null hypothesis that taxes are important and model (C) is used to test the null hypothesis that taxes aren't important. If the FIT coefficient is significant, then the null hypothesis will be rejected.

The results of this last test were that the null hypothesis that the tax-adjusted equation is the true model is rejected in only one of six instances. The author says that the one rejection is because of multicollinearity problems and not because the non-tax adjusted model was better.

The null hypothesis that the non-tax adjusted model was better was rejected at the 10% level of confidence in four of the six tries. The author concludes that these tests provide very strong evidence that taxes are important in the analysis of interest rates.

The empirical results of the papers covered here suggest estimates of the response of interest rates to inflation depend on the sample period, the maturity of the security, and the variables used to control for changes in the real interest rate. The various measures of the money supply and supply stocks have generally been found to be significant while the federal budget deficit and inflation uncertainty have not. Different measures of the level of economic activity, such as the GNP gap, are found to be significant in some models but not in others.

Taxes appear to be significant but the Darby effect [di/dp = 1/(1-t)] seems to be an overstatement.

Due to the varied results of models that include variables of control for changes in the real rate, it is suggested that a complete study should test as many of them as possible.

CHAPTER 3

PROPOSED MODEL

The method of this study is three-fold. First, attempt to replicate the basic findings of Makin in his August 1983 article in The Review of Economics and Statistics; second, to make minor modifications to his model; and finally, to re-estimate his equations with newly available data.

A modification of the IS-LM model will be combined with a tax adjusted Fisher equation, much like that used by Makin (1983), to produce a reduced form equation of nominal rates. This specification recognizes inflation, federal budget deficits, the GNP gap, inflation uncertainty, the elasticity of supply and demand for funds, and monetary policy as possible determinants of interest rates as suggested by various authors in the literature review. Numerical estimates of the effect of some of the variables such as taxes cannot be explicitly derived from the equation that will be estimated but are noted as being implicit in the coefficients that are estimated.

The modifications to the standard IS-LM model are the inclusion of inflation risk, life-cycle saving, and monetary shock variables.

The inflation risk variables, defined as the standard deviation of expected inflation as reported by Livingston, are included in both the investment and savings equations to serve as proxies for risk associated

with contracting in nominal rates. Increased risk would result in a shift to the left in both the supply and demand schedules for loans.

A life-cycle savings variable is added to account for the effects on savings of perceived temporary changes in income. Theory suggests that as income temporarily increases (decreases), above (below) its long term trend, savings will increase (decrease) so as to remain close to a long term, utility maximizing consumption stream.

The monetary shock variable is included because interest rates may be temporarily affected until the markets adjust to the new quantity of money. Another monetary policy variable, Money Expected, is included in some regressions to highlight the different effects of expected versus unexpected monetary policy as proposed by Mishkin in the theoretical literature review.

The structure of the model is as follows: The IS curve is constructed by setting the log of real autonomous spending,

$$A_t = A_0 - A_1 r_t - A_2 \text{var}(P_t) + A_3 X_t + e_{1t}, (A_1, A_2, A_3 > 0)$$

equal to the log of the sum of taxes and real saving.

$$S_t = S_0 + S_1 Y_t - S_2 \text{var}(P_t) + S_3 (Y_t - Y_{pt}) + e_{2t}, (S_1, S_2, S_3 > 0)$$

where:

A_t = log of real autonomous spending

S_t = log of real total non-expenditure

r_t = after-tax real interest rate

$\text{var}(P_t)$ = inflation uncertainty, measured as the standard deviation of inflation forecasts

X_t = a measure of real exogenous expenditure

e_t = normally distributed error term with mean = 0

Y_t = log of real income

Y_{pt} = log of expected permanent real income

P_t = expected inflation

The LM curve is

$$M_t = M_0+M_1Y_t-M_2P_t-M_3r_t+e_{3t}$$

where:

M_t = log of actual money supply

M_t^e = log of expected money supply

M_t^s = money surprise, or $(M_t - M_t^e)$

is solved for Y_t and substituted into the IS curve. Solving this new expression for r gives the reduced form equation for after-tax real interest rates.

The Fisher equation

$$i_t = [r_t+P_t(1-T')]/(1-T)$$

where:

T = marginal tax rate on interest income

T' = marginal tax rate on returns from real assets

is used to relate the after-tax real rate to the nominal interest rate. The resulting equation reduces to

$$i_t = V_0+V_1P_t+V_2(M_t^s+M_t^e)+V_3\text{var}(P_t)+V_4X_t+V_5(Y_t-Y_{pt})+V_6e_t$$

where:

All V_i's have the same common denominator D

$D = (1-T)A_1[1-(S_1M_1/M_3A_1)]$

$V_0 = (A_0-S_0+M_0S_1/M_3)/D$

$V_1 = -M_2S_1/DM_3+(1-T')/(1-T)$

$$V_2 = -S_1/M_3D$$

$$V_3 = (S_2-A_2)/D$$

$$V_4 = A_3/D$$

$$V_5 = -S_3/D$$

$$V_6 = [(e_{1t}-e_{2t})+(S_1e_{3t}/M_3)]/D$$

The size, or even the sign, of V_1 is indeterminant since both a positive and a negative coefficient enter into its definition. The first term of the expression is negative because as inflation rises, holding other things constant, people will want to hold less cash. The second part of the expression indicates that the degree to which inflation affects interest rates is partly dependent on how real and financial assets are taxed.

The sign on the unexpected money variable should be negative. As the money supply is increased beyond what is expected, the interest rate should fall because of the greater quantity of money available. In the regressions either the money surprise or the money surprise and money expected variables were included. The size of the coefficient for money expected is not anticipated to be significantly different from 0. The definition of money surprise was decided to be the residuals from an ARMA model of M_1 growth that left white noise residuals. An ARMA (5,0) model met this requirement.

The coefficient V_3 could be negative or positive. Increased inflation risk would induce borrowers to borrow less and/or demand a lower interest rate. Lenders, on the other side of the market, would want a higher interest rate and/or to lend less to compensate them for

greater inflation risk. The net effect on interest rates of increased inflation risk is not determinable by these theories.

The effect of an increase in exogenous expenditures on interest rates is positive. Trying to find a truly exogenous expenditure series is difficult. Net exports are used in some models, but net exports are dependent on the value of the dollar, which is somewhat dependent on interest rates. Thus, it appears that net exports are to some extent endogenous. In this study, the cyclically adjusted budget deficit as a percent of trend GNP is used as a measure of exogenous expenditures.

However, the effect of deficits on interest rates is controversial. Barro (1974) used the bequest motive for explaining how the Ricardian Equivalence Theorem operates. This theory suggests that if current taxes are cut and government spending stays constant, then the current generation will save the tax cut so they can leave it to their offspring to pay the future taxes required to repay the bond holders. This theory, which suggests that government deficits won't affect interest rates, is in contrast to the traditional Keynesian position that government deficits raise interest rates.

The expected sign on the coefficient for the GNP gap, that is the difference of the logs of current and expected GNP, is uncertain. As income rises above what is assumed to be a permanent level of income, people are presumed to save more to offset years when income is below what they had expected. The increased saving should have a depressive effect on the interest rate. On the other hand, when income is above its trendline, manufacturing plants would probably be nearing capacity. As plants approach capacity, the owners may be likely to borrow more

money to finance construction, which would exert a positive influence on interest rates.

The common denominator of all the V_i's, D, contains the tax term T, which unfortunately isn't constant over the sample period. The denominator D, along with more tax trends in variable V_i, makes estimation of this model virtually impossible. The estimation procedure described later does not address this problem. In effect, the simplifying assumption of a constant tax rate is implicitly made.

CHAPTER 4

MODEL ESTIMATION

The model developed in the previous section is estimated for three different time periods with the results shown in Tables 1, 2 and 3. Table 1 shows the results from the 1955-I to 1984-IV sample period, Table 2 shows the results from the 1968-I to 1984-IV period, and Table 3 shows the results of the 1959-II to 1981-IV period. The objective in choosing the first sample period was to obtain a large sample, but not to the extreme of including data points when the Federal Reserve Board pegged the Treasury Bill rates. The second sample was chosen because 1968 is about the time when inflation became high and highly variable. The 1968 to 1984 period witnessed the increase and then the decrease of inflation. The mid-1980's is the first time in years that researchers could get data without strong trends in many of the variables. The third sample period is the same as Makin's in his article, "Real Interest, Money Surprises, Anticipated Inflation and Fiscal Deficits," and is used in an attempt to duplicate his findings.

The size and sign of the expected inflation coefficient for the first sample is similar to the results of other researchers such as Fisher, Cargill, Gibson, and Tanzi. The coefficient estimate of about .9 indicates that historically a 1% change in expected inflation has caused a .9% change in the 3-month Treasury Bill rate.

Table 1. Estimated coefficients and t-ratios for 1955-I to 1984-IV.

Variable Names*								
Constant	Expected[d] Inflation	Unexpected Money	Inflation Uncertainty	Federal Deficit	GNP Gap	Expected Money	AR-1	R^2
2.41[c]	.915[c]	-.053[c]	.014				.874	.79
(4.98)	(6.27)(.59)	(3.08)	(.04)				(18.79)	
2.41[c]	.915[c]	-.052[c]	.014	-.004			.874	.79
(4.95)	(6.23)(.58)	(3.06)	(.05)	(.05)			(18.66)	
2.36[c]	.895[c]	-.050[c]	.087		.049		.872	.80
(4.94)	(6.19)(.72)	(2.95)	(.28)		(1.49)		(18.59)	
2.52[c]	.918[c]	-.062[c]	.005			-.026	.878	.79
(4.96)	(6.14)(.55)	(3.01)	(.02)			(.82)	(18.93)	
2.34[c]	.898[c]	-.050[c]	.082	.015	.049		.868	.80
(4.96)	(6.26)(.71)	(2.93)	(.26)	(.17)	(1.50)		(18.18)	

[a]Significant at .05 level.

[b]Significant at .01 level.

[c]Significant at .005 level.

[d]The first t-ratio is for null hypothesis di/dp=0, the second t-ratio is for the null hypothesis di/dp=1.

*See Appendix for estimation details and data sources.

Table 2. Estimated coefficients and t-ratios for 1968-I to 1984-IV.

Variable Names*								
Constant	Expected Inflation	Unexpected Money	Inflation Uncertainty	Federal Deficit	GNP Gap	Expected Money	AR-1	R^2
3.25[c]	.544[a]	-.081[a]	.840				.881	.80
(2.67)	(2.02)	(2.08)	(1.33)				(13.86)	
3.74[c]	.515[a]	-.083[a]	.878	-.217			.903	.80
(3.25)	(1.83)	(2.15)	(1.41)	(1.34)			(14.93)	
2.54[a]	.555[a]	-.072[a]	1.080[a]		.185[a]		.891	.81
(2.10)	(2.06)	(1.89)	(1.72)		(1.67)		(14.14)	
2.73[a]	.568[a]	-.059	.812			.082	.881	.80
(2.09)	(2.09)	(1.34)	(1.28)			(1.04)	(13.49)	
2.98[a]	.517[a]	-.075[a]	1.082[a]	-.188	.164		.911	.81
(2.37)	(1.83)	(1.96)	(1.73)	(1.16)	(1.48)		(15.08)	

[a]Significant at .05 level.

[b]Significant at .01 level.

[c]Significant at .005 level.

*See Appendix for estimation details and data sources.

Table 3. Estimated coefficients and t-ratios for 1959-II to 1981-IV.

Variable Names*								
Constant	Expected Inflation	Unexpected Money	Inflation Uncertainty	Federal Deficit	GNP Gap	Expected Money	AR-1	R^2
2.15[c]	.669[c]	-.036[a]	.840[a]				.84	.75
(4.17)	(4.09)	(1.97)	(1.70)				(13.21)	
2.15[c]	.670[c]	-.036[a]	.845[a]	-.012			.84	.75
(4.17)	(4.08)	(1.96)	(1.68)	(.12)			(13.06)	
2.09[c]	.670[c]	-.035[a]	.869[a]		-.031		.83	.75
(4.23)	(4.21)	(1.90)	(1.75)		(.92)		(12.51)	
2.23[c]	.677[c]	-.045[a]	.829[a]			-.024	.843	.75
(4.19)	(4.09)	(2.00)	(1.67)			(.70)	(13.11)	
2.10[c]	.671[c]	-.055[a]	.871[a]	-.0079	-.031		.83	.75
(4.22)	(4.21)	(1.89)	(1.73)	(.08)	(.91)		(12.35)	
Makin Results:								
2.06[c]	1.150[c]	-.038[c]	-.217				.845	.98
(15.80)	(5.22)	(4.46)	(1.37)				(19.1)	
2.24[c]	1.058[c]	-.024[c]	-.278[a]				ARMA (1,1)	.99
(17.20)	(7.33)	(3.59)	(1.81)					
2.19[c]	1.067[c]	-.024[c]	-.251[d]	.001[e]				
(15.57)	(7.25)	(3.61)	(1.60)	(1.10)				

[a]Significant at .05 level.

[b]Significant at .01 level.

[c]Significant at .005 level.

[d]Makin used the variance of inflation forecasts where this paper used the standard deviation.

[e]Makin used deficits measured as positive numbers in billions of dollars at seasonally adjusted annual rates. This paper uses cyclically adjusted deficits as a percent of trend GNP.

*See Appendix for estimation details and data sources.

The coefficient for inflation uncertainty is never significant for this sample.

The size of the expected inflation coefficient for the second sample is smaller than other researchers, such as Makin, have found and the coefficient for inflation uncertainty is much larger. These estimates suggest that a 1% change in inflationary expectations causes about a .5% change in Treasury Bill rates, and that a one standard deviation increase in the inflation forecasts causes about a .9% change in Treasury Bill rates. The point estimates of these coefficients are not accurate because of multicollinearity problems. Since inflation and inflation uncertainty are highly correlated, it is not possible, using these estimation methods, to accurately estimate their individual influences on the interest rate.

Estimated coefficients for the expected inflation variable in the third sample are smaller, but still significant, than in the first sample and are considerably different than those reported by Makin shown at the bottom of the page. The different heteroscedasticity corrections may account for part of this difference. All of the data in the Makin regressions were divided by expected inflation where the data in this paper were divided by the square root of expected inflation as described in detail in the appendix.

The coefficient for inflation uncertainty is of different signs in this paper versus the estimates of Makin. The coefficient in this paper is marginally significant at the .05 level with a one-tail t-test and is marginally significant in the Makin paper only when the regression is estimated as a transfer function with an ARMA (1,1) model of residuals.

In the sample in this study, multicollinearity problems were experienced which may have led to inaccurate estimates of expected inflation and inflation uncertainty.

Estimation of the coefficient for money surprise produced a coefficient that is of expected sign for all samples. The size of the coefficient is 60% larger in the second sample, but is not as significant. The second sample coefficient of -.08 means that as the money supply changes at an annual rate that is 1% different than what was expected, the Treasury Bill rate has changed in the opposite direction by .08%. The same coefficient in the third sample is considerably smaller but very similar to that published by Makin, even though he used an ARMA (0,8) model for money where, in the current paper, an ARMA (5,0) model was used.

A variable described as the expected monetary policy and defined to be the forecast of the money model was included in both samples to test the hypothesis that only unexpected government policy will have real effects on the economy. In no model specification was the coefficient significant.

The coefficient for the federal budget deficit is small in the first and third samples, large in the second, and significant in none. The size and sign of the variable are interesting in the second sample, but its significance is rejected even at the 10% level. The significance of this variable is not much different, although of a different sign, than that found by Makin.

The GNP gap data used in the model is the result of the first stage regression described in detail in the Appendix. The variable is

marginally significant at the 5-6% level and about three times as large in the second sample. The coefficient in the first sample indicates that if the GNP has been 1% below trend, the interest rate has been about 5/100% lower than otherwise. The coefficient for the same variable for the second sample indicates that when the GNP has been 1% below trend, the interest rate has been about 17/100% lower.

The constant for the regressions varies between 2.06 and 3.74, depending upon model specification and is always significantly positive. Using the results of the first regression of the first sample, the equation for the real rate is 2.41 + .915p-p, or 2.41-.085p. It is apparent from this equation that the real rate is negatively correlated with inflation and will, if projected beyond the range of the data it was estimated from, approach 0 as the inflation rate rises above 28%.

CHAPTER 5

CONCLUSION

The results of this thesis are that unexpected monetary policy and expected inflation are significant determinants of interest rates, while the federal budget deficit, expected monetary policy, and inflationary uncertainty are not significant, at least as specified in this paper. The results are mixed with respect to replicating Makin's results. The constant and the coefficient for unexpected money are similar to Makin's, but the coefficients for expected inflation and inflation uncertainty and the R^2 are considerably different. It was found that the magnitude of the estimated coefficients vary considerably with sample period, estimation procedure and the heteroscedasticity correction employed.

Table 4 shows the Table 1, equation 1 estimates compared to estimates of other researchers.

There are many areas for improvement in future work of this type, such as inclusion of taxes and depreciation laws, a better money model, the development of a dynamic macroeconomic model, and the recognition of foreign markets.

It may be constructive to explicitly include taxes and/or depreciation laws into the model since they change over time and may affect the way interest rates respond to inflation.

Table 4. Comparison of coefficients to those of other researchers.

Researcher Name	di/dp	dr/dp (di/dp-1)
Mundell, Tobin	>0	<0
Darby	1.35[a]	.35
Gandolphi	1.22 to 1.35[a,b]	.22 to .35[a,b]
Feldstein et al.	1.08[a]	.08[a]
Levi, Makin	.857 to 1.33	-.143 to .33
Fisher	.8 to .9	-.2 to -.1
Summers	.29 to .86	-.71 to -.14
Cargill	.01 to 1.08	-.99 to .08
Tanzi	.782 to .879	-.218 to -.121
Makin	1.06	.06
Wilcox	.987	-.013
Calvert	.915	-.085

[a]Using marginal tax of 25%
[b]Using marginal capital gains tax of 10%

The money model could be improved by including variables other than historic money growth. Some of the variables that could be included are the GNP gap, the value of the dollar, and a proxy to control for perceived risk in the banking system.

There may be other Federal Reserve actions that may affect interest rates other than the growth of money. Changing the time between Federal Open Market Committee meetings and the publication of these minutes, publishing targets for money growth, statements concerning future policy and other policies may be important information not explicitly included in this simple money model.

One of the problems of the Keynesian macroeconomic model this paper is based on is its exclusion of foreign financial markets. The combination of foreign exchange rates, interest rates and other factors could influence international flows of funds which could affect the U.S.

economy and financial markets. These international variables could become more important in the future as the U.S. share of world output decreases.

Continued research in this area would be interesting and potentially useful for government policy makers.

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APPENDIX

DATA AND ESTIMATION TECHNIQUE

The data series for expected inflation came from the Livingston survey. Joseph Livingston, a financial reporter, collects economic variable forecasts from many prominent economists with diverse backgrounds as part of a continuing survey.

The sampling frequency used in this paper is three months, so the semiannual six-month forecasts collected by Livingston were linearly interpolated for the second and fourth quarters. The expected inflation rate for the first quarter is assumed to be equal to the six-month forecast made in December. The second quarter expected inflation rate used was then the linear interpolation of the previous December and future June forecasts. This interpolation procedure, along with the facts that the original forecasts were made for six months rather than three, and that the inflationary expectations of this select group of economists may not be the same as those of most market participants, will introduce random errors in measurement which will bias the inflation coefficient towards zero. The use of 6-month Treasury Bills would have eliminated some of these problems, but that series doesn't begin until 1959.

The proxy used for inflation uncertainty also came from the Livingston survey. The variability measure used was the standard deviation of the inflation forecasts. The variance of the forecasts was also tried, but the results were insignificantly different. This

variability measure is interpolated just as the inflation variable is, and is therefore also biased towards zero because of random errors of measurement.

The money surprise variable is defined to be the residuals from an AR-5 model of M1 growth. This is the simplest model yielding white noise residuals, although the interest rate model is fairly insensitive to other definitions such as MA-6 and MA-8.

The other monetary variable, money expected, is defined as the forecast from the AR-5 model of money growth. The coefficients of the AR-5 model were estimated from the 1955-I to 1984-IV period. Ideally, only the data available at a particular point in time should be used in defining expectations, but in the interest of economy, it is assumed that expectations of future money growth at any time were similar to those estimated over the entire sample period.

The deficit variable is calculated as the cyclically adjusted federal budget deficit as a percent of trend GNP, as calculated by the Department of Commerce and reported in the "Survey of Current Business." Several measures of federal financing were considered to be used in the model, such as the change in the real debt and the change in the market value of the real debt. The change in the market value of the real debt is very dependent on the interest rate and therefore endogenous. It was decided that the cyclically adjusted federal budget deficit as a percentage of trend GNP would be as interesting a variable as the others.

Estimation

The interest rate used in the model is a three-month average of the three months' averages of new 91-day Treasury Bill yields at issue (U.S. Department of Commerce, 1959, 1961, 1963, 1984).

Two-Stage Least Squares is used to introduce a variable to serve as a proxy for the business cycle. The first stage is the regression of nominal GNP gap as a percent of trend GNP on all the other independent variables and the lagged dependent variable. The GNP gap and trend GNP are from the "Survey of Current Business" (Deleeuw and Holloway, 1983).

The first attempt at estimating the model, using OLS, resulted in heteroscedastic errors. The Park-Glejser test was performed to test the null hypothesis of no heteroscedasticity. The t-ratio of the beta coefficient is significant at greater than .001 probability, so the null hypothesis is rejected. This error problem is thought to originate from the inflation variable since the variance of the errors is correlated with the level of expected inflation. The reciprocal of several different powers of the expected inflation rate were multiplied by the raw data in an attempt to alleviate the problem. The square root of the expected inflation rate was finally chosen because it produced residuals with fairly constant variance.

For the years where the expected inflation rate is less than one percent, the heteroscedasticity correction was not applied, since dividing by a very small number would produce outliers which would be mistakenly given too great a weight in the regression.

The model was again estimated, using the data transformation noted above, using OLS to examine the errors again. The errors were autoregressive with the estimated ρ of .83 with a t-ratio of 16.22. The mean squared error was very significantly less ($F_{1,119}=249.41$) than that of the OLS residuals. The AR-1 model of the OLS residuals was tested against ARMA (2,0), (1,1), (1,2), and (2,2) models, with results of $F_{1,118}=2.80$, $F_{1,118}=1.55$, $F_{2,117}=1.75$, and $F_{3,116}=1.19$, respectively.

The coefficients of the autoregressive corrected model were similar to those of the OLS except for the money surprise variable in Table 1. The value of this variable increased from -.12 to -.05 and the t-ratio rose from 2.82 to 3.08.