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A COMPARATIVE ANALYSIS OF EXPECTED INFLATION ESTIMATES AND THE RESULTING IMPLICATIONS FOR FINANCIAL ASSET RETURNS

By

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ABSTRACT

A COMPARATIVE ANALYSIS OF EXPECTED INFLATION ESTIMATES AND THE RESULTING IMPLICATIONS FOR FINANCIAL ASSET RETURNS

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The purpose of this study is to re-examine the relationship between nominal asset returns and inflation. Since previous empirical findings may be a function of the proxy employed for expected inflation, this study provides a comprehensive analysis of several alternative proxies for expected inflation. In addition, this analysis encompasses the post-1971 period of high and volatile inflation. Furthermore, this study examines the relationship between inflation and the returns on some previously unstudied asset categories.

The empirical findings of this analysis indicate that none of the inflation proxies fully satisfies rationality. Of the proxies considered, the Survey Research Center measure has the smallest dispersion of forecast errors.

The findings of this study indicate that financial assets are poor hedges against expected inflation, which is contrary to the Generalized Fisher Hypothesis. The

results also indicate that the returns on both debt and equity securities are negatively related to unexpected inflation and the changes in inflationary expectations. Although the results are generally consistent for different inflation proxies, the magnitude of the relationship is, in some cases, dependent on the inflation measure that is employed.

This analysis also finds that the Geske-Roll reversed causality model holds for long-term debt securities and "small" stocks as well as for common stocks. Furthermore, this study provides an alternative test of the Darby-Feldstein Hypothesis by comparing the coefficient for expected inflation for non-taxable and taxable debt instruments. Although the results do not support the model in the short-run, the long-run results are consistent with the Darby-Feldstein Hypothesis.

CHAPTER ONE

INTRODUCTION

In the past decade, the United States has experienced high and volatile rates of inflation. With the variability in the general price level has come an appreciation of the importance of inflationary expectations in nominal interest rate determination and an increased interest in the relationship between inflation and the returns on various financial assets.

The Generalized Fisher Hypothesis expresses the nominal return on a financial asset as the sum of the expected real return on the asset and the expected inflation rate over the life of the instrument. Although asset payoffs are in nominal terms, rational investors are concerned with the real value of their wealth measured in terms of final goods and services. Therefore, investors should seek investments that are efficient in real terms.

The seminal study of the association between inflation and financial asset returns was undertaken by Fama and Schwert (1977). Fama and Schwert's analysis, which encompassed the 1953-1971 period, utilized the nominal Treasury Bill rate minus a constant for the real interest rate as an estimate of the expected inflation rate. The years 1953-1971 are unique in American history for their record of price stability. Subsequent studies, such as Hess and Bicksler, have indicated that the expected real return is not constant during periods of high inflation. Consequently, Fama and Schwert's methodology utilizing short-term interest rates as predictors of inflation may not be accurate in periods of rapid inflation. In turn, this leads to the possibility that Fama and Schwert's findings were period dependent and not representative of the post-1971 period.

In another comprehensive study, Huizinga and Mishkin (1984) analyzed the monthly data from 1959 to 1981 on the real returns for seven financial assets. They found that the ex-ante real rates on all seven assets were negatively correlated with actual inflation rates, and longer maturity assets were the worst inflation hedges. However, Huizinga and Mishkin's study utilized actual ex-post data for inflation. The relationship between asset returns and inflation is more properly investigated using expectations data.

This thesis re-examines the relationship between the returns on alternative asset categories and inflation. Since Gultekin (1983) suggested that the asset return-inflation relationship was dependent on the proxy used to measure inflation, it is instructive to consider other inflation proxies than those employed by Fama and Schwert and Huizinga and Mishkin. This thesis provides a comprehensive analysis of several alternative measures of expected inflation which have been identified in the literature. This should provide insight regarding the consistency of results for different inflation proxies.

This dissertation also employs a single comprehensive period, 1959-1983, which encompasses periods of both relatively high and low inflation. This will provide evidence as to whether Fama and Schwert's findings were period dependent. In addition, this study investigates the relationship between inflation and the returns for previously unstudied asset categories.

Chapter Two traces the historical development of the relationship between nominal interest rates and expected inflation and cites some associated empirical studies. In addition to the Fisher Effect, three alternative models of nominal interest rate determination are considered--the Mundell-Tobin Effect, the Darby-Feldstein Effect, and the Inverted Fisher Effect. The Mundell-Tobin Effect argues that the relationship between nominal interest rates and inflation is less than unity as a result of a decline in the real interest rate. On the other hand, the Darby-Feldstein Effect contends that the taxation of interest income (and/or tax deductibility of interest payments) implies a more than complete adjustment of nominal interest rates to anticipated inflation. The Inverted Fisher Effect suggests that nominal interest rates are constant and that real interest rates move inversely with the expected inflation rate.

Chapter Three reviews several alternative measures of expected inflation which have been utilized in previous empirical work. These include:

1. distributed lag model
2. extrapolative model
3. adaptive model
4. monetary information model
5. Livingston survey data
6 Survey Research Center data
7. nominal T-Bill rate model
8. time series (ARIMA) model

The distributed lag model argues that price expectations are formed autoregressively. The extrapolative model expresses the expected inflation rate as a linear combination of last period's actual inflation rate and a term reflecting the change in the actual inflation rate. The adaptive model expresses the expected inflation rate as a linear combination of the previous period's expected inflation rate and the previous period's actual inflation rate. The monetary information model hypothesizes that inflationary expectations reflects past rates of change in the money supply in addition to past rates of inflation. The Livingston survey data represent the consensus inflation forecasts of academic and professional economists. The Survey Research Center data are an alternative price expectations series which represent the inflation forecasts of consumers. The T-Bill rate model contends that the nominal T-Bill rate minus a constant reflecting the real interest rate is the best predictor of future inflation. The ARIMA model uses Box-Jenkins univariate time series techniques to construct a model to forecast the expected inflation rate.

Chapter Four considers the forecasting accuracy of the alternative inflation proxies. Each measure is statistically evaluated in terms of Muthian rationality which holds that expectations about future inflation are formed in a manner that fully incorporates all currently available and relevant information. Following the methodology suggested by Mullineaux (1977), this study tests the unbiasedness and efficiency of the alternative inflation measures. In addition, this chapter also considers three alternative measures of forecast dispersion--mean square error, mean absolute error, and Theil's U coefficient.

Chapter Five presents a literature review of the inflation hedging capability of alternative asset categories. The first section of the chapter defines the concept of an inflation hedge. The next section presents the major theoretical arguments regarding the inflation hedging capability of several assets. For equity securities, four alternative theories are considered--the Classical Hypothesis, the Price-Cost Sensitivity Hypothesis, the Tax Effects Hypothesis, and the External Financing Hypothesis. All but the Classical Hypothesis suggest that the returns on equities should be negatively impacted by an increase in inflation. This section also indicates that the returns on fixed-income securities should be negatively related to unanticipated inflation. The final section of Chapter Five reviews previous empirical studies of the relationship between inflation and the returns on alternative investments.

Chapter Six provides an empirical investigation of the relationship between inflation and asset returns. This chapter examines the extent to which a variety of assets were hedges against anticipated and unanticipated inflation for the 1959-1983 period. In addition to the financial assets studied by Fama and Schwert, this analysis includes municipal bonds, "small" common stocks, preferred stocks, and commodities. Chapter Six also tests the Geske-Roll reverse causality model which argues that the nominal return on an asset signals a change in inflationary expectations of the opposite sign. In addition, this chapter provides an alternative test of the Darby-Feldstein Hypothesis. This is accomplished by comparing the coefficients of inflation expectations for regressions involving nominal yields on taxable and tax-exempt debt instruments.

Finally, Chapter Seven summarizes the results of this study and makes some concluding remarks. In addition, this chapter presents a discussion of C.P.I. inflation futures, which should enable investors to lock in real rates of return.

CHAPTER TWO

INFLATION, INTEREST RATES, AND THE FISHER HYPOTHESIS

Irving Fisher's Theory of Interest (1930) has proven to be a durable and influential contribution to financial theory. A central element of Fisher's contribution is the "Fisher effect" which holds that the nominal rate of interest is equal to the sum of the real interest rate and the expected rate of inflation. A great amount of literature, both theoretical and empirical, has developed around the Fisherian analysis. This chapter provides a review of the significant studies following Fisher's pioneering work. The first section provides a discussion of the real rate of interest. Next, nominal interest rates are discussed. The third section covers the Fisher Effect. Next, theoretical issues concerning the relationship between inflation and nominal interest rates are summarized. The final section of this chapter reviews previous empirical findings concerning this relationship.

I. THE REAL RATE OF INTEREST

The real rate of interest is the equilibrium rate at which claims to future income are traded for current income. The real interest rate thus reflects the premium that individuals place on providing themselves with present consumption goods (or income) versus future consumption goods (or income). Thus, it may be regarded as the expected positive return in real purchasing power that is sufficient to induce potential lenders to part with their funds, thereby deferring their own spending. The real rate is expressed without reference to prices and represents the real growth in goods and services.

Investors expect the real rate of interest to be positive because: (1) resources have productive uses that should increase their value over time and (2) consumers have a positive time preference and thus must be paid to forego the present use of their resources.

The real interest rate is the equilibrium rate which equates the supply and demand for capital. The supply function depends on willingness of economic units to save, that is, to postpone consumption whereas the demand function depends on the opportunities for productive investment.

Each firm in the economy faces a downward sloping menu of investment opportunities which is depicted in the investment opportunity schedule. As the firm invests more, it exhausts opportunities for high rates of return and is forced to accept projects with gradually diminishing returns. Eventually, it will discontinue investing when there are no more projects offering rates of return greater than the opportunity cost of capital. The total demand for capital in the economy is the aggregation of all firms' investment opportunity schedules.

The total supply of capital depends on the amount economic units are willing to save at various interest rates. The supply of capital is an increasing function of the interest rate. The equilibrium real interest rate, r*, is achieved when savings (the supply of capital) equals investment (the demand for capital) for the economy as a whole. This occurs at the point of intersection of the investment and savings curves in Figure 2.1.

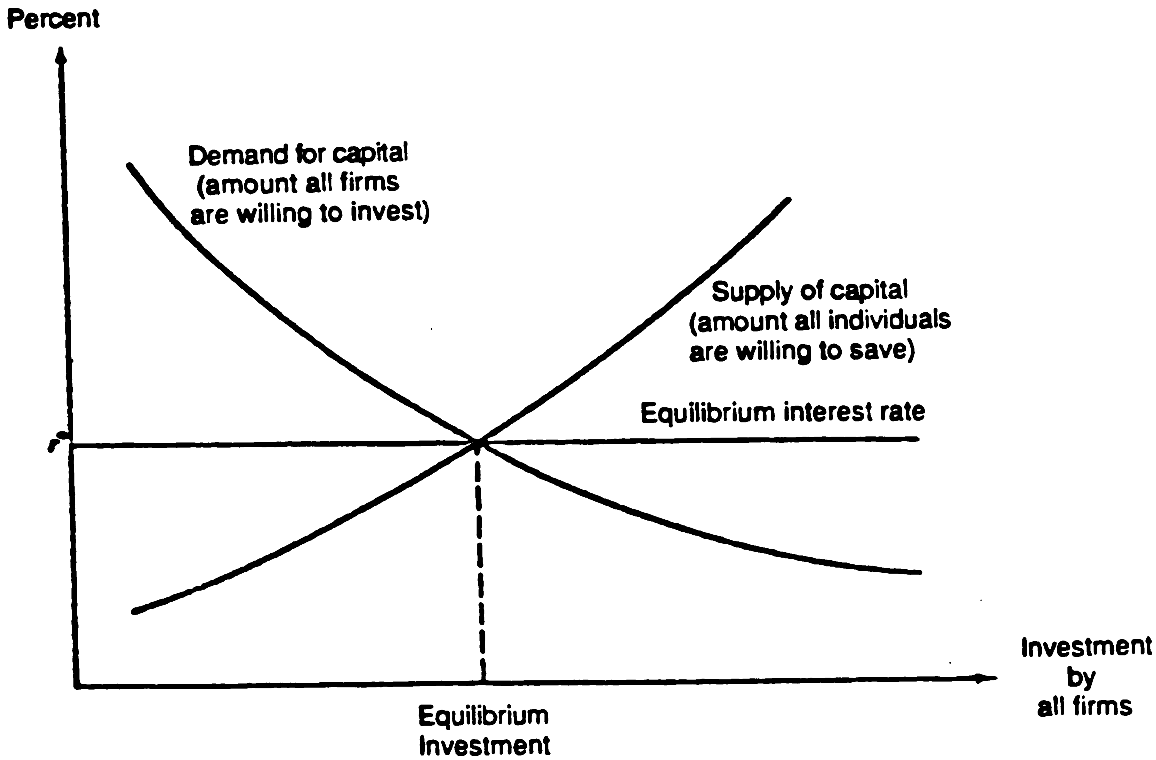
The real interest rate changes when one or both of these curves change. Hence, movements in the real rate of interest result either from changes in the underlying preferences for consumption goods vis-a-vis capital goods (which are the sources of future consumption goods) or from an increase in the productivity of capital.

II. NOMINAL INTEREST RATES

Because interest and principal payments are expressed in monetary terms and because the monetary standard changes over time, the real rate of return on a financial asset can differ from its nominal return. The expected return from a security is the discount rate which equates

FIGURE 2.1

DETERMINATION OF THE REAL INTEREST RATE



The expected real rate of interest, r*, is the rate at which the amount that savers are willing to lend is exactly equal to the amount that investors find worthwhile to borrow.

the present value of the stream of expected cash inflows with the purchase price of the asset. For a fixed-income security, the cash inflows consist of interest payments and the sales price. Likewise, for an equity security, the inflows include dividends and the sales price. The expected return from holding these financial assets is expressed in nominal terms, that is, the cash inflows are denominated in current dollars at the time of receipt. Thus, the interest rates observed in financial markets are nominal returns. The real rate of return may be viewed as the return realized when the future cash flows are placed on the same purchasing power basis as the security's initial purchase price.

Nominal interest rates represent the premium that a borrower must pay in a financial transaction involving the exchange of dollars now in return for a promise to repay dollars at some future date. Consequently, the parties involved in financial contracts are interested in the expected future value of goods and services that can be purchased when the loan is repaid. Because the (real) value of money varies inversely with movements in the general price level, the expected inflation rate over the period of the financial contract is one component of the nominal interest rate.

When inflation is expected to accelerate, lenders expect the real value of the principal and interest payments to depreciate and borrowers expect to repay loans with money having less real value. Thus, the impact of an increase in inflationary expectations is to increase the quantity of loans demanded and to decrease the quantity of loans supplied, both of which increase equilibrium nominal interest rates.

III. THE FISHER EFFECT

Fisher (1930) expressed the nominal rate of interest on a security as the sum of the expected real return on the security and the expected rate of inflation over the life of the financial instrument. More formally, we can express the nominal rate, i, as:

$$1 + i = (1 + r)(1 + \pi) \text{ or } \quad (2.1)$$

$$i = r + \pi + r\pi$$

where: r is the expected real rate of return and

π is the annual rate of inflation expected to prevail over the life of the security.

When inflation is moderate, the cross product term, $r\pi$, is small and therefore can be ignored in the formulation. Thus, we have:

$$i = r + \pi \quad (2.2)$$

Traditionally, this formulation is known as the "Fisher Effect."[1] Essentially, it states that the difference between the nominal rate of interest and the expected real rate of interest is the expected rate of inflation.

As the expected rate of inflation changes, the spread between the nominal interest rate and the expected real rate changes by the same amount. The change in the spread might result from two different events. At one extreme, the increase in expected inflation might result in an identical increase in the nominal interest rate with no change in the expected real rate. At the other extreme, the expected real interest rate might decrease by the amount of the increase in expected inflation, with no change in the nominal interest rate.

Fisher's theory emphasized the case where the real rate remains unchanged with an increase in inflation (i.e., $\frac{\partial r}{\partial \pi} = 0$). He believed that the real and monetary sectors of the economy were largely independent. Fisher argued that the expected real rate was determined by real factors such as productivity of capital, investor time preferences, and tastes for risk. Moreover, he argued that inflation had no lasting effect on real magnitudes. Thus, the only long run effect of an increase in expected inflation was to increase the nominal interest rate leaving the real rate unchanged.

Assuming a constant real rate, the Fisher effect suggests that the relationship of changes in nominal interest rates to changes in expected inflation is unity, (i.e., $\frac{\partial i}{\partial \pi} = 1$). Holding risk constant, economic units would be indifferent between investing in real assets or financial assets since financial markets equilibrate in terms of expected real rates of return. In other words both real and financial assets would provide the same expected return after adjusting for inflation.

IV. NOMINAL INTEREST RATES AND INFLATION: THEORETICAL ISSUES

The question of whether the relationship between changes in nominal interest rates and changes in expected inflation is one-to-one is a subject of considerable controversy. On a theoretical level, there are arguments justifying less than a one-to-one as well as more than a one-to-one relationship. Mundell (1963) presented a theory where changes in the anticipated rate of inflation increase or decrease the nominal interest rate by less than the change in the expected inflation (i.e., $\frac{\partial i}{\partial \pi} < 1$). In the Mundell model, the expected real return is inversely related to expected inflation. Thus, in the case of an increase in expected inflation, there is both an increase in the nominal rate of interest and a decrease in the real rate.[2] Fluctuations in the rate of inflation affect real economic variables and not only the nominal rate of interest.

Mundell contends that real interest rates fluctuate over time because of portfolio adjustments that accompany changes in expected inflation. An increase in the price level reduces the value of real money balances since money depreciates in real terms. Thus, expected inflation raises the opportunity cost of holding money. This factor, combined with the resulting decline in wealth, stimulates increased savings. In turn the increased supply of savings depresses the real return on financial assets (i.e., $\frac{\partial r}{\partial \pi} < 0$). Finally, the decline in the real rate of interest stimulates an increase in capital expenditures and real activity.[3]

Tobin (1965) obtained a result similar to Mundell--the response of nominal interest rates to anticipated inflation is only partial. In Tobin's model the partial response is a result of an inflation induced decrease in the demand for real money balances and an increase in capital intensity as wealth owners shift funds from money balances to capital.

Steindl (1973), however, contends that the Mundell-Tobin hypothesis, is valid only if the reduced demand for real money balances that results from an increase in expected inflation is in turn reflected in an increased real demand for bonds. A priori, it is not apparent that the decreased real demand for money will be reflected primarily in the bond market as opposed to the commodities market. Therefore, Steindl argues that it is not possible to predict the exact impact of changes in the expected rate of inflation on the nominal interest rate.

On the other hand, Darby (1975) and Feldstein (1976) posited a model whereby the response of the nominal rate of interest to the change in expected inflation would be greater than one-to-one. Their principal argument for the response being greater than unity has to do with tax effects.

A significant contribution to the Fisher equation literature was made by the introduction of taxation on interest income by Darby (1975). He argued that investors base their decisions not on expected real returns, but on expected real after tax returns:

(2.3) $$r = i(1 - t) - \pi$$

where: t is the proportional personal income tax rate and the other variables are as previously defined. Therefore, the nominal interest rate is given by:

(2.4) $$i = \frac{r + \pi}{1 - t}$$

Thus, if the marginal tax rate is positive, the nominal interest rate must increase by more than the increase in expected inflation in order for the after tax real return to remain unchanged (i.e., $\frac{\partial i}{\partial \pi} > 1$).

Feldstein (1976) arrived at a result similar to Darby's. The Feldstein effect differs from the Darby effect since it uses the corporate tax rate as compared to Darby's use of the personal income tax rates, and it arises in the context of allowing for the tax deductibility of interest payments in calculating the real cost of capital. However, the implications of the two models are identical--a greater than unity adjustment of nominal interest rates to expected inflation.

Darby and Feldstein's models were modified by Nielsen (1981) and Gandolfi (1982). These authors introduced the taxation of capital gains, and found that the response of nominal interest rates to anticipated inflation should be greater than the complete response suggested by Fisher, but less than the result suggested by Darby and Feldstein.[4]

$$1 \leq \frac{\partial i}{\partial \pi} \leq \frac{1}{1 - t} \qquad (2.5)$$

The introduction of a capital gains tax by Nielsen and Grandolfi increases the real cost of acquiring capital and thus reduces the magnitude of $\frac{\partial i}{\partial \pi}$ below $\frac{1}{1 - t}$

Carmichael and Stebbing (1983) suggest that the Fisher Effect was intended to apply to returns on capital rather than financial assets. Provided a minimum degree of regulation of interest rates (that being the non-payment of interest on money balances) and providing a relatively high degree of substitutability between money and financial assets, the Fisher hypothesis as applied to financial assets may give inverted results. In this model, referred to as the Inverted Fisher Effect, real interest rates move inversely with inflationary expectations and nominal interest rates are constant (i.e., $\frac{\partial r}{\partial \pi} = -1$ and $\frac{\partial i}{\partial \pi} = 0$). Thus, interest rates on financial assets behave in the exact opposite manner to that predicted by Fisher's hypothesis.

V. PREVIOUS EMPIRICAL FINDINGS

Despite the problems involved in empirical testing, there have been numerous direct and indirect tests of the Fisher Hypothesis. These studies point to a positive relationship between changes in inflation and changes in nominal interest rates during the post-World War II period. However, a number of econometric studies indicate that this relationship is less than one-to-one. In addition, the evidence of the 1960s and 1970s suggests that lenders' after-tax real returns decline with unanticipated increases in the inflation rate. Based on the empirical studies, it is possible that the real rate of interest is not constant. Furthermore, it is also possible that the statistical association between interest rates and expected inflation might reflect other factors affecting both inflation and interest rates. Hence, while expected inflation is of primary importance in explaining the movement of nominal interest rates, the relationship may not be as direct as implied by the Fisher effect. A review of some of the representative tests of the Fisher Hypothesis follows:

The standard Fisher equation may be rearranged to obtain

(2.6) $$\pi_t = i_t - r_t$$

Although investors can not predict actual inflation perfectly, we would expect the average forecasting error to be zero in an efficient market. If, on average, inflation estimates by market participants are realized, the actual rate of inflation (P_t) could be used as an estimate of the expected rate of inflation (π_t).

Fama (1975) fitted the following equation to data on U.S. Treasury Bills for the 1953-1971 period:

(2.7) $$P_t = a + b(i_t) + \varepsilon_t$$

If the Fisher equation is correct, the coefficient b should be close to 1.0 and the constant term a should be equal to minus the real interest rate. Fama found b = .98, consistent with the hypothesis that changes in short-term interest rates are entirely due to changes in inflationary expectations. In addition, the results supported a constant real interest rate. Yohe and Karnosky (1969), Feldstein and Eckstein (1970), and Gibson (1972) also found evidence of complete adjustment of nominal interest rates to expected inflation. However, these studies have been criticized for being period specific since they are all confined to the 1953-1971 sample period.

On the other hand, a number of empirical investigations, beginning with Fisher himself, have found the relationship less than one-to-one. Although Fisher's theoretical analysis predicted a complete adjustment of nominal interest rates to expected inflation, his empirical results indicated only a partial adjustment of nominal interest rates to expected inflation. Likewise, using one hundred, twenty years of data, Summers (1983) found evidence of less than complete adjustment. For every subperiod of the 1860-1979 sample period, the coefficient for expected inflation was consistently below unity. Fisher and Summers rationalized their empirical findings as reflecting "money illusion" on the part of money market participants, that is, market participants confused the distinction between nominal and real interest rates.

A number of other studies, such as Tanzi (1980) and Friedman (1982) also found evidence for only partial adjustment. Although "money illusion" may be a possible explanation, these results also suggest that additional macro-economic factors, such as the level of economic activity or the stage of the business cycle, play a significant (although secondary) role in the determination of nominal interest rates.

Evidence on the Darby-Feldstein hypothesis of more than complete adjustment has been mixed. Several studies, including Carr, Pesando, and Smith (1976), Cargill (1977), and Tanzi (1980) did not find compelling evidence for the hypothesis. However, Cargill and Meyer (1980) and Peek (1982) found support for more than complete adjustment of nominal interest rates to expected inflation.

There have also been a number of studies investigating the notion of a constant real rate of interest. Hafer and Hein (1982) rejected the hypothesis that the expected real rate on short term investments was constant over the 1955-79 period. Likewise, Hess and Bicksler (1975), Carlson (1977), and Nelson and Schwert (1977) found the real rate of interest to vary over time. Nelson and Schwert and Hess and Bicksler pointed out that the real interest was unusually stable during the period examined by Fama (1975), and hence the results may be period dependent. Fama and Gibbons (1982) discovered that the expected real rate varied inversely with the expected inflation rate. Rather than attribute the results to the Mundell-Tobin Hypothesis, they concluded that real returns varied with measures of real activity. On the other hand, Santoni and Stone (1981) utilized real as well as financial variables as proxies for the real rate and concluded that the real rate was constant over the 1954-80 period.

FOOTNOTES

[1]It should be noted that several 18th and 19th century economists--including Douglas, Thornton, and Marshall--expressed the proposition that equilibrium nominal rate adjustments entail no real effects. However, Fisher gave this concept its classic exposition.

[2]In the case of a decrease in the expected inflation, the opposite occurs. In this instance, the real rate rises and the nominal rate falls by less than the change in inflation.

[3]Fama and Gibbons (1982) found the relationship between the expected real return and measures of real activity to be positively rather than negatively related.

[4]Gandolfi also suggested that a relationship close to unity could occur even in the presence of taxes. This relationship would occur if the capital gains and ordinary income tax rates were equal and if the elasticity of investment with respect to after tax real rates was significantly greater than the elasticity of savings.

[5]The idea that the nominal yield on financial assets is constant and thus does not respond to inflation dates back to Keynes (1936).

CHAPTER THREE

THE MEASUREMENT OF EXPECTED INFLATION

This chapter provides a discussion of the measurement of changes in the general price level. The first section distinguishes between the actual rate of inflation and the expected rate of inflation. The remainder of the chapter provides a discussion of several alternative proxies for estimating expected inflation which have been employed in previous empirical investigations of the Fisher Effect.

I. ACTUAL VERSUS EXPECTED INFLATION

Inflation occurs when there is a general rise in the price level of goods and services over a period of time. This movement in the price level is typically measured by changes in various indices such as the Consumers Price Index, the G.N.P. Implicit Price Deflator, or the Producer Price Index and represents the "actual" rate of inflation.

As with most empirical studies, the Consumer Price Index (C.P.I.) is used to measure the actual inflation rate in this analysis.[1] The C.P.I., which is computed monthly by the U.S. Bureau of Labor Statistics, is the nominal or money value of a "market basket" of consumption goods and services where the weights given to individual items in the bundle are based on the proportions of family budgets allocated to these items by a large sample of urban wage earners.

Although the observed relationship between interest rates and actual inflation is interesting, it cannot be utilized to test the effect of expected inflation. The nominal interest rate in the Fisher Hypothesis is agreed to by borrowers and lenders based on ex-ante inflationary expectations rather than the ex-post realized rates of inflation. Since financial market participants do not have perfect foresight, actual inflation is not an appropriate measure of expected inflation.

Expected (or anticipated) inflation is that price level change currently recognized by financial market participants and embodied in expected asset returns. The anticipated rate of inflation is defined in terms of the expected annual rate of change in one of the aforementioned price indices. If the realized rate of inflation that actually occurs over the life of the instrument is exactly that which was anticipated, neither borrowers nor lenders gain (or lose) with respect to inflation. On the other hand, unanticipated (or unexpected) inflation represents a change in the rate of expected inflation that was unanticipated in advance by market participants, and is measured by the difference between actual and expected inflation. When unanticipated inflation occurs, borrowers gain and lenders lose since the unanticipated inflation has not been reflected in expected asset returns.

II. PROXIES FOR EXPECTED INFLATION

A problem in empirical testing of the Fisher hypothesis is that the expected rate of inflation is not directly observable and hence must be estimated. Although inflation expectations are invariably regarded as the fundamental determinants of nominal interest rates, no consensus exists regarding the appropriate determination of expected inflation. This analysis will examine several alternative methods of deriving expected inflation estimates which have been utilized in previous empirical studies. These proxies include:

1. Treasury bill rates
2. Survey estimates
   a. Livingston data
   b. Survey Research Center data
3. Expectations measures
   a. distributed lag
   b. adaptive
   c. extrapolative

d. monetary information

4. Time series (ARIMA) model

In order to permit a systematic comparison of the proxies, each model will utilize a six-month (bi-yearly) time horizon.

A. Treasury Bill Rates

One proxy often used for measuring the expected inflation rate is the nominal interest rate on U.S. Treasury Bills (minus a constant) under the assumption that the real interest rate is constant. This measure, which was suggested by Fama (1975), holds that short-term interest rates fully reflect expectations of changes in the future price level.[2] Fama found that short-term interest rates contained significant information beyond that embodied in past inflation rates, and hence concluded that nominal interest rates (on T-Bills) were the single best predictor of the future inflation rate. This proxy has the advantage of being based on observed economic behavior and of capturing the latest information available in the financial markets. This model may be represented as follows:

(3.1) $$\pi_t = i_t - r$$

where: π_t is the expected inflation rate for a six-month period beginning at time t;

i_t is the nominal interest rate on six-month Treasury bills at time t; and r is the real rate of interest which is assumed to be constant.

B. Survey Estimates

Another method of measuring expected inflation is to use direct inflation estimates from survey data. The direct survey estimates most employed in empirical work are the Livingston data and the University of Michigan Survey Research Center data.[3]

1. Livingston Data

Twice a year since 1947, Joseph Livingston, a financial columnist for the Philadelphia Inquirer, has compiled the inflation forecasts of approximately sixty business, government, and academic economists. These forecasts have the advantage of incorporating additional information beyond that contained in past inflation rates. Also, the economists selected tend to have a fairly significant influence in the financial markets. However, the sample surveyed is small and specialized so generalization to all market participants is difficult.

In order to accurately utilize the results of the Livingston surveys, researchers must be careful in specifying (1) the time horizon over which the forecasters are predicting the C.P.I. and (2) the most recent information available on the actual level of the C.P.I. when the forecast is made. In each survey, Livingston requests forecasts of the level of the C.P.I. for the following six and twelve months.[4] Livingston mails the survey participants the questionnaire one month prior to the publication of the survey data. The questionnaire includes the most current data available on the C.P.I., which is the value two months prior to publication. Thus, the actual forecasting horizon is eight rather than six months.

Livingston also sometimes adjusted the mean forecasts in an attempt to incorporate new information that was unavailable when the forecasts were made. Since the adjustments were not consistently applied, the original forecasts published by Livingston may contain measurement errors. In an effort to correct this deficiency, Carlson (1977) employed the unadjusted mean values to create a consistent series using an eight-month forecasting horizon. The adjusted Livingston measure, converted to an annual rate of change, is:

$$\pi_{6,t+2} = (F_t/P_t)^{12/8} - 1 \qquad (3.2)$$

where: $\pi_{6,t+2}$ is the expected rate of inflation;

F_t is the consensus expected level of the C.P.I.; and

P_t is the current level of the C.P.I. (October for December surveys and April for June surveys)

2. Survey Research Center Data

The Survey Research Center (SRC) data are an alternative series to the Livingston data of directly measured expectations about changes in the price level. This quarterly series, which consists of approximately 1,000 randomly selected households who are asked the prices of things "they buy," may be viewed as a measure of popular inflationary expectations. Rather than representing the expectations of professional economists (as with the Livingston data), the Survey Research Center series represents the expectations of consumers and businessmen.

Given their different perspectives and levels of knowledge of economic variables, we would expect that the process used by the two groups to forecast inflation would differ substantially. Juster and Comment (1975) have compared the behavior of the SRC expected price change series with the Livingston data. In general, they found that the SRC data exhibited greater mean values and substantially large standard deviations.[5] In addition, the distribution of the SRC data appears to be skewed to the right.

The form in which the SRC data has been obtained has gone through three major alterations since the series was first compiled. Until 1966, the survey only obtained qualitative information about the direction of expected price changes. Beginning in 1966, respondents expecting price increases were asked how much--1-2 percent, 5 percent, or 10 percent. In 1977, the questionnaire was improved to enable respondents to provide an open-ended response concerning the amount of expected inflation. Juster and Comment produced a consistent quantitative series by establishing a relationship between the survey answers during the years (1966-1977) in which the qualitative and quantitative data overlapped and extrapolating backwards. The SRC measure is given by:

$$\pi_t = \frac{\pi_t^Q + \pi_{t+1}^Q}{2} \tag{3.3}$$

where: π_t is the expected semi-annual inflation rate;

π_t^Q is the SRC quarterly expected inflation rate at time t (1 quarter ahead);

π_{t+1}^Q is the SRC quarterly expected inflation rate at time t+1 (2 quarters ahead).

C. Expectations Measures

Lahiri (1976) recognized that the Livingston price expectations may contain errors that might make them differ from the true, unobservable price expectations. Consequently, he combined the information from the

Livingston price expectations series with that from past rates of inflation to derive new estimated price expectations variables. In doing so, Lahiri employed three expectation hypotheses previously proposed by Turnovsky (1970)--distributed lag, adaptive, and extrapolative. Subsequently, other researchers suggested an expectations measure which included past monetary growth rates in addition to past inflation rates.

1. Distributed Lag

The distributed lag hypothesis utilizes some weighted average of past inflation rates as a proxy for expected inflation. This hypothesis assumes that price expectations are formed autoregressively, that is, the subset of available information used in forming price expectations is restricted to past rates of inflation. The distributed lag model may be represented as follows:

$$\pi_t = \sum_i W_i P_{t-i} \tag{3.4}$$

where: π_t is as before

W_i are the weights assigned to past inflation rates and

P_{t-i} the actual rate of inflation for a period ending at the time price expectations are formed.

In this study, i is assumed to have 3 lags.

In order to utilize the distributed lag model, the researcher must determine (1) how many past inflation rates are relevant and (2) the associated weights. In the case where the weights add to unity, the model is referred to as weighted expectations.

Gibson (1970) noted that prior to the mid-1960s, there were long lags in the formation of price expectations. Consequently, bond yields adjusted very slowly to past changes in the price level. However, studies using the distributed lag model with data obtained since the mid-1960s have indicated a marked acceleration in the formation of price expectations. In addition, when inflation is rapidly changing and volatile, past rates of inflation may not be a good proxy for future expectations. Hence, a model which employs a fixed number of past inflation rates may be inappropriate when there is a change in economic policy or a structural change that affects the inflation generating process.

2. Adaptive Expectations

The original form of the adaptive expectations model expressed the changes in price expectations as some fraction, λ, of the last period's forecast error. Formally, this version of the adaptive expectations model may be written as:[6]

$$(3.5) \qquad (\pi_t - \pi_{t-1}) = \lambda (P_{t-1} - \pi_{t-1}) \qquad 0 \leq \lambda \leq 1$$

where: π_t and P_t are as before; and π_{t-1} is the expected inflation rate for the six-month period beginning six months ago.

One problem with this formulation is that it leads to systematic underestimation of a trend in price changes. Therefore equation (3.5) was modified to:

(3.6) $$\pi_t = W_1 P_{t-1} + W_2 \pi_{t-2}$$

where: W_1 and W_2 are the weights and the other variables are as previously defined.

If $W_1 + W_2 > 1$, the forecaster will increase his expectations above last period's in order to reflect the trend.

3. Extrapolative Model

The extrapolative model may be expressed as:

(3.7) $$\pi_t = W_0 + W_1 P_{t-1} + W_2 (P_{t-1} - P_{t-2})$$

where: W_0 is a constant,

P_{t-1} is the actual inflation rate for the six-month period beginning six months ago, and the other variables are as previously defined.

In the case where $W_0 = 0$ and $W_1 = 1$, the hypothesis asserts that the expected price change for the next six months equals the price change for the last six months plus a correction to reflect the trend in changes in the actual price level over the past six months. The case where $W_0 = W_2 = 0$ and $W_1 = 1$ corresponds to static expectations, where next period's expected inflation rate equals the previous period's actual inflation rate.

4. Monetary Information Model

The aforementioned expectations hypotheses fail to consider other relevant macro-economic variables that may affect inflationary expectations. Therefore, these proxies may result in biased and inconsistent parameter estimates. Consequently, Rutledge (1976), Maital (1979), and Mullineaux (1980) have hypothesized that inflationary expectations should reflect past rates of change in the money stock in addition to past rates of inflation.

As Friedman (1969) has noted: "To the best of my knowledge there is no instance in which a substantial change in the stock of money per unit of output has occurred without a substantial change in the level of prices in the same direction . . . ." The monetary information model may be represented as:

$$\pi_t = \sum_i b_i P_{t-i} + \sum_j C_j M_{t-j} \tag{3.8}$$

where: π_t and P_t are defined as previously,

b_i are the coefficients for the past inflation rates,

C_j are the coefficients for the monetary growth rates and

M_t is the six-month growth rate in the money supply (i.e., M_1) for the period ending at time t.

In this analysis, it is assumed that both i and j have 2 lags. It is possible that additional macro-economic variables besides the growth rates in the money stock may influence inflationary expectations. However, Maital (1979) found inflationary expectations to be monetarist rather than fiscalist in nature. Consequently, this study will only consider monetary as opposed to fiscal variables (e.g., changes in the level of government expenditures).

D. Time Series Model

The final method used to derive estimates of expected inflation is the Box-Jenkins (1976) technique. A univariate time-series model, which is based on a single time series, describes the present value of the series as a function of the past values of the same series and a random error. In contrast to the assumption of statistical independence, the time series methodology presumes that the observations in a time series may be correlated. The appropriate time series model is used to explain the correlation pattern of the observations.

Box-Jenkins univariate time series modeling involves three steps: (1) model identification; (2) parameter estimation; and (3) diagnostic checking. These steps are done iteratively in order to derive an appropriate time series model. Appendix A contains a more detailed discussion of time series methodology.

The time series estimates in this analysis will be calculated as follows: First, Box-Jenkins time series techniques will be utilized to model the monthly Consumer Price Index for a base period, January 1953 to April 1959. The estimated model will then be used to forecast the C.P.I. for December 1959. Next, six more months of data will be added, the model will be re-estimated, and another forecast will be computed. This procedure will be followed until the last forecast date, April 1983, is reached.[7]

Analysis of the base period C.P.I. series indicates that the second difference of the C.P.I. can be modeled as a first order moving average process (ARIMA 0,2,1):

$$P_t = 2P_{t-1} - P_{t-2} + a_t - \theta a_{t-1}$$

where: P_t is the C.P.I. in month t and

a_t is the random error term which is assumed to be normally and independently distributed with mean zero and constant variance.

All estimates of the moving average parameter fall within the range of .76 to .79 and there is no evidence that the form of the stochastic process changed over the 1959-1983 period.

Chapter Three has reviewed the primary models for estimating expected inflation that have been used in previous empirical tests of the Fisher hypothesis. In the next chapter, the accuracy of these alternative inflation forecasts will be evaluated with the objective of determining a "preferred" inflation proxy.

FOOTNOTES

[1]The use of the C.P.I. can be questioned on several grounds. First, the C.P.I. largely excludes the prices of long-lived goods and existing capital assets. Second, the C.P.I. overstates inflation during the 1970s due to inappropriate treatment of residential housing costs. Third, improvements in the quality of goods are seldom incorporated in the Index. Finally, the substitution of relatively less expensive goods for those that have become relatively more expensive is not considered. However, any attempt to measure cost of living changes is likely to have drawbacks.

[2]Prior to Fama, the majority of empirical research indicated that there was no statistically reliable relationship between the rates observed in the market at a point in time and the rates of inflation subsequently observed. For a summary, see Roll (1972).

[3]There are two additional survey expectation series which could be used. Since 1970 the Bureau of Economic Analysis has surveyed businesses on their estimates of the rates of price change for goods and services sold and capital goods purchased. Also, since 1978, the Decision Makers Poll of institutional portfolio managers provides estimates of long-run inflation expectations over the next five- and ten-year periods. These proxies are not

employed in this analysis due to their comparatively short existence.

[4]Each December, Livingston publishes expected values of the level of the C.P.I. for June and December of the following year. In June, he presents forecasts for December and the following June.

[5]The SRC standard deviations are larger primarily because they are measured over a more informationally heterogeneous group than the Livingston standard deviations.

[6]This version of the adaptive expectations is the error-learning model proposed by Cagan (1956).

[7]To enhance comparability with the other proxies for expected inflation, the timing and horizons match those of the adjusted Livingston series.

CHAPTER FOUR

AN EVALUATION OF THE ACCURACY OF THE INFLATION PROXIES

Chapter Three discussed a number of alternative proxies for expected inflation. This chapter will examine the forecasting accuracy of these proxies, that is, how well the proxies track the corresponding actual inflation series. A number of alternative measures of forecasting accuracy including the coefficient of correlation, unbiasedness, efficiency, mean square error, mean absolute error, and Theil's U coefficient will be considered.

The means and standard deviations of the alternative inflation models for the 1959-1983 period are given in Table 4.1.[1] With the exception of the time series model, the means of the various models are less than the mean of the actual inflation rate, indicating that the models generally underestimate the actual inflation rate. Also, the standard deviation of the actual inflation rate is greater in all cases than the standard deviations of the alternative models.

I. CORRELATION COEFFICIENT

One measure of the forecasting accuracy is the coefficient of correlation between the alternative proxies for expected inflation and the actual inflation rate as measured by the C.P.I. The correlation

TABLE 4.1
MEANS AND STANDARD DEVIATIONS OF ALTERNATIVE INFLATION MODELS

Inflation Measure	Mean	Standard Deviation
ACTINF	.05199	.03715
TSINF	.05243	.03704
FAMAINF	.05953	.02951
WEXPINF	.03938	.02743
SRCINF	.05121	.02585
EXTRINF	.03961	.02732
ADAPINF	.04055	.02781
MONINF	.04058	.02687
LIVINF	.04143	.02795

coefficient, r, is given by

$$(4.1) \qquad r = \frac{\Sigma X_i Y_i}{\sqrt{\Sigma X_i^2}\ \sqrt{\Sigma Y_i^2}}$$

where: y is the dependent variable (the actual inflation rate) and

x is the independent variable (the inflation proxy).

The closer r is to +1, the stronger the degree of association between the inflation proxy and the actual rate of inflation.

The matrix of correlation coefficients for the alternative inflation measures is given in Table 4.2. The Survey Research Center data proxy is the model which is the most highly correlated with the C.P.I., whereas Fama's T-Bill measure is the least correlated with the actual inflation rate. The primary disadvantage associated with the correlation coefficient is that it does not penalize a model for exhibiting systematic linear bias.

II. RATIONALITY

There has been a growing emphasis in the theoretical literature that expectations formation should conform to the notion of rationality pioneered by John Muth (1961). The rational expectations hypothesis holds that

TABLE 4.2

MATRIX OF CORRELATION COEFFICIENTS FOR ALTERNATIVE INFLATION MEASURES: ORDINARY LEAST SQUARES 1959-1983

	ACTINF	TSINF	FAMAINF	WEXPINF	SRCINF
ACTINF	1.000	0.815	0.646	0.817	0.944
TSINF	0.815	1.000	0.712	0.962	0.840
FAMAINF	0.646	0.712	1.000	0.789	0.672
WEXPINF	0.817	0.962	0.769	1.000	0.865
SRCINF	0.944	0.840	0.672	0.865	1.000
EXTRINF	0.748	0.886	0.785	0.953	0.804
ADAPINF	0.784	0.938	0.802	0.976	0.846
MONINF	0.827	0.953	0.786	0.988	0.874
LIVINF	0.832	0.914	0.775	0.947	0.884

	EXTRINF	ADAPINF	MONINF	LIVINF
ACTINF	0.748	0.784	0.827	0.832
TSINF	0.886	0.938	0.953	0.914
FAMAINF	0.785	0.802	0.786	0.775
WEXPINF	0.953	0.976	0.988	0.947
SRCINF	0.804	0.846	0.874	0.884
EXTRINF	1.000	0.951	0.952	0.929
ADAPINF	0.951	1.000	0.963	0.943
MONINF	0.952	0.963	1.000	0.950
LIVINF	0.929	0.943	0.950	1.000

expectations about future inflation are formed in a manner that fully incorporates all of the relevant information contained in a specified information set that is available at the time the forecast is made.[2] In the context of this analysis, rationality encompasses two requirements--<u>unbiasedness</u> and <u>efficiency</u>. The unbiasedness criterion suggests that inflationary expectations are unbiased estimates of the actual inflation rate. Thus, the observed (actual) rate of inflation differs from the expected rate of inflation only by some random error term. The unbiasedness criterion may be stated algebraically as:

(4.2) $P_t = \pi_t + \varepsilon_t$

where: P_t is the actual rate of inflation experienced during period t;

π_t is the anticipated rate of inflation for period t; and

ε_t is a random error term with mean 0 and constant variance σ^2.

The unbiasedness criterion may be tested empirically by regressing the actual inflation rate on the predicted inflation rate, i.e., running the regression

(4.3) $P_t = \alpha + \beta\pi_t + \varepsilon_t$

where the variables are as previously defined.

The predictor π_t is termed unbiased if the sample estimates of α and β do not differ significantly from 0 and 1, respectively. Moreover, ε_t should exhibit no evidence of autocorrelation.

An additional criterion for rationality requires that inflation forecasts be efficient. In other words, the process by which inflation expectations are formed should be identical to the process that generates actual inflation. Therefore, any evidence suggesting that the specified information set is not being fully (i.e., efficiently) utilized would indicate rejection of rationality. Pesando (1975) tested this concept of rationality by assuming that both the expectations of inflation and actual inflation itself were described by the history of past rates of actual inflation (i.e., a distributed lag model). This interpretation of rational expectations may be expressed mathematically as:

(4.4a) $P_t = \sum_i \beta_i P_{t-i} + \mu_t$ and

(4.4b) $\pi_t = \sum_i \beta_i' P_{t-i} + V_t$

Efficiency requires that $\beta_i = \beta_i'$ for all $i, \ldots, n$.

Mullineaux (1978) demonstrated that the error variances of equations (4.4a) and (4.4b) were not identically distributed and therefore not homogeneous. Consequently, the test for rationality expressed in equations (4.4a) and (4.4b) was inappropriate.

When forecasting is done over several periods, a series of forecast errors is obtained. Mullineaux proposed an alternative efficiency test which alleviated the difficulty associated with the previous test by employing the forecast errors series:

$$(4.5) \quad FE_t = (P_t - \pi_t) = f(\text{information set used to generate the forecast})$$

Thus, assuming that the relevant information set is the past history of realized inflation rates, the concept of efficiency may be expressed as:

$$(4.6) \quad FE_t = \alpha + \sum_i \beta_i P_{t-i} + \varepsilon_t$$

where: $\varepsilon_t = \mu_t - V_t$ and the other variables are as previously defined.

Efficiency requires that FE_t be unrelated to any information known at the time the forecast was made (i.e., the series of past inflation rates). The null hypothesis requires that the coefficients of all the information variables equal 0. Stated formally, this requires that Ho: $\alpha = 0$ and $\beta_i = 0$ for all $i, \ldots, n$. A non-zero coefficient indicates that information was available at the time the forecasts were made which could have reduced forecast errors, but was not properly utilized in forming expectations. In addition, efficiency requires that the error term is serially uncorrelated, i.e., Cov $(\varepsilon_t, \varepsilon_i) = 0$ for $t = i$.

Pesando (1975) and Figlewski and Wachtel (1981) examined the Livingston expectations series for unbiasedness. Pesando was unable to reject unbiasedness using the consensus Livingston forecasts for the

1959-1969 periods. On the other hand, Figlewski and Wachtel were able to reject unbiasedness using a pooled time series/cross-section analysis of individual forecasts for the 1947-1975 period. Hafer and Resler (1980) also found the Livingston data to be biased for the 1959-1978 period.

Pesando, Carlson, and Mullineaux tested the efficiency of the Livingston inflation forecasts. Pesando was not able to reject the efficiency criterion for the 1959-1969 period. Using the adjusted version of the Livingston data, Carlson found that the inflation forecasts did not satisfy efficiency for the 1959-1969 period. Mullineaux employed the alternative test for rationality given in equation (4.6). Using Carlson's version of the Livingston data, he was unable to reject the efficiency hypothesis for the 1959-1969 period. However, for the data set used by Pesando (the original Livingston data), Mullineaux was able to reject efficiency.

Gramlich (1983) investigated the rationality of the Livingston and Survey Research Center forecasts of expected inflation. For both the Livingston and Survey Research Center data, he rejected the rationality hypothesis. In both instances, the expected inflation series appeared to be biased and inefficient. The results also indicated that the inflation forecasts of economists were more biased and inefficient than the forecasts of households.[3] This suggests that households are somewhat better in predicting inflation than economists.

To test for bias in the inflation forecasts, equation (4.3) was estimated and t-tests were conducted for the joint hypothesis that $\alpha = 0$ and $\beta = 1$ for each of the alternative inflation proxies.[4] The results of the unbiasedness test are shown in Table 4.3. The results indicate that the Fama T-Bill proxy, the SRC proxy, and the extrapolative and adaptive models are biased estimates of the actual inflation rate. On the other hand, the weighted expectations, monetary information, and Livingston measures appear to satisfy the unbiasedness criterion.

It is possible for inflation forecasts to show evidence of bias and yet still be "weakly" rational in the sense that forecasters efficiently utilize the information set. To test for efficiency, FE_t is calculated for each measure of expected inflation and used to estimate equation (4.5). Since the adaptive, extrapolative, and monetary information models utilize additional information other than past rates of inflation in generating inflationary expectations, the relevant information set is expanded to include the additional information.

TABLE 4.3

UNBIASEDNESS TEST OF EXPECTED INFLATION MEASURES

$$P_t = \alpha + \beta\pi_t + \varepsilon_t$$

Proxy	α (T-Ratio)[a]	β (T-Ratio)[b]	R^2[c]	D.W.[d]
FAMAINF	.0164 (1.15)	.5576 (-2.69)	.1586	2.27
WEXPINF	.0123 (1.70)	1.0073 (.0466)	.4683	2.16
SRCINF	-.0174 (-4.59)	1.3561 (5.37)	.8972	1.95
EXTRINF	.0206 (2.03)	.7656 (-1.15)	.1921	2.25
MONINF	.0085 (1.25)	1.0693 (.4956)	.5383	2.10
LIVINF	.0090 (1.13)	1.0355 (.2261)	.4555	2.11

[a] T-ratio is for $\alpha = 0$.

[b] T-ratio is for $\beta = 1$.

[c] Adjusted for degrees of freedom.

[d] Obtained from the maximum likelihood iterative technique to adjust for first order serial correlation of the error.

The results for the efficiency test are shown in Tables 4.4 and 4.5. These results indicate that only the Fama inflation proxy satisfies the efficiency test. The weighted expectations, Survey Research Center, Livingston, extrapolative, adaptive, and monetary information proxies do not appear to have efficiently utilized the appropriate information set. Taken together, the unbiasedness and efficiency tests indicate that none of the proxies for expected inflation fully satisfies the rationality criterion.

III. DISPERSION MEASURES

Granger and Newbold (1973) argue that any measure that looks at only the relationship between the predictor and actual series and not the magnitude and behavior of the forecast error series gives a misleading impression about the accuracy of the forecasts. Therefore, this anlaysis considers three alternative statistics which are commonly used to measure the accuracy of forecasts--mean absolute error (MABE), mean square error (MSE), and Theil's U coefficient.

While both the mean absolute error and the mean square error provide evidence on the dispersion of the forecast error, MABE gives equal weighting to all forecast errors whereas MSE gives greatest weight to

TABLE 4.4

EFFICIENCY TEST OF EXPECTED INFLATION MEASURES

$$FE_t = \alpha + \beta_1 P_{t-1} + \beta_2 P_{t-2} + \beta_3 P_{t-3} + \varepsilon_t$$

Proxy	α (T-Ratio)	β_1 (T-Ratio)	β_2 (T-Ratio)	β_3 (T-Ratio)	R^2 [a]	D.W.[b]
FAMAINF	.0110 (-.8673)	.0343 (.2142)	.1490 (1.10)	-.1471 (-.9221)	-.0191	2.30
WEXPINF	.0067 (2.19)	.8233 (5.96)	-.4254 (-1.92)	-.2944 (-2.16)	.5727	2.02
SRCINF	-.0105 (4.79)	.3204 (4.07)	.1935 (1.72)	-.2983 (-3.85)	.5967	2.08
LIVINF	.0053 (1.88)	.6441 (5.79)	.0383 (.2264)	-.5926 (-5.41)	.6530	2.14

[a]Adjusted for degrees of freedom.

[b]Obtained from the maximum likelihood iterative technique to correct for first order serial correlation of the error.

TABLE 4.5

EFFICIENCY TEST OF EXPECTED INFLATION PROXIES
1959-1983

EXTRAPOLATIVE PROXY

$$FE_t = \alpha + \beta_1 P_{t-1} + \beta_2 (P_{t-1} - P_{t-2}) + \varepsilon_t$$

α (T-Ratio)	β_1 (T-Ratio)	β_2 (T-Ratio)	R^{2a}	D.W.[b]
.0071 (1.06)	.5835 (.0453)	-.6388 (-2.00)	.4205	1.80

ADAPTIVE PROXY

$$FE_t = \alpha + \beta_1 P_{t-1} + \beta_2 \pi_{t-2} + \varepsilon_t$$

α (T-Ratio)	β_1 (T-Ratio)	β_2 (T-Ratio)	R^{2a}	D.W.[b]
.0071 (1.75)	.5835 (6.00)	-.6388 (-5.15)	.4205	1.80

MONETARY INFORMATION PROXY

$$FE_t = \alpha + \beta_1 P_{t-1} + \beta_2 P_{t-2} + \beta_2 M_{t-1} + \beta_4 M_{t-2} + \varepsilon_t$$

α (T-Ratio)	β_1 (T-Ratio)	β_2 (T-Ratio)	β_3 (T-Ratio)	β_4 (T-Ratio)	R^{2a}	D.W.[b]
.0171 (-1.58)	-.2375 (-1.85)	.2692 (2.11)	-.0869 (-1.12)	.0482 (-6470)	.0509	2.00

[a]Adjusted for degrees of freedom.

[b]Obtained from the maximum likelihood iterative technique to correct for first order serial correlation of the error.

large forecast errors. These two measures can be represented as follows:

$$(4.5) \qquad MABE = \frac{1}{N} \sum_{t=1}^{N} \left| \frac{F_t - A_t}{A_t} \right|$$

$$(4.6) \qquad MSE = \frac{1}{N} \sum_{t=1}^{N} \left[\frac{F_t - A_t}{A_t} \right]^2$$

where: F_t is the forecast value for time t;

A_t is the actual value for time t; and

N is the number of forecasts.

Theil's U statistic is defined as:[5]

$$(4.7) \qquad U = \sqrt{\frac{MSE}{\Sigma A_t^2/N}}$$

The coefficient always falls between zero and one.[6] It is equal to zero when there are perfect forecasts. On the other hand, U assumes the value of one when the predictive performance of the forecasting model is as bad as it possibly could be.

The results for the MABE, MSE, and Theil's U coefficient measures are reported in Table 4.6. These results indicate that the Survey Research Center measure is the most accurate inflation proxy since it has the lowest values for each of the measures of forecasting accuracy.

TABLE 4.6

FORECAST ERROR MEASURES OF INFLATION PROXIES
1959-1983

	MABE	MSE	THEIL'S U
SRC	.01146	.00023	.2388
TSINF	.01665	.00049	.3509
LIVINF	.01692	.00054	.3639
WEXPINF	.01789	.00062	.3902
MONINF	.01798	.00059	.3827
ADAPINF	.01834	.00067	.4080
EXTRINF	.01841	.00068	.4080
FAMAINF	.02329	.00088	.4673

It is interesting that the forecasts of households are better than those of economists. Presumably, the respondents to the Livingston surveys should be able to apply greater knowledge and expertise in weighing the various factors affecting the formation of inflation expectations. In addition, they may also have access to relevant information not available to the general public. Therefore, the Livingston forecasts would be expected to exhibit greater forecast accuracy than the SRC forecasts.

The SRC forecasts also are superior to those of the ARIMA model. Since the ARIMA model produces MSE inflation forecasts that fully incorporate all the information contained in the past series of inflation rates, this suggests that the respondents to the SRC surveys utilize additional information beyond that contained in the past history of inflation rates in forming price expectations.

Chapter Four has investigated the forecasting accuracy of the alternative inflation proxies. The SRC measures was the most highly correlated with the actual inflation rate. This chapter also found that none of the alternative inflation measures fully satisfied the rationality criterion. Finally, the SRC measure had the lowest mean absolute error, mean square error, and Theil's U coefficient.

FOOTNOTES

[1]The time period considered begins with 1959 to permit comparison among all the alternative inflation proxies.

[2]Rationality may be contrasted with completeness. Rationality implies that all information is utilized in an optimal manner, whereas completeness implies only that all information is utilized. Since such use of information need not be optimal, completeness is a necessary but not sufficient condition for rationality.

[3]Gramlich, however, failed to correct for first order serial correlation. The Livingston data exhibit significantly more serial correlation than the SRC data.

[4]The time series ARIMA model is not evaluated since by definition the ARIMA proxy provides rational inflation forecasts that fully incorporate all the information contained in the past series of inflation rates.

[5]Theil first defined the U coefficient as:

$$U = \frac{\sqrt{MSE}}{\sqrt{\Sigma A_t^2/N} + \sqrt{\Sigma P_t^2/N}}$$

However, Granger and Newbold (1983) argue that this measure does not provide a useful ranking of forecasts.

[6]Often, researchers decompose the MSE and Theil's U coefficient into bias, variance, and covariance proportions where:

$$U^M = \frac{(\bar{F} - \bar{A})^2}{MSE} \quad = \text{bias proportion}$$

$$U^S = \frac{(S_f - S_a)^2}{MSE} \quad = \text{variance proportion}$$

$$U^C = \frac{2(1 - r)S_f S_a}{MSE} = \text{covariance proportion}$$

However, Granger and Newbold (1983) argue that it is difficult to give any meaningful interpretation to U^S and U^C. Therefore, this study does not report the decomposition.

CHAPTER FIVE

INVESTMENT ASSETS AS INFLATION HEDGES

The impact of inflation on the rates of return of various investment assets are complex and difficult to disentangle. This chapter provides a discussion of the inflation hedging capability of various financial assets. The theoretical arguments regarding the ability of various asset categories to protect against price level changes is presented. In addition, previous empirical studies of the relationship between price level changes and the returns on different asset categories are summarized.

I. THE CONCEPT OF AN INFLATION HEDGE

As indicated earlier, investors are typically concerned with the real value of their income and wealth as measured in terms of final consumption goods and services. Therefore, investors will be concerned with the real or inflation-adjusted rate of return rather than the nominal rate of return on their investments.

Chapter Two introduced the "Fisher Effect," which holds that the nominal rate of interest is equal to the sum of the real interest rate and the expected rate of inflation. The Fisher equation can be generalized to the rates of return on common stock and other financial assets. The generalized Fisher equation asserts that an efficient market will set the prices of financial assets such that the expected nominal return is the sum of the equilibrium real return and the market's assessment of expected inflation over the life of the asset. This can be expressed formally as:

$$i_t = r + \pi_t \tag{5.1}$$

where: i_t is the expected nominal rate of return on the financial asset as time t;

r is the expected real rate of return; and

π_t is the expected rate of inflation at time t.

The generalized Fisher equation indicates that an increase in the expected inflation rate will increase the nominal rate of return, thereby leaving the real return on the asset unchanged.

In addition to expected inflation, the returns on securities could also be affected by unexpected inflation and changes in inflation expectations. Given efficient capital markets, investors can be expected to react to unanticipated inflation by revising their expectations of future returns, which in turn may lead to changes in the portfolio composition of assets. Furthermore, if forecasts of future inflation rates are influenced by economic factors other than past forecast errors, the change in inflationary expectations may reflect more information than that incorporated in the unexpected inflation rate. Thus, in evaluating the inflation hedging characteristics of various asset categories, it is useful to consider three aspects of inflation: (1) current expectations of inflation, (2) unexpected inflation, and (3) changes in inflation expectations.

An asset can be thought of as a hedge against expected inflation if the real return on the security is unaffected by expected inflation rates.[1] Likewise, an asset is a hedge against unexpected inflation if its real return is unaffected by the unanticipated inflation rate. Finally, an asset is a hedge against changes in inflationary expectations if the real return on the security is unaffected by changes in the expected rate of inflation.

Reilly, Johnson, and Smith (1976) have provided an alternative definition of an inflation hedge. They defined an asset to be a complete inflation hedge if the real rate of return in inflationary periods is at least as great as the real rate of return in non-inflationary periods.[2] In addition, they defined an asset to be a partial inflation hedge if the nominal rate of return in inflationary periods was greater than the nominal rate in non-inflationary periods.

Reilly, Johnson, and Smith's definition suffers from two major deficiencies. First, according to this interpretation, securities must be free of downside risk originating from all sources, not only from inflation. It is quite possible that factors other than inflation depress returns in inflationary periods. Second, Reilly et al. fail to distinguish between the three components of inflation.

II. INFLATION AND THE VALUATION OF EQUITIES

This section reviews some alternative theories about the relationship between inflation and common stock prices. Although classical economic theory suggests that there should be a positive relationship between the returns on common stocks and inflation, three alternative hypotheses--price cost sensitivity, tax effects, and external financing--suggest a negative relationship. In addition, this section will also discuss the association between inflation and small capitalization stocks.

A. Classical Theory

Traditionally, financial theorists have viewed common stocks as inflation hedges whose real returns should be independent of the rate of inflation. The classical position suggests that real returns accruing to the ownership of capital goods should be invariant to changes in the general price level, since these returns depend upon production functions and input-output relationships which are independent of the inflation rate. Furthermore, this position also held that the real capitalization rate should be invariant to the general price level, since this rate should reflect the marginal real product of capital goods and the marginal rate of time preferences, neither of which depend on the price level. Since both the flows of real returns and the real capitalization rate are invariant to inflation, the real present value of these cash flows should be unaffected by inflation. The invariance of real values implies that a change in the inflation rate should be accompanied by an equal change in the nominal rate of return on equity.

Classical economic theory also suggests that unanticipated inflation should result in a transfer of real wealth from net creditors to net debtors because the value of fixed monetary claims declines.[3] A net creditor is defined as an economic unit whose monetary assets exceed its monetary liabilities, whereas the opposite holds true for a net debtor. Given the fixed nature of debt obligations, net debtor firms should enjoy lower real capital costs during periods of unanticipated inflation. Therefore, the value of the common equity of net debtor firms should increase when inflation rates increase above their expected levels. Since the consolidated balance sheet of U.S. nonfinancial corporations has consistently been in a net debtor position, the classical theory would predict that the returns on common stock, in the aggregate, should increase when there is unanticipated inflation.[4]

B. Price-Cost Sensitivity

Van Horne and Glassmire (1972) contend that the costs of a firm's inputs and the prices and quantities of a firm's outputs may also be responsive to changes in the price level. The sensitivity of these factors to the inflation rate can result in significant changes in a firm's value. If the prices of the firm's output increase more rapidly than the costs of the firm's inputs, the operating earnings and the value of the firm should rise. Similarly, if they rise more slowly, the value of the firm should fall.

Many firms are unable to raise prices sufficiently to recapture increased production costs. The more rapid the inflation, the greater the likelihood of governmental action such as fiscal and monetary restraint or price guidelines or controls. To the extent that these policies succeed, operating income may be reduced. In addition, competition from substitutes with more stable cost structures limits firms' abilities to raise their prices. The inability to pass on price increases because of governmental pressure or competition from substitutes has an adverse impact on common stock returns.

C. Tax Effects Hypothesis

Feldstein (1980) argued that biases in the United States tax laws impair equity values during inflationary periods. These biases, chiefly the use of historic cost depreciation and first-in, first-out (FIFO) inventory accounting in the computation of the corporate profits tax base, erode after-tax earnings of firms by raising the effective tax rate on corporate profits.[5]

Depreciation charges based on the historical cost of assets do not change with inflation. However, if inflation results in large cash inflows, an increasing portion of these cash inflows is subject to taxation. Because the corporation is able to deduct only historical cost depreciation rather than replacement cost depreciation, its real rate of return is lower. This, in turn, depresses the value of common equities.

The same phenomenon also applies to FIFO inventory valuation. If a corporation uses the first-in, first-out method of inventory valuation, recorded inventory costs will be lower than replacement costs if inflation is positive. When the FIFO cost is used in the cost of goods sold calculation, accounting profits are overstated resulting in greater taxes than would be paid if replacement costs were used. Again, the real return on capital decreases which, in turn, depresses share values.

D. External Financing Hypothesis

Lintner (1975) argues that even if a corporation is able to maintain its real profit margin by increasing prices in proportion to costs, the companies relative dependence upon external financing will be higher, the greater the inflation rate, whether anticipated or unanticipated.[6] The greater relative dependence on outside financing reduces the value of outstanding equity and the real rate of return on equity. These results hold whether additional debt or new equity is issued to meet the additional financial requirement. If the added financing is obtained by debt, the after-tax cost of the new debt will reduce the real returns to equity owners even though the firm's real profits are maintained. Likewise, if the financing is obtained with a new equity issue, the owners of the previously issued shares will own a smaller portion of the firm's equity, thereby reducing their real returns.

However, in the long run, stocks must provide a positive expected real return in order for firms to attract capital. Since investors have little incentive to invest at a loss, firms must be able to offer positive expected returns. If new investments offer positive expected returns, the share of firms owning equivalent existing capacity should be bid up to comparable values. Therefore, after a period of adjustment to higher rates of inflation, the real rates of return on common equities should be just as high as before the increase in inflation rates.[7]

By reversing the arguments given above for an increase in inflation, we see that subsequent reductions in either expected or unexpected inflation will reduce firms' relative dependence on external financing. During the transitional period to lower rates of inflation, there will be unusually large capital gains on equities. Hence, the holding period returns on common stocks will be larger than expected.

E. Small Capitalization Stocks and Inflation

Banz (1981) and Reinganum (1981) examined the relationship between firm size and risk adjusted rates of return. The total market value of the firms was used as a proxy for size. Banz ranked all the firms on the New York Stock Exchange on the market value of their stock. Likewise, Reinganum ranked all the stocks on the American Stock Exchange on the basis of the market value of their stock. In each instance, the ranked samples were divided into ten portfolios assuming equal weighting of the stocks in the portfolio. Banz and Reinganum derived risk adjusted abnormal returns for the ten portfolios. Both found that the portfolios composed of small firms consistently experienced significantly greater risk adjusted abnormal returns than the portfolios consisting of large firms.

It is possible that inflation may assist in explaining the superior performance of small capitalization stocks. The prices and the returns of financial assets are affected by changes in the future expected cash flows and discount rates for those assets. If the effects of inflation are not perfectly incorporated in the cash flows and discount rates, the prices of financial assets will change. It is possible that the impact of inflation on the cash flows and discount rates of small capitalization stocks is different than for the aggregate stock market. If this is the case, there may be a differential relationship between the returns on the two categories of equities and inflation.

III. INFLATION AND THE VALUATION OF FIXED INCOME SECURITIES

In this section, theoretical arguments regarding the relationship between the returns on fixed income securities and inflation are presented. The analysis distinguishes between a number of alternative instruments offering fixed payments at periodic intervals, including conventional debt securities, municipal bonds, utility bonds, and preferred stock.

A. Conventional Debt Securities

As inflation becomes more uncertain, conventional debt securities offering a fixed nominal return (such as long-term government and corporate bonds) become less attractive to investors. To investigate the association between inflation and bond returns, it is instructive to review the general bond valuation model:[8]

$$P_0 = \frac{C}{(1 + k_1)} + \frac{C}{(1 + k_1)(1 + k_2)} + \ldots + \frac{C + F}{(1 + k_1)(1 + k_2) \ldots (1 + k_n)} \tag{5.2}$$

where: P_0 is the current price of a bond that matures in n years;

C is the annual coupon interest;

F is the face value at maturity; and

$k_1, k_2, \ldots, k_n$ are the discount rates expected to prevail during each of n years.

Since the coupon interest payments incorporate anticipated inflation at the time of issue, we would anticipate that all bonds would provide a hedge against expected inflation. However, to the extent that actual inflation exceeds anticipated inflation,.all bonds, regardless of maturity, should suffer from unanticipated inflation.

Fama (1975) and Roll (1972) have found that inflation rates are positively serially correlated suggesting that the expected rates of inflation in future periods are related to the amount of unanticipated inflation in the present period. Since an increase in the inflation rates expected for future periods should raise the term structure of interest rates, changes in inflationary expectations should have a negative impact on debt securities. Moreover, the price drop in long-term bonds should be greater than the price drop in short-term instruments for a given upward shift in the term structure.

Although both long-term and short-term interest rates contain an inflation premium, long-term bonds lock investors into the current interest rate for the life of the bond. Since the coupon payments are fixed in nominal terms (i.e., $\frac{\partial c}{\partial \pi} = 0$), the value of bonds decline if the discount factors subsequent to the initial period (i.e.,

$k_2, \ldots, k_n$) increase to reflect a revision in inflationary expectaions (i.e., $\frac{\partial k}{\partial \pi} > 0$). Since short-term bonds are better able to modify the coupon interest payments to incorporate increased inflationary expectations, we would expect the shorter the maturity of the bond, the better the hedge against changes in inflationary expectations.

B. Municipal Bonds

The interest payments received from holding municipal bonds issued by state and local governments are exempt from federal income taxes. If we assume that the total return on taxable and tax exempt bonds is equal to its coupon yield and the two bonds are identical in all respects except for the taxation of the coupon payments, the respective yields for the two instruments are linked by the following equilibrium condition:

$$R^T(1 - t_m) = R^E \tag{5.3}$$

where: R^T is the nominal return on the taxable bond;

R^E is the nominal return on the municipal bond; and

t_m is the marginal tax rate of the marginal purchaser of municipal bonds.

Equation (5.3) indicates that there is some break-even tax bracket above which investors prefer tax-exempts to taxables and below which investors prefer taxables to tax-exempts. The equilibrium relationship among the two financial instruments should also be reflected in their respective responses to anticipated inflation in order to equalize the expected after-tax real returns. This can be expressed as:

$$R^E - \pi = R^T(1 - t_m) - \pi \tag{5.4}$$

If the Darby-Feldstein hypothesis is an appropriate description of financial market behavior, the nominal tax-exempt rate of interest should adjust on a one-to-one basis with anticipated inflation, whereas the nominal taxable interest rate should adjust at a rate greater than one-to-one with changes in expected inflation.

Within the context of this analysis, it is also possible to infer the marginal tax bracket applicable to municipal bond pricing. The marginal tax bracket of the marginal investor in municipal bonds can be computed by comparing the yields on tax-exempt and taxable bonds, i.e.:[9]

$$t_m = 1 - R^E/R^T \tag{5.5}$$

The equilibrium marginal tax bracket changes in response to supply and demand conditions in the municipal bond market. Hendershott and Koch (1977) suggest that the supply of municipal bonds is interest inelastic. Therefore, the equilibrium marginal tax rate is principally determined by demand considerations. The major purchasers of municipal bonds are commercial banks and individuals. These two groups are segmented according to their preferred habitat. Commercial banks prefer to concentrate their holdings in shorter maturities. Consequently, the pricing of short-term municipals is determined primarily by the marginal tax rate of commercial banks. On the other hand, longer maturity tax-exempts are held primarily by individuals who have lower marginal tax rates than the commercial banks.[10] As a result, the yields on long-term tax-exempts must be higher relative to taxable bonds to induce individuals to hold them.

Mussa and Kormendi (1979) compared the actual tax-exempt and taxable yields in which the bonds of similar maturities and bond ratings were paired. They found that the relative long-term yield ratios were always higher than the relative short-term ratios. Moreover, they found that the applicable tax rate for short-term municipal yields was the corporate (commercial bank) rate, whereas the applicable tax rate for long-term municipal bond yields was the personal tax rate. Therefore, the differential response of short-term taxable and tax-exempt yields to expected inflation should reflect the corporate tax rate, whereas the long-term differential response should reflect the individual tax rate.

C. Utility Bonds

Expectations of increases in the general price level might cause interest rates on utility bonds to increase more than rates on industrial bonds. The logic behind this argument relates to the differences in pricing flexibility for the two segments of the economy. Utilities, which must obtain regulatory approval of rate increases, may find that their costs are increasing faster than their revenues. This, in turn, reduces the operating earnings of utilities, and increases the difficulty of repaying the principal and interest on bonds outstanding. On the other hand, industrial companies often have grater flexibility in raising their prices in response to increased costs. Therefore, industrial firms should be better able to maintain profit levels and their ability to meet debt obligations.

D. Preferred Stock

Preferred stock is a hybrid security having some of the characteristics of both debt and equity. Preferred dividends are a contractual obligation like the interest payments on debt. However, if the preferred dividends are not earned, the firm can forego paying them without danger of bankruptcy. In this regard, preferred stock is similar to common stock. Although preferred stock has rights and claims ahead of common stock, preferred shareholders do not generally benefit from increased earnings. Thus, to the investor, preferred stock is less risky than common stock but riskier than bonds.

Although preferred stock issues may be callable and may be retired, most are perpetuities. The yield on preferred stock is calculated as:

$$(5.6) \qquad Y_p = \frac{D_p}{P_p}$$

where: Y_p = the yield on preferred stock;

D_p = the fixed preferred dividends; and

P_p = the price of preferred stock.

If the economy experiences unanticipated inflation, preferred stock with fixed dividend rates becomes less desirable. With unanticipated inflation, the prices of existing preferred stock decline in order to make the dividend yields on existing issues competitive with the yields on newly issued preferred stock.[11]

Moody's classifies preferred stock into three homogeneous default-risk categories:

High grade (11)

Medium grade (20)

Speculative grade (10)

The number of preferreds used in each category is shown in parentheses following each group. Bildersee (1971) has shown that high grade preferred stock behaves more like bonds than common stock, whereas low quality preferreds are more similar to common stock. The returns of medium grade preferred stock were correlated with the returns on both bonds and common stock.

IV. INFLATION AND THE VALUE OF COMMODITIES

Robichek, Cohn, and Pringle (1972) and Bodie (1983) found that movements between various types of real and financial assets were less positively correlated than those for financial assets alone. The lack of a significant positive correlation of the returns between commodities and other investments suggest that commodities may provide opportunities for portfolio diversification. Since commodities represent ownership of real assets which reflect the price behavior of the economy as a whole, they should be a hedge against anticipated inflation. Similarly, since commodity prices and consumer prices tend to move together, commodities should be positively related to unanticipated inflation.

V. PREVIOUS EMPIRICAL STUDIES

There have been numerous tests of the Generalized Fisher Effect, although none considers all the asset categories mentioned above. This section reviews the major empirical studies investigating the relationship between the returns on alternative investments and inflation. This section is divided into three parts: (1) comprehensive empirical studies; (2) studies of the common stock/inflation relationship; and (3) studies of the relationship between other assets and inflation.

A. Comprehensive Empirical Tests

Fama and Schwert (1977) examined the relationship between realized rates of return on various assets and the inflation rate. Their study concerned both expected and unexpected inflation and involved the return to stock portfolios, U.S. Treasury Bills, U.S. government bonds, and private residential real estate for the 1953-1971 period. Of all the assets, only private residential real estate was a complete hedge against both expected and unexpected inflation during 1953-1971. Government debt instruments (i.e., bonds and bills) were a complete hedge against expected inflation, but not against unexpected inflation. Finally, common stock returns were negatively related to both anticipated and unanticipated inflation.

Huizinga and Mishkin (1984) analyzed the monthly data from 1959 to 1981 on real returns for seven securities: (1) 3-month Treasury bills; (2) 6-month Treasury bills; (3) 12-month Treasury bills; (4) intermediate term (5- 10-year) Treasury bonds; (5) long-term Treasury bonds; (6) long-term corporate bonds; and (7) common stocks. They found that the ex-ante real rates on all seven assets were negatively correlated with actual inflation rates. Moreover, as the maturity length of the asset increased and the asset became closer in its risk characteristics to equity, an increase in inflation was associated with an even larger decrease in the ex-ante real return. Mishkin and Huizinga concluded that all seven assets have been imperfect hedges against inflation, and the longer maturity assets have been the worst hedges. Hence, Fama and Schwert's concluson that U.S. Treasury bills and Treasury bonds of five years maturity or less were reasonably good hedges against inflation was not supported.

B. Tests of Common Stock/Inflation Relationship

A number of studies have found a negative relationship between inflation and the returns on common stocks. Reilly, Johnson, and Smith (1970) found that the average real return on several well-known stock price series were negative or below the indices' long-term average return for five rapid inflation periods during 1937-1973. A study by Oudet (1973) indicated that, during the total period 1953-1970, the returns on common stock were highest during the periods of least inflation and lowest during the periods of high inflation. Jaffe and Mandelker (1976) regressed both monthly and yearly stock returns on inflation rates. The results using monthly data for the 1953-1971 period indicated a significant negative relationship for contemporaneous data or using data with various leads or lags. In a similar study, Nelson (1976) found a significant negative relationship between the returns on common stock and inflation.

Bodie (1976) examined the extent to which common stocks could be used to reduce the uncertainty of real returns resulting from uncertainty about the future price level. Using the proportionate reduction in the variance of the real return of a nominal bond attainable by combining it with an equity portfolio as a measure of hedging effectiveness, he found that the real return on equities was negatively related to both anticipated and unanticipated inflation. Bodie concluded that only a short position in common stock would have produced a hedge against inflation.

A study by Cagan (1974), which dealt with the long-run returns from common stocks, found that U.S. stock prices increased by 3 percent more annually than wholesale prices over 1871-1971. However, a careful analysis of the results indicated that stocks did not do well during periods of high inflation, but made up for the loss when inflation subsided. In contrast to earlier studies, Gultekin (1983) used the Livingston data to relate expected stock returns to expected inflation. His results indicated a strong positive relationship between expected stock market returns and expected inflation.

Following the publication of empirical studies indicating a negative association between the returns on common stock and inflation, a number of theoretical arguments were advanced to explain the negative relationship. Modigliani and Cohn (1979) argued that investors systematically confused real and nominal discount rates when valuing common equity. Malkiel (1979) attributed the decline in share values to an increase in the perceived riskiness of common stock investment as compared to bonds. Fama (1981) hypothesized that the negative relationship between stock returns and inflation was a result of a negative relationship between inflation and changes in real variables that reduced the return on capital. This proposition was supported and further elaborated by Geske and Roll (1983). Pindyck (1984) argued that the variance of firms' gross marginal returns on capital increased which, in turn, increased the relative riskiness of real returns from common stock.

C. The Relationship Between Other Assets and Inflation

Using data up to 1972, Gibson (1972) found that bond yields were positively related to expected inflation. Jaffe and Mandelker (1979) investigated the relationship between the returns on fixed income securities and inflation for the 1953-1971 period. Their empirical findings suggested a positive relationship between the returns to bondholders and anticipated inflation. In addition, their research indicated that the returns on fixed-income securities were negatively related to unanticipated inflation. On the other hand, Eddy and Seifert (1984) found that the returns on both long-term corporate and government bonds were negatively related to both expected and unexpected inflation for the 1968-1981 period.

Bodie and Rosanski (1980) reported that for 1950-1976 commodity futures prices tended to move inversely with stock prices, and to do best during periods of rapid inflation. Bodie (1983) found that the real returns on commodity futures were positively correlated with the actual inflation rate and negatively correlated with the real rates of return on other major asset categories.

Chapter Five has reviewed the concept of an inflation hedge. Next, it summarized theoretical arguments regarding the association between inflation and the returns on equities, fixed-income securities, and commodities. Finally, the chapter discussed previous empirical tests of the inflation hedging capability of alternative assets. With the exception of commodities, previous studies have indicated a negative relationship between asset returns and inflation. Chapter Six will present another comprehensive study of the relationship between asset returns and inflation.

FOOTNOTES

[1]Alternatively, an asset is said to be a hedge against a particular aspect of inflation if the nominal return on the asset varies in one-to-one correspondence with the particular inflation component.

[2]Reilly, et al., referred to the rate of return in non-inflationary periods as the "normal" return. The normal rate of return should equal the risk-free interest rate plus a risk premium commensurate with the business and financial risks involved.

[3]There have been a number of tests of debtor-creditor wealth transfers with inflation. Early studies by Kessel (1956) and Alchian and Kessel (1959) suggested that there is a wealth transfer from net creditors to net debtors with inflation. However, subsequent tests by Hong (1977) and French, Ruback, and Schwert (1983) did not find support for the debtor-creditor hypothesis.

[4]Since the total real value of the firm is invariant to changes in the price level, the losses incurred by debt holders accrue to the owners of equity when there is unanticipated inflation.

[5]Since depreciation and inventory tax shields are based on historical costs, their real value declines with inflation. This, in turn, depresses the real value of the firm.

[6]It is important to note that the dependence on external financing increases when inflation rates increase. If the price level rises at a constant rate, the dependence on external funds will remain constant. Also, if inflation rates decline, the dependence on external funds will decrease.

[7]The real return on common equity will be maintained at the level it otherwise would have been, assuming the same level of business risk and degree of financial leverage.

[8]Because the federal government has the power to tax and print money, securities issued by the U.S. Treasury are free of default risk. On the other hand, fixed income securities issued by corporations carry the risk that the issuer will default on the contractually promised cash flows. In this case, the expected cash flows can be calculated by multiplying each possible cash flow in the period by its probability of occurrence and summing the products.

[9]Skelton (1982), however, argues that it is inappropriate to infer marginal tax brackets directly from yield ratios since long-term relative yields are sensitive to a measure he derived which forecasts future short-term yields.

[10]Miller (1977) and Fama (1975) assert that the marginal bondholder's tax rate must be equal to the

corporate (i.e., commercial bank) rate. Fama suggests that arbitrage across the tax-exempt and taxable bond markets ensures that the relative pricing of two securities reflects the marginal tax rate of the banks. Likewise, Miller suggests that the choice of debt or equity financing by firms in the aggregate ensure that the relevant tax bracket is the corporate rate.

[11]In order to make preferred issues more attractive to investors, many companies, particularly utilities, have begun to issue adjustable rate preferred stock with the dividends tied to rates on U.S. government obligations. With adjustable rate preferred stock, the price fluctuations resulting from unanticipated inflation are significantly reduced.

CHAPTER SIX

EMPIRICAL TESTS OF THE RELATIONSHIP BETWEEN INFLATION AND ASSET RETURNS

This chapter re-examines the empirical relationship between the components of inflation and the returns on a variety of assets. The first section of this chapter discusses the deficiencies associated with previous empirical investigations of the Generalized Fisher Hypothesis. The next section presents the total return and yield data. The third section discusses the methodology that is used in empirical tests of the inflation hedging capability of alternative assets. The fourth section presents the results of a series of regression equations. The fifth section tests the Geske-Roll reverse causality model. Finally, the last section of this chapter provides an alternative test of the Darby-Feldstein Hypothesis.

I. DEFICIENCIES OF PREVIOUS STUDIES

As mentioned in Chapter Five, Fama and Schwert (1977) and Huizinga and Mishkin (1984) previously conducted comprehensive studies of the relationship between asset returns and inflation. Fama and Schwert's (1977) study, which employed the nominal T-Bill rate as the measure of expected inflation, assumed that the real interest rate was constant. However, a number of previous studies--such as Hess and Bicksler (1975), Nelson and Schwert (1977) and Levi and Makin (1979)--have indicated that the expected real interest rate is not constant during periods of high inflation. Consequently, Fama and Schwert's methodology utilizing short-term T-Bill rates as predictors of inflation may not be accurate in periods of rapid inflation.

Small changes in the real rate of interest can cause significant and opposite percentage change in the prices of financial assets. This effect can be demonstrated utilizing a simple valuation formula:

$$(6.1) \qquad V_t = \frac{\Sigma CF_t}{(1 + k)^t}$$

where: V_t is the price of the financial asset at time t;

CF_t is the (perpetual) cash flow at time t; and

k equals the constant discount factor.

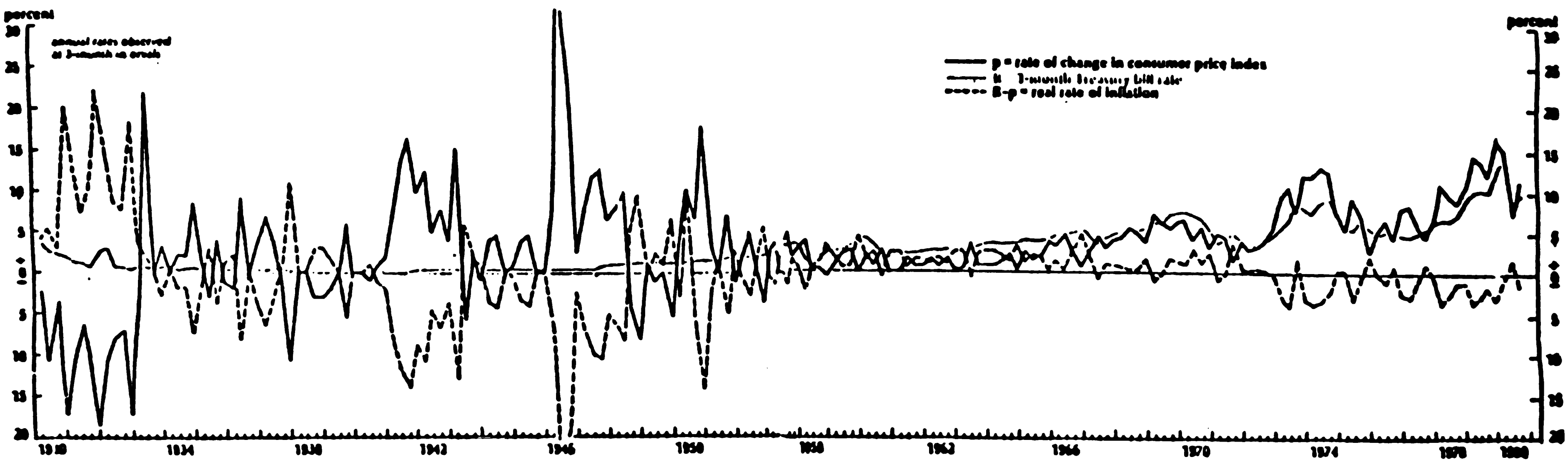
The real interest rate, r, is an integral subset of the discount factor since $k = r + \pi$. Since $\frac{\partial v}{v} = \frac{-\partial k}{k}$, a change in the real rate of interest induces an opposite change in financial asset values. Thus, to the extent that changes in the Treasury Bill rate--Fama and Schwert's inflation proxy--are due to changes in the real interest rate rather than to changes in expected inflation, we would expect a contemporaneous asset return of the opposite sign.

Also, as Nelson and Schwert (1977) and Fama and Gibbons (1982) have indicated, the 1953-1971 period examined by Fama and Schwert was one of little variation in the rate of inflation. On the other hand, the post-1971 period was characterized by high and variable rates of inflation. The heterogenous characteristics of the inflation rate for the two periods are shown in Figure 6-1. The differences between the two periods lead to the possibility that Fama and Schwert's findings were period dependent and not representative of the post-1971 experience.[1]

Huizinga and Mishkin (1984) utilized actual ex-post data as their measure of inflation. However, the relationship between asset returns and inflation is more properly investigated using expectations data. Also, Huizinga and Mishkin failed to distinguish between the three components of inflation. Furthermore, Huizinga and Mishkin used real returns rather than nominal returns in their analysis. Estimates of the real rate of return on an asset are dependent on the proxy used to measure

FIGURE 6.1

HISTORICAL RECORD OF INFLATION AND INTEREST RATES



Graph of inflation rates, T-Bill rates, and real interest rates for 1930-1980. Note the unusual stability of the rates for the 1953-71 period examined by Fama & Schwert.

inflation, whereas nominal returns have the advantage of being directly observable.

This thesis will re-examine the relationship between the returns on financial assets and the components of inflation. Since Gultekin (1983) found that the effect of inflation on asset returns may be largely a function of the proxy used to measure inflation, this analysis will include three alternative inflation proxies--the ARIMA measure, Fama and Schwert's T-Bill measure, and the Survey Research Center measure. This should provide evidence regarding the consistency of results across different measures for expected inflation. The thesis will use a comprehensive single period, 1959 through 1983, which encompasses periods of both relatively high and low inflation. In addition, this study will investigate the relationship between inflation and the returns for previously unstudied asset categories.

II. THE DATA

This study will analyze the relationship between inflation and the semi-annual nominal returns on the following asset categories for the 1959-1983 period:[2]

(1) Treasury Bills

(2) Long-term government bonds

(3) Long-term corporate bonds

(4) Commodities

(5) Common stock and

(6) Small common stock.

In addition, the thesis will explore the association between inflation and the six-month yields for the following fixed-income securities:

(1) Aaa corporate bonds

(2) Baa corporate bonds

(3) Composite industrial bonds

(4) Composite utility bonds

(5) Long-term municipal bonds and

(6) High grade preferred stock.

A. Total Return Series

For the U.S. Treasury Bill index, this analysis uses the data from the CRSP Government Bond File. The index measures one-month holding period returns for Treasury Bills of not less than one month in maturity. Since T-Bills do not pay coupon interest and are sold at a discount from maturity value, their returns may be represented by:

$$(6.2) \qquad i = \frac{\text{capital gain or loss}}{\text{purchase price}}$$

Then, the average of all the Treasury Bills is calculated to obtain the returns for the index.

To measure the total returns on long-term U.S. governmental bonds, this analysis uses the U.S. Governmental Bond File prepared by the Center for

Research in Security Prices (CRSP). This index attempts to maintain a twenty-year bond portfolio whose returns do not reflect the potential tax benefits, impaired negotiability, or special redemption or call privileges that may characterize government bonds. The return for each bond in the portfolio is calculated as follows:

$$(6.3) \qquad i = \frac{\text{capital gain or loss} + \text{coupon interest}}{\text{purchase price at beginning of period}}$$

Then, the returns of all the bonds were averaged to calculate the index's return.

This index measures the total return on corporate bonds with approximately twenty years to maturity. The index is based upon Salomon Brothers' Long-Term Corporate Bond Index from its beginning in 1969 through 1983. For the 1959-1968 period, Salomon Brothers' index is backdated using Salomon Brothers' monthly yield data. The return on each bond in the portfolio is calculated in accordance with equation (6.3)

The returns on commodities are based on Moody's Daily Price Commodity Index, which is a weighted average price of fifteen leading commodities in which there is an active business and speculative interest. The index is based on daily closing spot prices for the commodities. Each quotation is weighted and the weighted total is expressed as a relative number.[3] The return for the index is computed as:

$$(6.4) \quad i = \frac{\text{end of period number} - \text{beginning of period number}}{\text{beginning of period number}}$$

The Standard & Poor's (S&P) 500 Composite Index of diversified common stocks with all cash dividends reinvested is used as the index for common stock returns. Each common stock's rate of return is computed as follows:

$$(6.5) \quad i = \frac{\text{Capital gain or loss + cash dividend}}{\text{Purchase price at beginning of period}}$$

Adjustments are made to compensate for any stock that has a stock split or a stock dividend, so that these changes do not distort the returns. Then the rates of return on all 500 stocks are averaged together using their relative market values as weights. Therefore, stocks of the larger companies are given larger weight in this index.

To represent the equities of smaller companies, this analysis uses a historical series developed by Banz. This index is comprised of the set of stocks making up the fifth smallest quintile of New York Stock Exchange stocks, where the stocks are ranked by market capitalization (price times number of shares outstanding). The returns on the portfolio of small common stocks are calculated in the same manner as the returns from the overall common stock index above.

B. Yield Series

For the yields on debt securities, the composite data from Moody's Bond Yield Averages are used. The yield-to-maturity is calculated for each bond in a given category. Then, the yields of the individual bonds are averaged on a simple arithmetic basis to obtain the averages for each rating group.

The yield-to-maturity is the interest rate that equates the future interest payments and the payment at maturity to the current market price of the bond. The yield-to-maturity is approximated by:

$$\text{(6.6)} \qquad YTM = \frac{I + \frac{PV - MV}{N}}{(MV + PV)/2}$$

where: I is the periodic interest payment;

PV is the par value of the bond ($1,000);

MV is the market value of the bond; and

N is the number of periods to maturity.

This study considers the yields-to-maturity for both Aaa and Baa bonds. Bonds which are rated Aaa are judged to be of the highest quality and carry the smallest degree of investment risk. The capacity to pay interest and repay principal on these bonds is extremely strong. Bonds which are rated Baa are considered medium grade obligations, which are neither highly protected nor poorly secured. These bonds lack outstanding investment characteristics and have some speculative characteristics as well. The use of two indices should provide insight into the differential impact of inflation on the returns of bonds of different risk classes.

The composite yields for industrial bonds are the average yields of forty long-term industrial bonds including 10 Aaa, 10 Aa, 10 A, and 10 Baa bonds. The composite yields for utility bonds are also composed of the average yields of forty long-term bonds, ten in each of four rating groups. The composite yields for municipals are based on a broad sample of long-term municipal bonds composed of bonds in each of the four rating categories.

The yields on preferred stocks are based on the yields of Moody's High-Grade Preferred Stock Index. This group of preferred stocks has the least risk of default. The yields were calculated in accordance with equation (5.6).

The means and the standard deviations of the total return series and the yield series for the 1959-1983 period are shown in Tables 6.1 and 6.2, respectively. In general, there is a positive relationship between risk and return which is in accordance with capital market theory. However, the mean return for T-Bills is higher than for long-term government and corporate bonds even though the standard deviation of T-Bills is lower. This suggests that holders of long-term debt instruments suffered capital losses during this period as a result of unanticipated inflation. In addition, Tables 6.1 and 6.2 also suggest the importance of distinguishing between the total return and the yield of fixed-income securities. As these tables indicate, the two series have significantly different characteristics.

III. METHODOLOGY

The generalized Fisher equation can be tested with the following simple regression model:

$$(6.7) \quad i_t = \alpha + \beta\pi_t + \varepsilon_t$$

where all terms are as previously defined.

As in previous empirical studies investigating the Fisher hypothesis, this analysis assumes that the expected real return is constant or independent of the expected inflation rate.[4] Thus, equation (6.7) represents a test of the joint hypothesis that the market is efficient in pricing expected inflation and that the expected real return and the expected inflation rate are independent.

An estimate of the α coefficient that is indistinguishable from unity is consistent with the hypothesis that the expected return on financial assets moves in a one-to-one correspondence with the expected inflation rate. Furthermore, an estimate of β which is indistinguishable from unity is consistent with the hypothesis that the expected real return on the financial asset and the expected inflation rate are unrelated.

TABLE 6.1

MEANS AND STANDARD DEVIATIONS OF

TOTAL RETURN SERIES

1959-1983

	Mean	Standard Deviation
TBILL	.0610	.0315
GVTBND	.0485	.1388
CRPBND	.0544	.1545
COMMOD	.0760	.2215
COMMSTK	.1149	.2695
SMLLSTK	.2453	.4667

TABLE 6.2

MEANS AND STANDARD DEVIATIONS OF

YIELD SERIES

1959-1983

	Mean	Standard Deviation
AAABND	.0762	.0297
BAABND	.0863	.0241
INDBND	.0786	.0306
UTILBND	.0820	.0337
MUNIBND	.0576	.0236
PDFSTK	.0745	.0258

Equation (6.7) fails to differentiate between expected and unexpected inflation. It is possible that a security might serve as a hedge against expected inflation, but not against unexpected inflation. Therefore, it is preferable to treat the two aspects separately. To incorporate the effect of unanticipated inflation, we modify equation (6.7) to obtain:

$$(6.8) \qquad i_t = \alpha + \beta_1\pi_t + \beta_2(P_t - \pi_t) + \varepsilon_t$$

where: P_t is the actual inflation rate for time t;

$(P_t - \pi_t)$ is the unanticipated component of the inflation rate; and

ε_t is the random error term.

An estimate of the regression coefficient β_2 in equation (6.8) which is statistically indistinguishable from 1.0 is consistent with the proposition that the nominal return on the financial asset varies in one-to-one correspondence with unexpected inflation.

If the empirical results of equation (3) suggests that $\beta_1 = 1$, the asset is said to be a complete hedge against expected inflation. When β_2 equals 1.0, the asset is a complete hedge against unexpected inflation. Finally, when the results suggest that $\beta_1 = \beta_2 = 1.0$, the asset is said to be a complete hedge against both expected and unexpected inflation. In this instance, the nominal return on the asset varies in one-to-one correspondence with both expected and unexpected inflation, and the ex-post real return on the asset is uncorrelated with the ex-post inflation rate.

In addition, it is also useful to test a model which incorporates a term representing the revision in inflationary expectations. To test the impact of changes in inflationary expectations, equation (6.8) is modified as follows:

(6.9) $i_t = \alpha + \beta_1\pi_t + \beta_2(P_t - \pi_t) + \beta_3(\pi_t - \pi_{t-1}) + \varepsilon_t$

where: $(\pi_t - \pi_{t-1})$ represents the change in inflationary expectations and all other terms are as previously defined.

If the asset is a hedge against changes in inflation expectations, the estimated value of β_3 in equation (6.9) should be close to 1.0. When the $\beta_1 = \beta_2 = \beta_3 = 1.0$, the asset is said to be a complete hedge against all three aspects of inflation.

It is also possible to modify equations (6.7), (6.8), and (6.9) to obtain the results of regressing real financial returns on inflation. For example, the ability of the real returns on a financial asset to provide a hedge against anticipated inflation is tested with the following model:[5]

(6.10) $r = \alpha + (\beta_1 - 1)\pi_t + \varepsilon_t$

If the expected real returns on the asset are independent of inflationary expectations, then $(\beta_1 - 1)$ should be close to zero. Similarly, one can test the ability of the real returns on a security to provide a hedge against unanticipated inflation and against the changes in inflationary expectations. This is accomplished by examining whether $(\beta_2 - 1) = 0$ for unanticipated inflation and $(\beta_3 - 1) = 0$ for changes in inflationary expectations.

IV. RESULTS AND INTERPRETATION

Initially, this study investigates the extent to which various assets were hedges against anticipated and unanticipated inflation. This is done by estimating equation (6.8) for the various asset categories using three alternative measures for expected inflation--Fama and Schwert's T-Bill proxy, the ARIMA proxy, and the Survey Research Center proxy. The results using Fama and Schwert's inflation proxy are given in Table 6.3 for the total return data and Table 6.4 for the yield data.

Using Fama and Schwert's inflation proxy, the following results are obtained:

1. T-Bills are a complete hedge against expected inflation. Although the T-Bill coefficient for unexpected inflation is positive and more than two standard errors from zero, the estimate is reliably less than unity. This suggests that T-Bills are a partial hedge against unexpected inflation.

TABLE 6.3

HEDGES AGAINST EXPECTED AND UNEXPECTED INFLATION--
FAMA AND SCHWERT INFLATION PROXY: 1959-1983

$$i_t = \alpha + \beta_1\pi_t + \beta_2(P_t - \pi_t) + \epsilon_t$$

Asset	α	β_1 (T-Ratio)	β_2 (T-Ratio)	F	R^2 [a]	D.W.[b]
TBILL	-.0002 (-.0595)	1.0466 (23.82)	.1548 (3.47)	284.57	.9267	1.14
GVTBND	-.0107 (-.2559)	.7872 (1.23)	-1.8644 (-2.86)	5.80	.1696	2.02
CRPBND	.0032 (.0693)	.5457 (.7784)	-2.4738 (-3.48)	7.17	.2081	1.90
COMMOD	.06414 (1.01)	.3787 (.2929)	1.2873 (1.0132)	.48	.0213	1.94
COMMSTK	.1183 (1.51)	-.2917 (-.2435)	-2.1656 (-1.75)	1.55	.0245	2.02
SMLLSTK	.1978 (1.37)	.5956 (.2702)	-2.1525 (-.9526)	.58	.0176	1.99

[a]Adjusted for degrees of freedom.

[b]Obtained from the maximum likelihood iterative technique to correct the first order serial correlation of the error.

TABLE 6.4

HEDGES AGAINST EXPECTED AND UNEXPECTED INFLATION--
FAMA AND SCHWERT INFLATION PROXY: 1959-1983

$$i_t = \alpha + \beta_1 \pi_t + \beta_2 (P_t - \pi_t) + \epsilon_t$$

Asset	α	β_1 (T-Ratio)	β_2 (T-Ratio)	F	R^{2} [a]	D.W. [b]
AAABND	.0721 (2.50)	.1641 (3.28)	.0202 (.5134)	3.48	.0980	1.29
BAABND	.0797 (2.73)	.1807 (3.15)	-.0160 (-.3527)	4.60	.1260	1.08
INDBND	.0720 (2.74)	.1822 (3.60)	.0004 (.0098)	5.44	.1626	1.27
UTILBND	.0766 (2.62)	.1886 (3.44)	.0202 (.4682)	4.11	.1199	1.10
MUNI	.0565 (3.10)	.0835 (1.45)	-.0350 (-.7686)	1.46	.0209	1.27
PFD	.0687 (3.41)	.1604 (3.96)	-.3110 (-.0975)	8.42	.2445	1.53

[a] Adjusted for degrees of freedom.

[b] Obtained from the maximum likelihood iterative technique to correct the first order serial correlation of the error.

2. The coefficient for expected inflation for the total return on both government and corporate bonds is positive but not significantly different from zero. This indicates that neither government nor corporate bonds are a hedge against expected inflation.[6]

3. Although the coefficients for both expected and unexpected inflation for commodities are positive, neither is significantly different from zero. This suggests that the return on commodities are not a hedge against expected and unexpected inflation.

4. The coefficient for expected inflation for the S&P 500 common stock index is negative, whereas this coefficient is positive for small common stocks. However, the estimates are not significantly different from zero in either case indicating that neither asset is a hedge against expected inflation. Likewise, neither asset is a hedge against unexpected inflation since the coefficient for unexpected inflation is negative in both instances.

5. Yields on both Aaa and Baa bonds are partial hedges against expected inflation since the estimated coefficients are positive and more than two standard errors from zero. However, the coefficients are less than one in both cases. The yields on both Aaa and Baa bonds are ineffective hedges against unexpected inflation

since the coefficients for unexpected inflation for both assets are insignificantly different from zero.

6. Similarly, the yields on both industrial and utility bonds are positive and significantly different from zero. However, both coefficients are significantly less than one. Thus, the yields on industrial and utility bonds are a partial hedge against expected inflation.

7. The dividend yield on preferred stocks is a partial hedge against expected inflation. However, the yield on municipal bonds is not an effective hedge against expected inflation since the coefficient for expected inflation is not reliably different from zero. Neither the dividend yield on preferred stocks nor the yield on municipal bonds is a hedge against unexpected inflation as the coefficient for unexpected inflation for both assets is negative.

The results for the T-Bills and common stocks for the 1959-1983 period are in agreement with Fama and Schwert's (1977) earlier study. However, in contrast to Fama and Schwert's prior results, government bonds are not a hedge against expected inflation.

The results for equation (6.8) for the ARIMA inflation proxy are shown in Tables 6.5 and 6.6. In general, the results for the total return data are quite similar to those obtained with the Fama and Schwert

TABLE 6.5

HEDGES AGAINST EXPECTED AND UNEXPECTED INFLATION--
ARIMA INFLATION PROXY: 1959-1983

$$i_t = \alpha + \beta_1\pi_t + \beta_2(P_t - \pi_t) + \varepsilon_t$$

Asset	α	β_1 (T-Ratio)	β_2 (T-Ratio)	F	R^2 [a]	D.W. [b]
TBILL	.0418 (3.28)	.4282 (3.62)	.2771 (3.82)	7.60	.2156	1.99
GVTBND	.0664 (1.85)	-.3493 (-.6104)	-.9358 (-.9968)	.55	.1910	2.11
CRPBND	.0922 (2.34)	-.7498 (-1.20)	-1.5699 (-1.53)	1.46	.0190	2.03
COMMOD	.0385 (.6008)	.7173 (.7053)	1.7361 (1.18)	.73	.0111	1.96
COMMSTK	.1291 (2.42)	-.3176 (-.3740)	-5.6950 (-3.68)	7.00	.2002	2.05
SMLLSTK	.2018 (2.04)	.7713 (.4900)	-7.9774 (-2.83)	4.94	.1408	1.99

[a] Adjusted for degrees of freedom.

[b] Obtained from the maximum likelihood iterative technique to correct the first order serial correlation of the error.

TABLE 6.6

HEDGES AGAINST EXPECTED AND UNEXPECTED INFLATION-- ARIMA INFLATION PROXY: 1959-1983

$$i_t = \alpha + \beta_1 \; _t + \beta_2(P_t - \pi_t) + \epsilon_t$$

Asset	α	β_1 (T-Ratio)	β_2 (T-Ratio)	F	R^2[a]	D.W.[b]
AAABND	.0773 (2.70)	.1521 (2.37)	.0718 (1.91)	.99	.0033	1.05
BAABND	.0861 (3.03)	.1603 (2.12)	.0557 (1.24)	.79	.0891	1.02
INDBND	.0788 (2.90)	.1365 (2.00)	.0642 (1.58)	.38	.0162	1.14
UTILBND	.0826 (2.67)	.1855 (2.65)	.0827 (1.98)	1.66	.0268	.93
MUNI	.0599 (3.43)	.0735 (1.02)	.0826 (.1926)	.33	.1424	.97
PFD	.0752 (3.63)	.0954 (1.68)	.0522 (1.55)	.85	.0065	1.32

[a]Adjusted for degrees of freedom.

[b]Obtained from the maximum likelihood iterative technique to correct the first order serial correlation of the error.

inflation proxy. However, using the ARIMA inflation measure, T-Bills are shown to be only a partial hedge against expected inflation since the coefficient for expected inflation is reliably different from one. In addition, the signs for the expected inflation coefficients for both government and corporate bonds are negative (although insignificantly diffetent from zero). The signs for unexpected inflation for the ARIMA proxy are negative and significantly different from zero for both common stocks and small stocks. On the other hand, although the coefficients for unexpected inflation for corporate and government bonds are negative, they are insignificantly different from zero.

The results using the yield data for the ARIMA proxy are also somewhat different than for the T-Bill measure. The yields for Aaa bonds and utility bonds are positive and significantly different from zero, although reliably different from one. This suggests that the yields on Aaa bonds and utility bonds are partial hedges against unanticipated inflation. Also, the signs for the unexpected inflation component are positive for each of the yield series.

The results for equation (6.8) for the Survey Research Center inflation measure are shown in Tables 6.7 and 6.8. For the total return data, the following results are obtained:

TABLE 6.7

HEDGES AGAINST EXPECTED AND UNEXPECTED INFLATION--
SURVEY RESEARCH CENTER INFLATION PROXY: 1959-1983

$$i_t = \alpha + \beta_1 \pi_t + \beta_2 (P_t - \pi_t) + \varepsilon_t$$

Asset	α	β_1 (T-Ratio)	β_2 (T-Ratio)	F	R^2 [a]	D.W. [b]
TBILL	.0457 (3.15)	.3439 (2.79)	.2155 (2.24)	6.13	.1761	1.80
GVTBND	.0002 (.0040)	1.0045 (1.12)	-3.4356 (-2.16)	2.42	.0558	1.99
CRPBND	.0281 (.5163)	.5624 (.5579)	-3.8202 (-2.17)	2.88	.0725	2.00
COMMOD	.0134 (.1448)	1.2064 (.7252)	.1611 (.0655)	.35	.0149	1.93
COMMSTK	.0758 (.8435)	.8562 (.5109)	-4.9937 (-1.63)	1.65	.0264	2.06
SMLLSTK	-.0346 (-.2357)	5.7151 (2.08)	-12.9938 (-2.58)	3.34	.0888	2.03

[a] Adjusted for degrees of freedom.

[b] Obtained from the maximum likelihood iterative technique to correct the first order serial correlation of the error.

TABLE 6.8

HEDGES AGAINST EXPECTED AND UNEXPECTED INFLATION--
SURVEY RESEARCH CENTER INFLATION PROXY: 1959-1983

$$i_t = \alpha + \beta_1 \pi_t + \beta_2 (P_t - \pi_t) + \varepsilon_t$$

Asset	α	β_1 (T-Ratio)	β_2 (T-Ratio)	F	R^{2}[a]	D.W.[b]
AAABND	.0877 (8.58)	.0654 (.8939)	.0706 (1.26)	1.23	.0109	.77
BAABND	.1015 (8.48)	.0216 (.2527)	.0668 (1.02)	.55	-.0189	.69
INDBND	.0903 (8.46)	.0620 (.8119)	.0600 (1.02)	.88	-.0413	.83
UTILBND	.0944 (8.30)	.0740 (.9093)	.0785 (1.26)	1.24	.0115	.63
MUNI	.0675 (6.25)	.0197 (.2550)	-.0677 (-.1141)	.04	-.0427	.80
PFD	.0814 (9.22)	.0819 (1.30)	.0338 (.6971	1.11	.0058	.91

[a]Adjusted for degrees of freedom.

[b]Obtained from the maximum likelihood iterative technique to correct the first order serial correlation of the error.

1. T-Bills are a partial hedge against both expected and unexpected inflation.

2. The coefficients for expected inflation for both government and corporate bonds are positive, but insignificantly different from zero. Thus, neither debt instrument is a hedge against anticipated inflation. The coefficients for unanticipated inflation are negative and significantly different from zero. This indicates that the returns for both government and corporate bonds are negatively related to unanticipated inflation.

3. The coefficients for both anticipated and unanticipated inflation for commodities are positive, but not reliably different from zero. Thus, commodities are not a hedge against either expected or unexpected inflation.

4. The coefficient for expected inflation for common stocks is positive but insignificantly different from zero. On the other hand, the coefficient for expected inflation for small stocks is positive and significantly different from zero. These results suggest that small stocks are a hedge against expected inflation, whereas common stocks, in general, are not. The coefficients for unexpected inflation for both common stocks and small stocks are negative suggesting that neither asset category is a hedge against unexpected inflation.

The results using the yield data indicate that the nominal yields for each of the fixed-income securities are unrelated to either expected or unexpected inflation. Thus, the nominal yields on these financial assets appear to be constant, and the real rates are inversely related to the expected inflation rate as suggested by the Inverted Fisher Hypothesis.

Next, this study estimates equation (6.9) for each of three alternative inflation proxies (see Appendix B for other inflation proxies). This provides evidence regarding the ability of the various asset categories to hedge against changes in expected inflation. The results for the T-Bill inflation proxy are shown in Tables 6.9 and 6.10 for the total return and yield data, respectively. The coefficients for the change in expected inflation are negative with the exception of government bonds and commodities for the total return data. Although the coefficients are positive for government bonds and commodities, they are insignificantly different from zero. For the yield data, all the coefficients are negative and significantly different from zero. These results suggest that none of the asset categories provide a hedge against changes in inflationary expectations.

The results for the ARIMA model are given in Tables 6.11 and 6.12. For the total return data, all the coefficients for the change in inflationary expectations

TABLE 6.9

EFFECTS OF CHANGES IN EXPECTATIONS OF INFLATION:
FAMA AND SCHWERT INFLATION PROXY: 1959-1983

$$i_t = \alpha + \beta_1\pi_t + \beta_2(P_t - \pi_t) + \beta_3(\pi_t - \pi_{t-1}) + \varepsilon_t$$

Asset	α	β_1 (T-Ratio)	β_2 (T-Ratio)	β_3 (T-Ratio)	F	R^2[a]	D.W.[b]
TBILL	-.0009 (-.2325)	1.064 (18.79)	.1657 (3.35)	-.2460 (-3.84)	116.33	.8853	1.98
GVTBND	-.0091 (-.2063)	.7546 (1.10)	-1.8740 (-2.84)	.1656 (.1487)	3.79	.1511	1.99
CRPBND	.0020 (.0409)	.5693 (.7609)	-2.4668 (-3.41)	-.1197 (-.9846)	4.68	.1903	1.92
COMMOD	.0898 (1.01)	-.0809 (-.0589)	1.3175 (1.05)	1.7191 (.9581)	.64	.0212	1.96
CMMSTK	.0813 (1.14)	.5170 (.4658)	-1.5048 (-1.33)	-5.57521 (-2.33)	2.91	.1157	2.08
SMLLSTK	.1533 (1.08)	1.5186 (.6866)	-1.6064 (-.7276)	-5.6844 (-1.34)	.97	.0116	1.99

[a]Adjusted for degrees of freedom.

[b]Obtained from the maximum likelihood iterative technique to correct the first order serial correlation of the error.

TABLE 6.10

EFFECTS OF CHANGES IN EXPECTATIONS OF INFLATION:
FAMA AND SCHWERT INFLATION PROXY: 1959-1983

$$i_t = \alpha + \beta_1\pi_t + \beta_2(P_t - \pi_t) + \beta_3(\pi_t - \pi_{t-1}) + \varepsilon_t$$

Asset	α	β_1 (T-Ratio)	β_2 (T-Ratio)	β_3 (T-Ratio)	F	R^2 [a]	D.W.[b]
AAABND	.0585 (2.45)	.3837 (4.98)	.1287 (.3635)	-.1581 (-3.50)	6.83	.2788	1.57
BAABND	.0636 (2.68)	.4411 (5.04)	-.2468 (-.6128)	-.1876 (-3.65)	8.08	.3226	1.52
INDBND	.0578 (2.55)	.4096 (5.31)	-.0073 (-.2047)	-.164 -3.62)	8.67	.3403	1.64
UTILBND	.0614 (2.37)	.4377 (5.26)	.0118 (.3088)	-.1798 (-.368)	7.73	.3112	1.51
MUNI	.0379 (3.38)	.3733 (4.33)	-.4468 (-1.10)	-.2065 (-4.06)	6.74	.2789	1.63
PFD	.0577 (3.44)	.3393 (5.46)	-.9111 (-.3187)	-.1289 (-3.54)	10.96	.4008	2.10

[a]Adjusted for degrees of freedom.

[b]Obtained from the maximum likelihood iterative technique to correct the first order serial correlation of the error.

TABLE 6.11

EFFECTS OF CHANGES IN EXPECTATIONS OF INFLATION:
ARIMA INFLATION PROXY: 1959-1983

$$i_t = \alpha + \beta_1 \pi_t + \beta_2 (P_t - \pi_t) + \beta_3 (\pi_t - \pi_{t-1}) + \varepsilon_t$$

Asset	α	β_1 (T-Ratio)	β_2 (T-Ratio)	β_3 (T-Ratio)	F	$\bar{R}^{2}$[a]	D.W.[b]
TBILL	.0375 (3.16)	.5113 (3.84)	.2587 (3.44)	-.1055 (-1.14)	5.70	.2272	1.89
GVTBND	.0499 (1.45)	-.0054 (-.0098)	-.7555 (-.8545)	-2.8974 (-2.68)	2.81	.1015	2.15
CRPBND	.0715 (2.05)	-.3172 (-.5633)	-1.3531 (-1.43)	-3.5715 (-3.07)	4.55	.1817	2.01
COMMOD	.0472 (.7153)	.5404 (.5110)	1.7800 (1.20)	1.2587 (.7019)	.62	.02417	1.94
COMMSTK	.1251 (2.28)	-.2309 (-.2605)	-5.5391 (-3.43)	-.7789 (-.3893)	4.64	.1851	2.05
SMLLSTK	.1924 (1.90)	.9714 (.5945)	-7.6602 (-2.63)	-1.7809 (-.4945)	3.32	.1268	1.99

[a] Adjusted for degrees of freedom.

[b] Obtained from the maximum likelihood iterative technique to correct the first order serial correlation of the error.

TABLE 6.12

EFFECTS OF CHANGES IN EXPECTATIONS OF INFLATION:
ARIMA INFLATION PROXY: 1959-1983

$$i_t = \alpha + \beta_1\pi_t + \beta_2(P_t - \pi_t) + \beta_3(\pi_t - \pi_{t-1}) + \varepsilon_t$$

Asset	α	β_1 (T-Ratio)	β_2 (T-Ratio)	β_3 (T-Ratio)	F	$\bar{R}^{2a}$	D.W.[b]
AAABND	.0738 (2.90)	.2416 (3.39)	.0536 (1.44)	-.1121 (-2.43)	2.71	.1532	1.25
BAABND	.0809 (3.20)	.2994 (3.78)	.2537 (.612)	-.1749 (-3.41)	4.52	.1802	1.32
INDBND	.0746 (3.15)	.2448 (3.30)	.0408 (1.05)	-.1357 (-2.63)	2.96	.1093	1.38
UTILBND	.0784 (2.83)	.2955 (3.57)	.0589 (1.48)	-.1357 (-2.79)	3.87	.1523	1.23
MUNI	.0564 (3.24)	.1636 (2.03)	-.0121 (-.2865)	-.1148 (-2.20)	1.84	.0498	1.18
PFD	.0714 (3.89)	.1936 (3.18)	-.03088 (.9735)	-.1234 (-3.14)	3.99	.1573	1.55

[a]Adjusted for degrees of freedom.

[b]Obtained from the maximum likelihood iterative technique to correct the first order serial correlation of the error.

different from zero. Again, this indicates that none of the asset categories provides a hedge against the change in inflationary expectations.

The results for equation (6.9) for the Survey Research Center proxy are given in Tables 6.13 and 6.14. For the return data, all the coefficients for the change in inflationary expectations are negative suggesting that none of the asset categories provides a hedge against the change in expected inflation. Similarly, for the yield data, all the coefficients are negative for the change in expected inflation.

The coefficients for the changes in inflationary expectation for fixed-income securities merit further analysis. As indicated in Chapter Five, short-term debt instruments should provide a better hedge against changes in inflationary expectations since they are better able to incorporate increased inflationary expectations. The results using the ARIMA proxy are consistent with this hypothesis since the coefficient is more strongly negative for government and corporate bonds than for T-Bills. On the other hand, the results using Fama and Schwert's inflation proxy and the Survey Research Center proxy are not consistent with the hypothesized relationship. For Fama and Schwert's proxy, the coefficient for the change in expected inflation for government bonds is positive. Moreover, the coefficient

TABLE 6.13

EFFECTS IN CHANGES IN EXPECTATIONS OF INFLATION: SURVEY RESEARCH CENTER INFLATION PROXY: 1959-1983

$$i_t = \alpha + \beta_1 \pi_t + \beta_2 (P_t - \pi_t) + \beta_3 (\pi_t - \pi_{t-1}) + \epsilon_t$$

Asset	α	β_1 (T-Ratio)	β_2 (T-Ratio)	β_3 (T-Ratio)	F	R^2 [a]	D.W. [b]
TBILL	.0356 (2.54)	.5560 (3.00)	.2076 (2.15)	-.1765 (-1.43)	4.96	.1983	1.78
GVTBND	-.0098 (-.2057)	1.2290 (1.38)	-3.7508 (-2.37)	-1.6140 (-1.05)	2.24	.0717	1.99
CRPBND	.0074 (.1411)	1.0158 (1.04)	-4.4773 (-2.58)	-2.4038 (-1.48)	3.24	.1226	2.00
COMMOD	.0083 (.0839)	1.3151 (.7314)	.1505 (.0060)	-.4759 (-.2014)	.22	.0143	1.92
CMMSTK	.0424 (.5451)	1.6707 (1.15)	-5.1555 (-2.01)	-11.6789 (-4.71)	8.77	.3270	2.06
SMLSTK	-.0470 (-.3628)	6.2000 (2.56)	-11.5863 (-2.63)	-19.9247 (-4.62)	4.23	.3398	1.98

[a] Adjusted for degrees of freedom.

[b] Obtained from the maximum likelihood iterative technique to correct the first order serial correlation of the error.

TABLE 6.14

EFFECTS OF CHANGES IN EXPECTATIONS OF INFLATION:
SURVEY RESEARCH CENTER INFLATION PROXY: 1959-1983

$$i_t = \alpha + \beta_1 \pi_t + \beta_2 (P_t - \pi_t) + \beta_3 (\pi_t - \pi_{t-1}) + \varepsilon_t$$

Asset	α	β_1 (T-Ratio)	β_2 (T-Ratio)	β_3 (T-Ratio)	F	R^2[a]	D.W.[b]
AAABND	.0835 (7.28)	.1395 (1.20)	.0675 (1.20)	-.0619 (-.8275)	1.01	.0039	.79
BAABND	.0947 (7.11)	.1407 (1.05)	.0618 (.9421)	-.0995 (-1.14)	.78	-.0019	.74
INDBND	.0853 (7.14)	.1485 (1.23)	.0564 (.9584)	-.0723 (-.9277)	.85	-.0725	.86
UTILBND	.0877 (6.93)	.1904 (1.49)	.0737 (1.18)	-.0973 (-1.18)	1.26	.0199	.66
MUNI	.0678 (5.55)	.0159 (.1292)	-.0066 (-.1010)	.3146 (.0395)	.02	-.0663	.80
PFD	.0762 (7.57)	.1726 (1.74)	.0300 (.6104)	-.0758 (-1.18)	1.17	.0145	.96

[a]Adjusted for degrees of freedom.

[b]Obtained from the maximum likelihood iterative technique to correct the first order serial correlation of the error.

for T-Bills is more strongly negative than for corporate bonds. For the SRC proxy, the coefficient for T-Bills is more strongly negative than for government bonds.

In sum, the results of this chapter suggest that Fama and Schwert's results may have been period dependent as well as proxy dependent. In general, this study reaches a negative assessment regarding the inflation hedging capabilities of the various asset categories. The results using the yield data indicate that nominal yields on financial assets adjust partially to inflation expectations when the T-Bill and ARIMA inflation proxies are used. However, nominal yields do not appear to be influenced by inflation expectations when the SRC inflation proxy is used.

V. A TEST OF THE GESKE-ROLL REVERSE CAUSALITY MODEL

This chapter also presents a test of the Geske-Roll reverse causality model. Geske and Roll (1983) argue that a change in the nominal return on common stocks signals a change in inflationary expectations through a chain of macro-economic events. First, a change in stock returns predicts a change in government tax revenues. Second, since government expenditures are largely fixed, fluctuations in government revenues lead to budget deficits. Third, budget deficits lead to an increase in Treasury borrowing and debt monetization. Finally, debt monetization results in an increase in the rate of inflation. Thus, the negative association between inflation and stock market returns is a spurious relationship which is induced by a combination of a reversed adaptive inflation expectations model and a reversed money growth/stock returns model.

Although this model was originally developed for stock market returns, it should be applicable to bond market returns as well. Since the findings of the earlier empirical tests indicate an inflation relationship for bond returns which is similar to stock returns, bond returns should also signal changes in the inflationary process. The Geske-Roll model is tested by estimating the following regression model:[7]

$$(6.11)\quad (\pi_t - \pi_{t-1}) = \alpha + \beta_1 i_t + \beta_2 \pi_{t-1} + \varepsilon_t$$

where all the terms are as previously defined. Geske and Roll hypothesize that both β_1 and β_2 should be negative.

The model is tested for (1) T-Bills; (2) government bonds; (3) corporate bonds; (4) common stocks; and (5) small stocks for the 1959-1983 period. The results for the ARIMA proxy, Fama and Schwert T-Bill proxy, and the Survey Research Center proxy are given in Tables 6.15, 6.16, and 6.17, respectively.

Geske and Roll hypothesized that both the relationship between (1) the return on the asset and

TABLE 6.15

TESTS OF THE GESKE-ROLL MODEL: 1959-1983
FAMA AND SCHWERT PROXY

$$(\pi_t - \pi_{t-1}) = \alpha + \beta_1 i_t + \beta_2 \pi_{t-1} + \varepsilon_t$$

Asset	α	β_1 (T-Ratio)	β_2 (T-Ratio)	F	R^2 [a]	D.W. [b]
TBILL	.0020 (1.29)	.6333 (13.37)	-.6788 (-13.05)	90.45	.7957	2.43
GVTBND	.0037 (1.11)	-.0387 (-2.61)	-.0126 (-.2316)	4.08	.1191	2.29
CRPBND	.0037 (1.16)	-.0398 (-3.27)	-.0843 (-.1651)	6.04	.1808	2.33
COMMSTK	.0061 (1.79)	-.0230 (-2.96)	-.0397 (-.7478)	5.15	.1536	2.10
SMLLSTK	.0064 (1.68)	-.0072 (-1.50)	-.0596 (-1.01)	1.96	.0410	2.00

[a] Adjusted for degrees of freedom.

[b] Obtained from the maximum likelihood iterative technique to correct the first order serial correlation of the error.

TABLE 6.16

TESTS OF THE GESKE-ROLL MODEL: 1959-1983
ARIMA PROXY

$$(\pi_t - \pi_{t-1}) = \alpha + \beta_1 i_t + \beta_2 \pi_{t-1} + \epsilon_t$$

Asset	α	β_1 (T-Ratio)	β_2 (T-Ratio)	F	R^2[a]	D.W.[b]
TBILL	.0003 (.0512)	.3009 (2.17)	-.3519 (-3.04)	4.66	.1324	1.99
GVTBND	.0078 (1.97)	-.0461 (-2.65)	-.0989 (-1.57)	5.41	.1551	1.96
CRPBND	.0080 (2.19)	-.0503 (-3.39)	-.0911 (-1.60)	7.67	.2176	1.97
COMMSTK	.0077 (1.66)	-.0000 (-.0031)	-.1393 (-1.92)	1.87	.0351	1.99
SMLLSTK	.0078 (1.64)	.0017 (.3062)	-.1501 (-2.00)	2.01	.0403	2.00

[a]Adjusted for degrees of freedom.

[b]Obtained from the maximum likelihood iterative technique to correct the first order serial correlation of the error.

TABLE 6.17

TESTS OF THE GESKE-ROLL MODEL: 1959-1983
SURVEY RESEARCH CENTER PROXY

$$(\pi_t - \pi_{t-1}) = \alpha + \beta_1 i_t + \beta_2 \pi_{t-1} + \varepsilon_t$$

Asset	α	β_1 (T-Ratio)	β_2 (T-Ratio)	F	R^2 [a]	D.W. [b]
TBILL	.0058 (1.48)	.1144 (1.28)	-.2383 (-2.23)	2.80	.0697	1.98
GVTBND	.0065 (2.01)	-.0154 (-1.21)	-.1001 (-1.78)	2.35	.0532	2.00
CRPBND	.0071 (2.22)	-.0194 (-1.76)	-.1066 (-1.93)	3.23	.0849	2.00
COMMSTK	.0083 (2.72)	-.0261 (-3.37)	-.0904 (-1.68)	12.61	.3261	2.02
SMLLSTK	.0077 (2.37)	-.0142 (-3.99)	-.0688 (-1.17)	.5091	.0209	2.35

[a] Adjusted for degrees of freedom.

[b] Obtained from the maximum likelihood iterative technique to correct the first order serial correlation of the error.

changes in inflationary expectations and (2) the previous period's expected inflation rate and changes in inflationary expectations should be negative. For T-Bills, the coefficient for the return on the asset is positive in all three cases. However, for both government and corporate bonds, both coefficients are negative for all three inflation proxies. With the exception of the ARIMA model, the two coefficients are also negative for both common stock and small stock returns. Thus, the results indicate that the Geske-Roll reversed causality model is a reasonable explanation for the relationship between inflation and the returns on both debt and equity securities.

VI. AN ALTERNATIVE TEST OF THE DARBY-FELDSTEIN HYPOTHESIS

As discussed in Chapter Two, Darby (1975) and Feldstein (1976) modified Fisher's analysis to allow for the taxation of nominal interest income and/or the tax deductibility of nominal interest payments. These authors argued that investors base their decisions not on expected real returns, but on expected real after-tax returns. Assuming that the real after-tax interest rate remains constant, this implies that the response of nominal interest to anticipated inflation is given by:

$$\frac{dR}{d\pi} = \frac{1}{1 - t}$$

As discussed in Chapter Five, if the Darby-Feldstein hypothesis is an appropriate characterization of financial market behavior, the nominal tax-exempt interest rate should adjust on a one-to-one basis with expected inflation. Similarly, the nominal taxable interest rate should adjust at a rate greater than one-to-one with changes in expected inflation.

Most of the prior empirical studies have attempted to examine the effects of taxes on nominal interest rates by distinguishing between the Fisher and Darby-Feldstein hypotheses. This, in turn, was usually done by looking at the coefficient of inflation expectations in a reduced form equation for the nominal interest rate. According to this approach, a coefficient of expected inflation greater than one provides support for the Darby-Feldstein hypothesis.

Using a random walk intercept model, Yun (1984) estimated the relative responses of taxable and tax-exempt yields to expected inflation. The results indicated that the nominal yields on Treasury Bills rise at a rate greater than one-for-one with expected inflation, while the nominal yields on default-free municipal bonds rise approximately one-for-one with expected inflation. However, Yun fails to relate the results to empirical evidence of pricing in the municipal bond market by distinguishing between short run and long run results.

A. Methodology

This study examines the effects of taxes on the response of the nominal interest rate to expected inflation by comparing the coefficient of inflation expectations in the reduced-form equations for nominal interest rates on tax-exempt and taxable debt instruments for both the short run and the long run. For this purpose, we estimate the following regression equations:

$$(6.12) \quad R_t^E = \alpha + \beta_E \pi_t + \mu_t$$

$$(6.13) \quad R_t^T = \alpha + \beta_R \pi_t + V_t$$

Since the interest income on municipal bonds is tax-exempt, the coefficient of inflation expectations in the municipal bond rate regressions (β_E) provides an estimate of the response of nominal interest rates to expected inflation in the absence of any tax effects. In order for this coefficient to be consistent with the Fisher and Darby-Feldstein effects, one might hypothesize that this coefficient should not be significantly different from unity.

The coefficient of expected inflation (β_T) in the taxable rate regression provides the magnitude of the response of nominal interest rates which includes the Darby-Feldstein tax effect. In accordance with the Darby-Feldstein hypothesis, this coefficient should be greater than one, its level being determined by the prevailing marginal tax rate.

In our approach, the difference between the coefficients of inflation expectations in the tax-exempt and taxable rate regressions provides a measure of the tax effect from which the implied marginal tax rate across the tax-exempt and taxable debt markets can be calculated. Assuming that the equilibrium condition between tax-exempt and taxable debt holds, the marginal tax rate can be calculated from:

$$(6.14) \quad t_m = 1 - B_E/B_T$$

B. Empirical Results

Initially we estimate equations (6.12) and (6.13) for short-term debt instruments. One-year Treasury bills and one-year prime housing notes are used as our proxies for default-free taxable bonds and tax-exempt bonds, respectively. The yields on one-year Treasury bills and one-year prime housing notes were obtained from Salomon Brothers' An Analytical Record of Yields and Yield Spreads. As our measure of short-run inflation expectations, we use the twelve-month direct survey estimates from the Livingston series.[8] Our sample period covers 1961 through 1984.

Using short-term data, we obtain the following estimates for equations (6.12) and (6.13). (t statistics are given in parentheses.)

$$(6.12') \quad R_t^E = \underset{(3.86)}{2.018} + \underset{(4.63)}{.455}\pi_t$$

$$\bar{R}^2 = .1397 \quad D.W. = 2.070 \quad S.E.(\beta_E) = .0983$$

$$(6.13') \quad R_t^T = \underset{(3.71)}{3.166} + \underset{(5.57)}{.895}\pi_t$$

$$\bar{R}^2 = .2081 \quad D.W. = 2.183 \quad S.E.(\beta_T) = .1607$$

The equations indicate that estimate of both β_E and β_T are less than one. The coefficient of expected inflation in the municipal bond rate regression is significantly different from one thus contradicting the Darby-Feldstein hypothesis. Although the coefficient of expected inflation in the Treasury bill rate regressions is not significantly different from one, the coefficient is less than unity which is inconsistent with the Darby-Feldstein hypothesis. In both cases the adjusted R^2 is quite low suggesting that factors other than expected inflation influence nominal yields. Using equation (6.14), the implied short-run marginal tax rate applicable to municipal bonds is 49.2 percent. This is consistent with the hypothesis that the relevant short-run tax rate is that of commercial banks.

We might expect the long-run response of nominal yields to anticipated inflation to be larger than the short-run response. It is possible that nominal rates adjust to expected inflation with a lag. Consequently, we re-estimate equations (6.12) and (6.13) using long-term interest rates. In this instance, we use the yields on long-term corporate bonds and long-term municipal bonds from Moody's Industrial Manual as our proxies for taxable and tax-exempt nominal rates. In order to equate the risk of taxable and non-taxable obligations, we use Aaa rated debts for both the financial instruments.[9] It is, however, inappropriate to use short-run expectations for regressions involving long-term interest rates. Following Summers (1983), we derive a series of long-term inflation expectations by removing cyclical effects. However, unlike Summers we do not use the actual inflation rates as a proxy for expected inflation. Instead, we use a twenty-period moving average of six-month inflation forecasts from the Livingston series.[10]

We re-estimate equations (6.12) and (6.13) using the long-term interest rates and our measure of long-run inflation expectation (π^{LR}). The results of these regressions are (t statistics in parentheses):

(6.12") $$R_t^E = \underset{(3.512)}{2.434} + \underset{(6.055)}{.889}\pi^{LR}$$

$\bar{R}^2 = .2467$ D.W. $= 1.940$ S.E.$(\beta_E) = .1468$

(6.13") $$R_t^T = \underset{(7.327)}{3.701} + \underset{(10.537)}{1.146}\pi^{LR}$$

$\bar{R}^2 = .4985$ D.W. $= 2.145$ S.E.$(\beta_T) = .1057$

The long-run coefficients on expected inflation are greater in both instances than the short-run coefficients. For both taxable and tax-exempt obligations, the coefficients on expected inflation are insignificantly different from one. For municipal bonds, this suggests that long-term nominal yields fully incorporate expected inflation, which is consistent with the Fisher and Darby-Feldstein hypotheses. The inflation coefficient in the corporate bond rate regressions, although insignificantly different from one, is greater than 1.0 suggesting that long-term corporate yields incorporate tax effects.

The implied marginal tax bracket applicable to long-term municipal bonds is calculated from equation (6.14) to be 22.4 percent. Seater (1985) has calculated a series of marginal federal income tax rates for private individuals in the United States based on data reported in the United States Treasury Department's Statistics of Income. For the 1961-1980 subperiod, this rate was calculated to be in the 14 to 18 percent range. However, Seater's estimates are based on all incomes, not just interest income. One might expect that the marginal investor in municipal bonds would have a rate somewhat greater than those reported by Seater. In fact, Feldstein and Summers (1979) and Gordon and Malkiel (1979) have provided estimates of average marginal tax rates for interest income which are much higher than Seater's. Feldstein and Summers estimated this rate to be 42 percent, and Gordon and Malkiel's study suggested a tax rate of 33 percent.

Even if we use Gordon and Malkiel's intermediate rate of 33 percent, to be consistent with the Darby-Feldstein hypothesis, the estimate of β_T should be 1.327. We found that the value of β_T so calculated is not significantly different from our estimate of 1.146 (at 5 percent level of significance) thus supporting the Darby-Feldstein hypothesis. However, as our estimate of β_T lies between 1.000, required to be consistent with the Fisher hypothesis, and 1.327, to be consistent with the Darby-Feldstein hypotehsis, one may conjecture that the value of β_T of 1.146 is also consistent with the Nielsen-Gandolfi hypothesis. Moreover, the implied marginal tax bracket applicable to long-term municipal bonds is consistent with individuals being the primary holders of long-term municipal debt. Thus, our evidence is consistent with the preferred habitat model of municipal pricing.

It may be noted that while estimates of the coefficient of inflation expectations in the tax-exempt long-term municipal rate and taxable long-term corporate rate regressions are not significantly different from one, the absolute difference between them is not trivial. In fact, we found that the difference between the two coefficients is significantly different from zero at the 99 percent level of confidence. This evidence is consistent with Darby-Feldstein and Nielsen-Gandolfi hypotheses.

Chapter Six has conducted a number of empirical tests investigating the relationship between asset returns and inflation. The next chapter summarizes the results of this study and presents some concluding remarks.

FOOTNOTES

[1]Fama and Schwert excluded observations after 1971 because queues, side payments, and increases in the various forms of non-price rationing due to price controls prevented stated prices from accurately measuring the costs of acquiring goods.

[2]The time period considered begins with 1959 in order to permit comparison with the ARIMA model. The price data used to estimate the ARIMA model began with 1953. Data prior to 1953 would not be particularly meaningful in estimating the ARIMA model since there was a substantial upgrading of the C.P.I. at the beginning of 1953. The number of items in the C.P.I. increased substantially and the major items were sampled more frequently beginning in 1953. Also, we used 1959 because there were no U.S. Treasury Bills with more than three months of maturity until April of that year.

[3]The commodities included in Moody's Daily Commodity Price Index, with approximate weights are: cocoa--2; coffee--4; copper--5; corn--4; cotton--13; hides--5; hogs--13; lead--3; rubber--4; silk--4; silver--3; steel scrap--10; sugar--10; wheat--13; and wool--7. This index may not completely reflect the returns obtainable from commodities futures contracts. When investors take a long position in a futures contract, they do not buy it

in the sense that they would buy a stock or bond or the physical commodity itself. Instead, they agree to purchase the commodity for a specified price at a specified time in the future. Since traders must deposit only 5 to 15 percent of a contract's value, price fluctuations are magnified greatly.

[4]As indicated earlier, there is a great deal of controversy regarding this point.

[5]The standard error of the coefficient is unaffected by algebraic manipulation.

[6]It can also be noted that the coefficients for expected inflation for long-term government and corporate bonds are also insignificantly different from 1.0 due to the large standard errors of the estimate. Thus, the power of the test, Ho: $\beta_1 = 1$, is weak. Following Eddy and Seifert (1985), this study adopts the convention that if a coefficient is insignificantly different from zero, the asset is not an inflation hedge (even though the coefficient may also be insignificantly different from one).

[7]Although the original Geske-Roll model was a non-linear one, they found that the ordinary least squares estimates were very close to the ones using the non-linear method.

[8]The twelve-month Livingston data used in this section is the original unadjusted series published by Livingston.

[9]Trzcinka (1982) argues that the rating agencies do not attempt to make ratings comparable between corporate and municipal bonds. He suggests that municipals are somewhat more risky than corporate bonds of the same rating.

[10]This measure of long-run inflation expectations may be questioned. However, in the absence of the availability of direct survey data on long-term inflation expectations, any empirical study employing long-run expectations is likely to suffer from this drawback.

CHAPTER SEVEN

SUMMARY AND CONCLUDING REMARKS

This chapter consists of three sections. In the first section, the major empirical results of this study are reviewed and summarized. The second section cites some limitations of this study. The third section discusses C.P.I. Inflation Futures Contracts which can assist the investor in protecting against price level changes.

I. SUMMARY

The importance of inflationary expectations in nominal interest rate determination and the association between inflation and the returns on alternative asset categories have attracted substantial attention in the literature. However, theoretical and empirical studies on these issues have led to conflicting results.

Although the Fisher Hypothesis suggests that the nominal rate of return on a financial asset is equal to the real rate of return and the expected inflation rate over the life of the asset, three alternative hypotheses have been proposed. The Mundell-Tobin Effect argues that the real rate is inversely related to the expected inflation rate and therefore the nominal interest rate changes by less than the changes in expected inflation.

The Feldstein-Darby Effect argues that the response of nominal interest rates to expected inflation is greater than unity due to tax effects. Finally, the Inverted Fisher Effect suggests that the nominal interest rate is constant and the real interest rate is inversely related to the expected inflation rate.

Since the expected inflation rate is not directly observable, several alternative measures have been utilized in previous empirical work. These include:

1. distributed lag model
2. extrapolative model
3. adaptive model
4. monetary information model
5. Livingston survey data
6. Survey Research Center data
7. nominal T-Bill rate measure
8. time series (ARIMA) model.

This study provides a comprehensive analysis of the forecasting accuracy of these inflation proxies for the 1959-1983 period. The Survey Research Center measure was the most highly correlated with the actual inflation rate. This study also found that none of the alternative inflation proxies fully satisfied rationality. Therefore, expectations about future inflation do not appear to have been formed in a manner that fully incorporates all currently available and relevant information.

Finally, this analysis found that the Survey Research Center measure had the lowest forecast dispersion as indicated by the mean absolute error, mean square error, and Theil's U coefficient.

After reviewing the theoretical arguments regarding the inflation hedging capabilities of several alternative asset categories, the dissertation re-examines the relationship between the returns on the alternative asset categories and the components of inflation. This study augments the previous work on the Fisher Hypothesis as it applies to the returns on alternative asset categories in three important ways. First, this analysis covers a more recent time period than earlier studies which used data prior to the 1970s. Rates of inflation have been substantially higher and more volatile since 1971. Second, the conflicting results of prior studies suggest that the effects of inflation on asset returns may be a function of the proxy used to measure expected inflation. Therefore, this thesis uses three different proxies--including the ARIMA model, the Survey Research Center model, and the nominal Treasury Bill rate model to measure the effect of inflation on asset returns. Third, this study includes previously unstudied asset categories such as "small" common stocks, municipal bonds, and commodities.

The empirical results of this study suggest that, in general, financial assets are poor hedges against expected inflation. In contrast to Fama and Schwert's previous study, government bonds do not appear to be a hedge against expected inflation. This suggests that Fama and Schwert's previous results may have been period dependent. Although the coefficients for expected inflation for small stocks and commodities are positive for both the ARIMA and Treasury Bill proxies, the estimates are not significantly different from zero. On the other hand, the coefficient for expected inflation for small stocks is significantly greater than zero, suggesting that small stocks are a partial hedge against expected inflation. This suggests that the results of empirical investigations of the relationship between asset returns and inflation may be proxy dependent. Of the assets considered, only Treasury Bills appear to offer a partial hedge against expected inflation. This suggests that the real returns on debt and equity securities are negatively related to the expected inflation rate.

The results indicate that the returns on both debt and equity securities are negatively related to both unanticipated inflation and the changes in inflation expectations. However, the magnitude of the coefficients for the changes in inflation expectations for Treasury Bills, government bonds, and corporate bonds differs depending on which proxy is employed.

The coefficients for expected inflation for fixed-income securities are, in general, significantly greater than zero for both the ARIMA and Treasury Bill inflation proxies. However, these coefficients are also significantly different from one, suggesting partial adjustment of nominal interest rates to inflation. On the other hand, the coefficients for expected inflation for fixed-income securities are insignificantly different from zero when the Survey Research Center proxy is employed. Therefore, the results for the Survey Research Center measure are consistent with the Inverted Fisher Hypothesis.

This study also tests the Geske-Roll reverse causality model which argues that a change in the nominal return on a financial asset signals a change in inflationary expectations of the opposite sign. The results indicate that the Geske-Roll reverse causality model holds for long-term government and corporate bonds as well as for equity securities.

The dissertation also provides an alternative test of the Darby-Feldstein hypothesis by comparing the coefficient of inflation expectations for two regression equations involving nominal yields for taxable and tax-exempt debt. Using short-run inflation expectations, the Darby-Feldstein hypothesis is not empirically supported. However, using long-run inflation expectations, the nominal yields on corporate bonds adjust at a rate greater than one-for-one with expected inflation, whereas the nominal yields on municipal bonds rise one-for-one with expected inflation. This evidence is consistent with the Darby-Feldstein hypothesis in the long run. In addition, these results also support a preferred habitat theory of municipal bond pricing.

II. LIMITATIONS

Although this study has provided additional insight into the relationship between asset returns and inflation, several limitations may be noted. First, it is apparent that the relationship between inflation and the returns on financial assets does not lend itself to simple explanations, nor does it appear to be stable over time. Therefore, it would be useful to examine the association between inflation and asset returns over heterogeneous subperiods. In particular, it would be interesting to determine if there was a change in the relationship following the shift in Federal Reserve Board operating procedures in October 1979. In addition, the generally low coefficients of determination in this analysis indicate that other macro-economic variables affect nominal asset returns. Further research should be done to identify these variables.

In addition, it would be useful to examine the relationship between inflation and asset returns over a longer time period. As Chapter Six indicated, it is possible that nominal interest rates adjust to inflation expectations with a lag. Therefore, researchers must be careful in specifying the holding period of the security. The influence of six-month inflation expectations should diminish as the holding period of the asset extends beyond six months. Consequently, the adjustment of long-run nominal interest rates to inflation expectations should be investigated using some measure of long-run inflation expectations. It is likely that interest rates adjust more completely to long-run inflation expectations. Although it is difficult to predict expected inflation when one is dealing with long time periods, future research efforts should be devoted to determining a measure of long-run inflation expectations.

Finally, it would be instructive to examine whether the relationship between inflation and asset returns is consistent across different industries. It is likely that there are cross-sectional differences since inflation should have a heterogeneous impact on different industries.

III. THE C.P.I. INFORMATION FUTURES MARKET

The preceding analysis has indicated that conventional financial assets do not provide sufficient protection against price level changes. However, the C.P.I.-W futures market should enable investors to lock in real rats of return through the creation of inflation-proof derivative investments.

A. Contract Characteristics

The C.P.I. Inflation Futures Contract was developed by the Coffee, Sugar, and Cocoa Exchange in 1985 in order to provide a mechanism for hedging against purchasing power risk. The basis of the futures contract is the C.P.I.-W, the Consumer Price Index for Urban Wage Earners and Clerical Workers.[1]

The futures contracts use 1967 as the base year and one hundred as the C.P.I.-W index for that year. The contracts are traded for quarterly settlement (in January, April, July, and October) during the nearest twelve months and semi-annual settlement (in January and July) over the next 24 months. The face value of the futures contract is $1,000 multiplied by the actual index number released each month by the Bureau of Labor Statistics of the U.S. Department of Labor. The exchange requires the trader to put down only $1,500 in cash for each contract.

Cash settlement is an integral feature of the C.P.I. futures contract. Unlike most futures contracts on commodities and government securities, no intent to deliver are required. Settlement involves a cash payment or collection on any contract not offset prior to the expiration of trading. Settlement takes place on the day the C.P.I.-W is announced by the Bureau of Labor Statistics. Trading in the futures contract ends at the close of trading two business days prior to the settlement date.

A position in the C.P.I. futures contract can be liquidated prior to the expiration of trading through the execution of an offsetting transaction. A long (buy) position in a futures contract can be liquidated through the sale of a futures contract with the same expiration date. Likewise a short (sell) position can be liquidated by an offsetting purchase. In either case, the gain or loss on the futures position is determined by the difference between the purchase price and the sales price.

Futures prices are quoted and traded in two decimal points. The minimum price fluctuation is .01 or $10 per contract. The maximum daily price fluctuation is 3.00 points, or $3,000 per contract.

The C.P.I.-W is not seasonally adjusted and has only been revised twice since February 1971. Although the C.P.I.-W is only compiled and released on a monthly basis, the underlying data for the index are constantly changing. The fact that the index is compiled on a monthly basis is no more an impediment to trading than the fact that securities which are actively traded report earnings on a quarterly basis.

Trading in the C.P.I. futures contracts provides an ongoing market derived consensus of inflation expectations. A major difficulty in previous empirical studies involving inflation has been the problem of measuring the ex-ante inflation rate. Economists have often failed to correctly forecast future price level changes. The C.P.I. futures market should provide valuable data concerning future inflation trends, thus facilitating empirical investigation of inflation expectations.

B. Uses of the Futures Contracts

In the C.P.I. futures market, investors can buy or sell claims to future market baskets of goods services by trading claims to dollars. The current price of the futures contract represents an equilibrium price in the sense that those who believe that inflation will be more rapid than that level implied by futures price will buy futures contracts, whereas those who believe inflation will be less rapid will sell the contracts. Thus, buyers of the futures contracts can achieve protection against a higher than expected rate of inflation. Likewise, sellers of the future contract can achieve protection against a lower than expected rate of inflation.

Investors and money managers can buy the C.P.I. futures contracts to hedge against inflation risk and lock in real rates of return. For example, an investor could lock in the real rate of return by combining fixed income contracts with C.P.I. futures contracts. Except for transaction costs, the buyer's financial position after liquidating his C.P.I. future position would be the same as if inflation had advanced at the consensus rate forecasted by C.P.I. futures traders. If inflation pushes the index to a level above that predicted by C.P.I. futures traders, the investor would lose more purchasing power to inflation than anticipated. However, that loss would be offset by gains on the C.P.I. contract. Similarly, if future inflation is less than the consensus forecasted value, the futures buyer's contract will lose some of its value, but the underlying asset that is being hedged will retain more of its value.

Alternatively, participants in the inflation futures market may utilize speculative strategies in the pursuit of profit. Buyers of C.P.I.-W futures profit from an increase in the rate of inflation and lose from a decrease in the rate of inflation. On the other hand, sellers of C.P.I.-W futures contracts gain from a decrease in the inflation rate and lose from an increase in the inflation rate.

Most participants in the C.P.I. futures market are expected to be buyers rather than sellers. Therefore, the market might be expected to have a forward price which is greater than the spot price. This is often cited as the major potential difficulty associated with this market.

C. Concluding Comments

Inflation changes have not been well correlated with the changes in returns of financial assets. In addition, economists have encountered difficulty in forecasting price level changes. These concerns may be alleviated by the C.P.I. futures market. This market enables investors to hedge against unforeseeable variability in rates of inflation, and therefore lock in real rates of return. Also, the inflation futures market provides an ongoing measure of consensus price expectations which should be useful in future empirical studies.

FOOTNOTES

[1]The Bureau of Labor Statistics also publishes the C.P.I.-W, the Consumer Price Index for all urban consumers. The price movements of the two indices are highly correlated. The futures contract is based on the C.P.I.-W because it is the index used in conjunction with wage and Social Security cost of living adjustments.

APPENDIX A

TIME SERIES METHODOLOGY

APPENDIX A

TIME SERIES METHODOLOGY

This dissertation uses the Box-Jenkins modeling techniques to construct a forecasting model for the C.P.I. inflation rate. This methodology has been used in several previous studies of the Fisher hypothesis including Hess and Bicksler (1975) and Pearce (1979). A discussion of the classes of time series models follows. The second section of the appendix presents a discussion of the ARIMA model building process.

I. CLASSES OF ARIMA MODELS

ARIMA models can be used to forecast future values of a time series using the past values and/or the past error terms (shocks) of a time series. These models are used to determine the process generating an economic variable using a set of autoregressive, integrative, and moving average terms.

A fundamental assumption of the time series technique is that the time series is stationary. A stationary series is in a state of statistical equilibrium. This occurs when the joint probability distribution of the series is invariant with respect to where one looks in the series. Thus, the mean, variance, and higher moments are the same throughout the series. If the underlying series is not stationary, various transformations are available in order to obtain a stationary series. Differencing is one of the most common transformations used to induce stationarity.

If differencing is used, one must sum the differences to a starting value in order to return to the original data. The process of summing the differences to a starting value is referred to as "integrating" in time series nomenclature.

If the current observation of the time series can be expressed as a linear function of the previous values of the series and a random shock, the analysis is referred to as an "autoregressive" (AR) process. If the current observation is a linear function of the current and previous disturbance terms or shocks, the analysis is referred to as a "moving average" (MA) process. A combination of autoregressive and moving average components can often be used to explain the sequence of observations. A model using both autoregressive and moving average terms is called an ARMA process. In the case where differencing is used along with autoregressive and moving average components, the process is referred to as an "autoregressive, integrative, moving average" or ARIMA model.

Box and Jenkins (1976) provided a set of symbolic operators for describing ARIMA models in a concise manner.

If we let Z_t be the deviation of an observation from its mean value, then the AR model may be represented as

$$Z_t = \phi_1 Z_{t-1} + \phi_2 Z_{t-2} + \cdots + \phi_p Z_{t-p} + a_t \tag{A.1}$$

Where the ϕ's are the AR parameters, and the a_t is the random shock term. In this process it can be seen that the series Z_t is "regressed" against past values of itself.

Equation (A.1) is referred to as an autoregressive process of order "p."

Alternatively, AR models can be represented using the backshift operator notation. The backshift operator, B, is defined as:

$$B^k Z_t = Z_{t-k}. \qquad (A.2)$$

Note that B shifts the time subscript backward by the exponent of B.

Equation (A.1) may now be represented as

$$Z_t = (\phi_1 B + \phi_2 B^2 + . . . + \phi_p B^p) \qquad (A.3)$$

and letting

$$\phi(B) = 1 - \phi B - \phi_2 B^2 - . . . . - \phi_p B^p \qquad (A.4)$$

Likewise, equation (A.1) can be represented symbolically by:

$$\phi(B) Z_t = a_t. \qquad (A.5)$$

The MA class of models may be represented symbolically as:

$$Z_t = a_t - \theta_1 a_{t-1} - \theta_2 a_{t-2} - . . . . - \theta_q a_{t-q} \qquad (A.6)$$

Where Z_t is the deviation of the observation from its mean, a_t is the ramdom shock term at time "t," and the 's are the MA parameters. Equation (4.9) is referred to as a moving-average process of order "q."

Employing the backshift operator, equation (A.6) can be represented as:

$$Z_t = (1 - \theta_1 B - \theta_2 B^2 - . . . . - \theta_q B^q) a_t \qquad (A.7)$$

Letting

$$(B) = 1 - \theta_1 B - \theta_2 B^2 - . . . . - \theta_q B^q \qquad (A.8)$$

then Equation A.9 may be represented compactly as

$$Z_t = \theta(B)\, a_t \qquad \text{(A.9)}$$

An important reason for employing a moving average process is that the number of parameters can be greatly reduced. Parsimony is the concept of adequately modeling the process with the fewest number of parameters. In the interest of parsimony, a mixed model incorporating both autoregressive and moving average components (i.e., an ARMA process) may lead to a model having fewer parameters than either an AR or a MA process used alone.

In the case of an ARMA model, the current observation is a function of past values and past disturbances. This model may be written as:

$$Z_t = \phi_1 Z_{t-1} + \dots + \phi_p Z_{t-p} + a_t - \theta_1 a_{t-1} - \dots - \theta_q a_{t-q} \qquad \text{(A.10)}$$

Combining the compact representation of the AR model in equation (A.5) with the compact representation of the MA process in equation (A.9), the mixed ARMA model in equation (A.11) may be written as

$$\phi(B) Z_t = \phi(B)\, a_t \qquad \text{(A.11)}$$

Often a time series has no affinity for a mean value. If this is the case, it is said to be nonstationary and certain transformations are necessary to render the series stationary. A stationary process is a process in which the joint distribution ($Z_1, \dots, Z_t$ and Z_{t+1}) is invariant with regard to displacements in time. Thus, a time series process is stationary if the mean and variance are constant over time, and if the autocorrelation between values of the process depends only on the distance between the two time points and not on the time period itself.

To construct a time series model such as that in equation (A.11) it is first necessary to render the series stationary, using transformations such as taking the natural logarithm or dividing by a scale variable. Often, first and higher order order differencing can be used to induce stationarity. For example, the process may be nonstationary, but the differences may be stationary. This can be represented as:

$$\phi(B)(1 - B)\ Z_t = \phi(B)\ a_t \tag{A.12}$$

or in the general form

$$\phi(B)(1 - B)\ ^dZ_t = (B)\ a_t \tag{A.13}$$

where "d" is the number of consecutive differences.

In sum, the general class of Box-Jenkins autoregressive, integrated, moving average (ARIMA) models can be expressed as:

$$(1 - \phi_1 B - \ldots - \phi_p B^p)\ (1 - B)^d\ Z_t = (1 - \theta_1 B - \ldots\ \theta_q B^q) q_t \tag{A.14}$$

The θ_m, m = 1,2,...p, are the autoregressive parameters whereas θ_m, m = 1,2,...,q are the moving average parameters. The model is based on the assumption that the series being modeled is stationary, or that stationarity is induced by differencing the series an appropriate number of times, d. In simplified notation, we may denote the general model as ARIMA (p,d,q).

II. MODEL BUILDING

The Box-Jenkins iterative approach for constructing linear time series models follows a three stage process. These stages are identification, estimation, and diagnostic checking. The following paragraphs describe these steps in the model building process.

A. Identification

In the identification stage, one selects several possible models from the general class of ARIMA models presented earlier. There are two basic tools available for the identification of time series models, the autocorrelation function and the partial autocorrelation function. Several models are usually identified because the sample autocorrelation (ACF) and partial autocorrelations (PACF) are subject to sampling error and may be difficult to match with a specific ARIMA process.

The first step in the identification process is to examine the series in order to determine the transformations necessary to convert the original series into a stationary series. This is accomplished by plotting the data and calculating the sample autocorrelation function. If the sample autocorrelation function dies out slowly, nonstationarity is suspected and further differencing is suggested. When the spikes in the ACF die out rapidly, there is no need for additional differencing.

Next, the ACF and the PACF of the differenced series are calculated. Each form of the ARIMA model has a theoretical ACF and PACF. The orders of p and q are determined by comparing the sample ACF and PACF with the theoretical functions for a particular form of the model. An AR model of order p is characterized by an ACF that tails off after lag p and a PACF that cuts off abruptly at lag p. Similarly, a MA model of order q exhibits an ACF that cuts off abruptly at lag q and a PACF that tails off after lag q. Finally, if both the ACF and PACF die off slowly it is an indication of a mixed ARMA process.

B. Estimation

For the preliminary models identified previously, the values for the autoregressive and moving average parameters are then determined. Preliminary estimates of the parameter values are obtained by comparing the values of the sample autocorrelations with the parameter representation of the population autocorrelations and then solving for each individual parameter. An iterative process is then used to obtain the maximum likelihood estimates of the parameters.

C. Diagnostic Checking

After the parameter estimates for the identified models are generated, several checks need to be made on the adequacy of the models. One check is the significance of the coefficients of the estimated models. Another check on the estimated models is whether their residuals are random noise. If a posited model adequately describes the underlying process then the residuals should exhibit no significant pattern in their autocorrelation function. Another factor used in determining the appropriateness of a model is parsimony. As mentioned earlier, parsimony is the concept of adequately representing the model with the smallest number of parameters.

A plot of the residuals and their autocorrelation function is helpful in checking for patterns in the residuals. From the plot of the residuals, one can inspect for the stationarity of the residuals and for constant variance.

Two statistics have been developed to test if the residuals are serially uncorrelated. The first of these is the Box-Pierce Q statistic which is compared to the chi-square distribution. Ljung and Box (1978) reported that the statistic was biased downward. They proposed a statistic which eliminated the bias found in the Box-Pierce statistic.

The previous sections of this appendix discussed the categories of time series models. The symbolic notation used to describe ARIMA models was presented. In addition, the three steps of the model building process were summarized. Those desiring a more comprehensive discussion of time series models should refer to Box and Jenkins (1976).

FIGURE A.1

AUTOCORRELATION FUNCTION FOR THE ARIMA MODEL

```
ACF

          -1.0  -.8  -.6  -.4  -.2   .0   .2   .4   .6   .8  1.0
            +----+----+----+----+----+----+----+----+----+----+
 1   -.386                XXXXXXXXXXX
 2   -.141                       XXXXX
 3    .082                           XXX
 4   -.012                           X
 5   -.067                         XXX
 6    .100                           XXX
 7   -.131                        XXXX
 8    .034                           XX
 9    .019                           X
10    .166                           XXXXX
11   -.091                         XXX
12   -.095                         XXX
13    .040                           XX
14   -.079                         XXX
15    .134                           XXXX
16   -.029                          XX
17   -.066                         XXX
18    .052                           XX
19   -.081                         XXX
20    .067                           XXX
21    .003                           X
```

FIGURE A.2

PARTIAL AUTOCORRELATION FUNCTION

FOR THE ARIMA MODEL

```
PACF

            -1.0  -.8  -.6  -.4  -.2   .0   .2   .4   .6   .8  1.0
              +----+----+----+----+----+----+----+----+----+----+
 1   -.386                      XXXXXXXXXXX
 2   -.341                       XXXXXXXXXX
 3   -.162                            XXXXX
 4   -.119                             XXXX
 5   -.158                            XXXXX
 6   -.019                                X
 7   -.172                            XXXXX
 8   -.124                             XXXX
 9   -.125                             XXXX
10    .156                                XXXXX
11    .115                                XXXX
12   -.013                                X
13   -.318                                X
14   -.180                           XXXXXX
15    .048                                XX
16    .008                                X
17    .016                                X
18    .314                                X
19   -.191                           XXXXXX
20   -.099                              XXX
21   -.110                             XXXX
```

APPENDIX B

EMPIRICAL TESTS OF THE RELATIONSHIP BETWEEN INFLATION AND ASSET RETURNS: OTHER INFLATION PROXIES

TAPLE B.1

EFFECTS OF CHANGES IN EXPECTATIONS OF INFLATION:
DISTRIBUTED LAG INFLATION PROXY: 1959-1983

$$i_t = \alpha + \beta_1 \pi_t + \beta_2 (P_t - \pi_t) + \beta_3 (\pi_t - \pi_{t-1}) + \varepsilon_t$$

Asset	α	β_1 (T-Ratio)	β_2 (T-Ratio)	β_3 (T-Ratio)	F	R^2 [a]	D.W.[b]
TBILL	.0326 (2.91)	.7181 (3.82)	.2553 (3.33)	-.1508 (-.8729)	6.23	.2608	1.90
GVTBND	.0511 (1.69)	.6242 (1.02)	-1.9500 (-2.06)	-2.4252 (-1.15)	3.19	.1302	2.00
CRPBND	.0680 (2.08)	.4434 (.6695)	-2.2947 (-2.25)	-4.3410 (-1.92)	5.16	.2195	2.03
COMMOD	.0474 (.7010)	.1371 (.0998)	1.4254 (1.25)	.2748 (.0817)	.51	.0354	1.96
CMMSTK	.1284 (2.21)	1.3550 (1.15)	-5.1974 (-2.96)	-.8731 (-.2245)	3.80	.1600	2.03
SMLLSTK	.1907 (1.86)	3.7181 (1.79)	-6.9262 (-2.21)	-4.3011 (-.6214)	3.16	.1284	1.98

[a]Adjusted for degrees of freedom.

[b]Obtained from the maximum likelihood iterative technique to correct the first order serial correlation of the error.

TABLE B.2

EFFECTS OF CHANGES IN EXPECTATIONS OF INFLATION:
DISTRIBUTED LAG INFLATION PROXY: 1959-1983

$$i_t = \alpha + \beta_1\pi_t + \beta_2(P_t - \pi_t) + \beta_3(\pi_t - \pi_{t-1}) + \varepsilon_t$$

Asset	α	β_1 (T-Ratio)	β_2 (T-Ratio)	β_3 (T-Ratio)	F	R^2 [a]	D.W.[b]
AAABND	.0713 (2.77)	.4000 (3.73)	.0554 (1.48)	-.1567 (-1.82)	3.12	.1266	1.27
BAABND	.0779 (3.01)	.5372 (4.61)	.0198 (.4894)	-.3073 (-3.25	5.85	.2464	1.40
INDBND	.0716 (3.04)	.4302 (3.86)	.0452 (1.17)	-.1812 (-2.02)	3.48	.1445	1.39
UTILBND	.07575 (2.62)	.5023 (4.50)	.0483 (1.25)	-.2828 (-3.15)	5.32	.2259	1.34
MUNI	.0530 (3.27)	.3229 (2.67)	-.0139 (-.3256)	-.1914 (-1.95)	2.20	.0768	1.23
PFD	.0684 (3.68)	.4051 (4.69)	.0319 (1.06)	-.2051 (-2.96)	6.65	.2757	1.66

[a] Adjusted for degrees of freedom.

[b] Obtained from the maximum likelihood iterative technique to correct the first order serial correlation of the error.

TABLE B.3

EFFECTS OF CHANGES IN EXPECTATIONS OF INFLATION:
ADAPTIVE INFLATION PROXY: 1959-1983

$$i_t = \alpha + \beta_1 \pi_t + \beta_2 (P_t - \pi_t) + \beta_3 (\pi_t - \pi_{t-1}) + \epsilon_t$$

Asset	α	β_1 (T-Ratio)	β_2 (T-Ratio)	β_3 (T-Ratio)	F	R^2 [a]	D.W. [b]
TBILL	.0261 (2.56)	.8575 (4.59)	.2712 (3.66)	-.1825 (-1.17)	8.73	.3258	1.83
GVTBND	.04212 (1.49)	.7565 (1.33)	-1.823 (-2.28)	-3.4825 (-1.71)	4.85	.1940	2.03
CRPBND	.0600 (1.95)	.6029 (.9898)	-2.2588 (-2.70)	-5.6627 (-2.68)	7.89	.3001	2.05
COMMOD	.0427 (.5768)	.5091 (.3415)	.7203 (.5056)	4.6388 (1.50)	.91	.0569	1.87
CMMSTK	.1188 (2.12)	1.0302 (.9144)	-3.566 (-2.29)	-4.6046 (-1.16)	3.53	.1367	2.05
SMLLSTK	.1792 (1.75)	3.1937 (1.55)	-4.7295 (-1.71)	-8.9941 (-1.30)	2.90	.1064	1.99

[a] Adjusted for degrees of freedom.

[b] Obtained from the maximum likelihood iterative technique to correct for the first order serial correlation of the error.

TABLE B.4
EFFECTS OF CHANGES IN EXPECTATIONS OF INFLATION:
ADAPTIVE INFLATION PROXY: 1959-1983

$$i_t = \alpha + \beta_1 \pi_t + \beta_2 (P_t - \pi_t) + \beta_3 (\pi_t - \pi_{t-1}) + \epsilon_t$$

Asset	α	β_1 (T-Ratio)	β_2 (T-Ratio)	β_3 (T-Ratio)	F	R^{2a}	D.W.[b]
AAABND	.0672 (2.87)	.5004 (4.21)	.0634 (1.76)	-.2176 (-2.69)	4.57	.1824	1.25
BAABND	.0711 (3.22)	.6914 (5.56)	.3194 (.8460)	-.3830 (-4.52)	9.44	.3454	1.35
INDBND	.0667 (3.11)	.5555 (4.60)	.0499 (1.36)	-.2779 (-3.38)	5.83	.2317	1.42
UTILBND	.0697 (2.82)	.6480 (5.36)	.0654 (1.78)	-.3148 (-3.82)	8.15	.3089	1.23
MUNI	.0467 (3.68)	.4550 (3.48)	-.0029 (-.0698)	-.2385 (-2.61)	4.10	.1627	1.24
PFD	.0639 (3.90)	.4818 (4.93)	.0479 (1.61)	-.2063 (-3.09)	7.53	.2897	1.72

[a]Adjusted for degrees of freedom.

[b]Obtained from the maximum likelihood iterative technique to correct for the first order serial correlation of the error.

TABLE B.5

EFFECTS OF CHANGES IN EXPECTATIONS OF INFLATION:
EXTRAPOLATIVE INFLATION PROXY: 1959-1983

$$i_t = \alpha + \beta_1\pi_t + \beta_2(P_t - \pi_t) + \beta_3(\pi_t - \pi_{t-1}) + \varepsilon_t$$

Asset	α	β_1 (T-Ratio)	β_2 (T-Ratio)	β_3 (T-Ratio)	F	R^2 [a]	D.W.[b]
AAABND	.0690 (2.80)	.4251 (3.87)	.0700 (1.97)	-.0906 (-1.17)	4.35	.1732	1.27
BAABND	.0745 (3.11)	.5592 (4.46)	.0371 (.9141)	-.2343 (-2.66)	5.39	.2155	1.37
INDBND	.0689 (3.00)	.4657 (4.06)	.5781 (1.55)	-.1360 (-1.68)	4.50	.1800	1.41
UTILBND	.0738 (2.77)	.4856 (3.94)	.0658 (1.65)	-.1900 (-2.19)	3.91	.1539	1.32
MUNI	.0494 (3.61)	.3742 (3.00)	.0010 (.2508)	-.1316 (-1.48)	3.21	.1211	1.22
PFD	.0653 (3.80)	.4411 (4.90)	.0373 (1.28)	-.2083 (-3.29)	7.29	.2855	1.77

[a]Adjusted for degrees of freedom.

[b]Obtained from the maximum likelihood iterative technique to correct for the first order serial correlation of the error.

TABLE B.6

EFFECTS OF CHANGES IN EXPECTATIONS OF INFLATION: EXTRAPOLATIVE INFLATION PROXY: 1959-1983

$$i_t = \alpha + \beta_1\pi_t + \beta_2(P_t - \pi_t) + \beta_3(\pi_t - \pi_{t-1}) + \epsilon_t$$

Asset	α	β_1 (T-Ratio)	β_2 (T-Ratio)	β_3 (T-Ratio)	F	R^2 [a]	D.W. [b]
TBILL	.0306 (2.87)	.7310 (3.91)	.2810 (3.83)	-.0185 (-.1222	8.01	.3046	1.96
GVTBND	.0568 (1.39)	.7758 (1.64)	-2.5760 (-2.89)	-5.0299 (-1.63)	8.79	.3274	2.05
CRPBND	.0568 (1.96)	.7758 (1.31)	-2.5760 (-3.36)	-5.0299 (-2.62)	8.79	.3274	2.05
COMMOD	.0423 (.6014)	.4356 (.3024)	1.4148 (.9974)	-1.1302 (-.3697)	.40	.0262	1.95
CMMSTK	.1183 (2.08)	.9464 (.8105)	-3.1379 (-2.15)	-5.3991 (-1.50)	3.12	.1169	2.04
SMLLSTK	.1731 (1.67)	3.3609 (1.58)	-4.738 (-1.82)	-8.4873 (-1.34)	2.71	.0967	1.99

[a] Adjusted for degrees of freedom.

[b] Obtained from the maximum likelihood iterative technique to correct for the first order serial correlation of the error.

TABLE B.7

EFFECTS OF CHANGES IN EXPECTATIONS OF INFLATION: MONETARY INFORMATION INFLATION PROXY: 1959-1983

$$i_t = \alpha + \beta_1\pi_t + \beta_2(P_t - \pi_t) + \beta_3(\pi_t - \pi_{t-1}) + \varepsilon_t$$

Asset	α	β_1 (T-Ratio)	β_2 (T-Ratio)	β_3 (T-Ratio)	F	R^2 [a]	D.W.[b]
AAAABND	.0714 (2.72)	.3468 (3.08)	.0543 (1.40)	-.1408 (-1.63)	2.05	.0614	1.37
BAABND	.0779 (2.95)	.4416 (3.46)	.0205 (.4649)	-.2553 (-2.60)	3.05	.1135	1.35
INDBND	.0724 (2.87)	.3523 (2.97)	.0428 (1.05)	-.1648 (-1.81)	1.87	.0515	1.37
UTILBND	.0758 (2.64)	.4205 (3.49)	.0481 (1.16)	-.2403 (-2.59)	3.17	.1195	1.33
MUNI	.0542 (3.49)	.2443 (1.92)	-.0140 (-.3152)	-.1599 (-1.62)	1.18	.1133	1.21
PFD	.0681 (3.57)	.3413 (3.66)	-.0274 (.8532)	-.2015 (-2.81)	4.31	.1712	1.64

[a] Adjusted for degrees of freedom.

[b] Obtained from the maximum likelihood iterative technique to correct the first order serial correlation of the error.

TABLE B.8

EFFECTS OF CHANGES IN EXPECTATIONS OF INFLATION: MONETARY INFORMATION INFLATION PROXY: 1959-1983

$$i_t = \alpha + \beta_1\pi_t + \beta_2(P_t - \pi_t) + \beta_3(\pi_t - \pi_{t-1}) + \varepsilon_t$$

Asset	α	β_1 (T-Ratio)	β_2 (T-Ratio)	β_3 (T-Ratio)	F	R^2[a]	D.W.[b]
TBILL	.0266 (2.64)	.8492 (4.81)	.2363 (3.18)	-.2639 (-1.65)	9.04	.3345	1.95
GVTBND	.0488 (1.61)	.5182 (.8139)	-1.6204 (-1.761)	-3.3910 (-1.74)	2.91	.1064	2.02
CRPBND	.0687 (2.03)	.3475 (.4914)	-2.2615 (-2.28)	-4.4792 (-2.13)	4.38	.1744	2.04
COMMOD	.0357 (.5033)	.6709 (.4581)	.9675 (.6208)	1.695 (.5261)	.32	.0210	1.93
CMMSTK	.1190 (2.07)	1.4768 (1.22)	-5.6206 (-3.31)	.8289 (.2307)	3.90	.2064	2.04
SMLLSTK	.1741 (1.75)	4.082 (1.95)	-8.1035 (-2.70)	-.9515 (-.1492)	3.34	.1274	1.97

[a]Adjusted for degrees of freedom.

[b]Obtained from the maximum likelihood iterative technique to correct the first order serial correlation of the error.

TABLE B.9

EFFECTS OF CHANGES IN EXPECTATIONS OF INFLATION:
LIVINGSTON INFLATION PROXY: 1959-1983

$$i_t = \alpha + \beta_1\pi_t + \beta_2(P_t - \pi_t) + \beta_3(\pi_t - \pi_{t-1}) + \varepsilon_t$$

Asset	α	β_1 (T-Ratio)	β_2 (T-Ratio)	β_3 (T-Ratio)	F	R^2 [a]	D.W. [b]
TBILL	.0233 (2.35)	.9252 (5.33)	.2164 (2.99)	-.3635 (-2.60)	10.65	.3762	1.95
GVTBND	.0462 (1.67)	.3581 (.6490)	-.6576 (-.7792)	-7.1311 (-3.81)	6.73	.2636	2.01
CRPBND	.0671 (2.11)	.1419 (.2238)	-1.299 (-1.38)	-7.6689 (-3.76)	7.45	.2873	2.01
COMMOD	.0413 (.5976)	.5196 (.3772)	1.0601 (.6386)	1.8370	.39	.0253	1.94
CMMSTK	.1322 (2.20)	.5276 (.4411)	-3.3583 (-1.86)	-4.3636 (-1.10)	2.35	.0778	2.04
SMLLSTK	.1924 (1.86)	2.8858 (1.40)	-5.8655 (-1.87)	-4.9237 (-.7101)	2.26	.0731	2.00

[a] Adjusted for degrees of freedom.

[b] Obtained from the maximum likelihood iterative technique to correct the first order serial correlation of the error.

TABLE B.10

EFFECTS OF CHANGES IN EXPECTATIONS OF INFLATION: LIVINGSTON INFLATION PROXY: 1959-1983

$$i_t = \alpha + \beta_1\pi_t + \beta_2(P_t - \pi_t) + \beta_3(\pi_t - \pi_{t-1}) + \varepsilon_t$$

Asset	α	β_1 (T-Ratio)	β_2 (T-Ratio)	β_3 (T-Ratio)	F	R^{2} [a]	D.W. [b]
AABND	.0648 (2.89)	.5314 (5.03)	.4791 (1.40)	-.2746 (-3.74)	6.84	.2674	1.23
BAABND	.0726 (3.25)	.5551 (4.30)	.0300 (.7196)	-.3182 (-3.54)	5.04	.2014	1.19
INDBND	.0658 (3.11)	.5231 (4.60)	.0427 (1.17)	-.2899 (-3.67)	5.73	.2282	1.32
UTILBND	.0704 (2.82)	.5527 (4.58)	.4987 (1.28)	-.2557 (-3.05)	3.57	.2221	1.09
MUNI	.0463 (3.64)	.4344 (2.52)	-.1371 (-.3363)	-.2614 (-3.01)	4.30	.1709	1.11
PFD	.0650 (3.98)	.3920 (4.06)	.0420 (1.35)	-.2386 (-3.55)	5.45	.2177	1.57

[a] Adjusted for degrees of freedom.

[b] Obtained from the maximum likelihood iterative technique to correct the first order serial correlation of the error.

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