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Prices, Interest Rates, Actual and Anticipated Inflation:
A Theory and Some Evidence*

by Allan H. Meltzer

The relations between money, prices, interest rates and inflation form the core of classical and neo-classical monetary theory. Changes in money affect the price level permanently and the rate of interest only during the transition from one equilibrium to the next. Changes in the rate of inflation affect market interest rates and possibly real rates as well.

The magnitude of the responses and truth of the propositions are matters in dispute. Among the central issues in the dispute are the degree to which inflation is monetary phenomenon and the extent to which market interest rates fully reflect the anticipated rate of inflation. Related, and no less important, is the effect of actual and anticipated inflation on the real rate of interest, saving and the rate of capital accumulation.

Resolution of these issues requires more care than is frequently given to a central distinction in monetary theory: the difference between inflation and the adjustment of the price level. All price changes are not inflationary; some are once-and-for-all adjustments of the level of prices. Tests of the propositions of monetary theory usually do not distinguish the two.

A typical estimate of the effect of inflation on market interest rates uses a weighted average of past rates of price change to measure the currently anticipated rate of inflation. Recent work on efficient markets[] and rational expectations[] raises doubt about the accuracy and reliability of such measures. A much older tradition in

monetary theory questions the rationale. All increases in the measured price level do not contribute to anticipated inflation. Some are once-and-for-all adjustments that have no effect on inflation and no lasting effect on market rates of interest. Measured rates of price change in any finite period combines once-and-for-all adjustment and fully anticipated inflation. The problem for economic analysis is to separate the two.

Real rates of interest are often assumed to be constant in discussions of inflation and of the effect of inflation on interest rates. This, too, is a denial of standard, economic theory. Theory implies that real rates of interest are constant only in a steady state -- where tastes and productive opportunities are fixed and the fully anticipated rate of inflation is constant. Evidence of the so-called "Fisher effect" or tests of the relation between prices, inflation and rates of return that assume efficient markets[] but depend on assumed constancy of the real rate are of limited value, therefore.

There are some additional gaps between the theory relating prices, interest rates and inflation and the evidence that purports to support or reject the theory. Output and employment fluctuate in response to monetary and real shocks. Real wages fluctuate also. Phillips curves provide a popular explanation of the links between output or employment and rates or price change.

Real rates of return should respond to differences between the actual and expected rate of price change and to fluctuations in output. It is difficult to accept a theory that assumes real rates are constant

while real wages, employment, output and prices fluctuate. Standard theory implies the opposite [].

A main problem in estimating economic relations and testing economic theory is to separate anticipated and actual values. Recent work on rational expectations, particularly the work of Lucas [] and Sargent [] casts doubt on the validity of many of the estimates of anticipations obtained by taking a weighted average of past income. Below, I propose an alternative approach that seems more consistent with rational behavior.

The following section develops a model that relates output, income, rates of price change and inflation to capital, labor force and to monetary and fiscal variables. I use the theory to determine anticipated income and the anticipated rate of price change and to estimate these variables for most of the years in this century. The estimated values of anticipated income and inflation permit a test of classical and neo-classical propositions of the relation between interest rates, actual and anticipated rates of price change. Discussion of particular periods that have absorbed the attention of economists particularly the thirties, sixties and seventies provides information about the power of the hypothesis under conditions of inflation and deflation. A conclusion discusses some limitations and summarizes some principal findings.

A Theory of Income, Inflation and Prices

Individuals hold anticipations of their lifetime incomes and consumption. The anticipations are consistent. Labor and leisure choice, consumption

plan, and anticipated income are part of a rational plan. Each consumer behaves as if he maximizes the utility of consumption subject to a budget constraint, the present value of his wealth. The theory of consumer behavior is well-known from the work of Friedman [] and Modigliani and Brumberg [].

There is no risk aversion, but there is uncertainty about the timing of receipts and payments. Nature is one source of uncertainty; government is the other. Crops fail and harvests are bountiful. There are inventions and innovations. The government hires labor, issues debt and prints money, so shocks are both real and nominal and there is uncertainty about both nominal and real values for the individual and in the aggregate.

Tangible wealth consists of real assets -- capital and inventories of durables -- debt and real money balances. When current receipts differ from the anticipated income of the period, individuals maintain consumption and adjust wealth. Receipts in excess of anticipated income are saved; wealth held in the form of money, bonds and real assets increases. When receipts are less than anticipated income, asset stocks decline.

The basic theory relating consumption to permanent or anticipated income is well-known as the permanent income theory []. The general idea was not unknown to Keynes (1936, Appendix to Chapter 6) and to classical writers. The use of money as a buffer that individuals hold to bridge the gap between receipts and payments is a classical justification for money holding.

If money is a buffer, current spending fluctuates around more stable consumption. When receipts exceed anticipated income, spending and money balances increase by less than receipts. Borrowing and lending permit consumers to narrow the gap between consumption and spending. Households with receipts in excess of income lend to households with income in excess of receipts.

This section applies the theory of individual behavior to aggregates. There are shocks to the system, so aggregate receipts may exceed or fall short of anticipated aggregate income. Shocks may be real or monetary. Both types cause aggregate receipts to differ from aggregate anticipated income. Aggregate consumption depends on aggregate income; aggregate spending depends on aggregate receipts. Shocks to the system -- both real and monetary shocks -- cause aggregate receipts to differ from aggregate income and therefore cause aggregate spending to differ from aggregate consumption.

Consumption, spending, income and receipts are composite goods. Fluctuations in relative prices of current output do not affect aggregates, but the relative price of current and future consumption and spending changes. Real rates of interest fluctuate from period to period.

In other respects, the economy is a classical or neo-classical economy. There is a steady state path of aggregate, anticipated income, denoted g . The steady state of the economy is described by eq. (1).

$$(1) \quad \mu + \hat{V}_g = \pi + g$$

where μ is maintained rate of monetary growth and π is the fully anticipated rate of inflation. On any path, $\mu = \pi$, so the growth rate of steady state velocity, \hat{V}_g equals the steady state growth rate of real income.

In a world of certainty, stability and full information, the economy moves along a path g . Aggregate real income equals aggregate output. The distribution of income can change, but changes in the distribution do not affect the aggregate. Aggregate income is determined by real resources.

Current aggregate receipts, y_t , fluctuate around aggregate income as shown in (2), where

$$(2) \quad y_t = y_0 e^{gt} + \epsilon_{1,t}$$

$\epsilon_{1,t}$ is a random variable. If $\epsilon_{1,t}$ is serially uncorrelated with zero mean and constant variance, rational individuals should not attempt to forecast real receipts or revise anticipated income on the basis of current or past receipts. Moreover, (2) denies that current or past monetary and fiscal policies have any effect on current receipts.

Eq. (2) makes income depend solely on the determinants of the growth path. The error term, $\epsilon_{1,t}$, is the deviation of current receipts from income that is sometimes called "transitory income." Equation (2) counts all fluctuations in income as transitory income.

It is a peculiar and, I believe, untenable assumption that agents have no information about fluctuations. Rational individuals with a knowledge of the past know that successive differences between income and receipts are serially correlated. Economists have long recognized that expansions and recessions last more than a year. ¹ Rational

individuals use this and other available information to forecast current receipts.

Fluctuations in income may be fully described by equation (2), but fluctuations in receipts are not. Two options are open. Either treat ϵ_1 as a serially correlated disturbance or specify the determinants of anticipated receipts more fully. I have chosen the latter approach.

Each individual acts as if his anticipated current receipts depend on the way in which the community uses available resources. Anticipated aggregate receipts, y^* , is obtained by summing individual anticipations to obtain (3).

$$(3) \quad y^* = H^*(K, L, lg, \frac{D}{p}, N)$$

The arguments of the H^* -function are: K , the stock of private capital; L , the total labor force; lg , the number of workers absorbed by government; $\frac{D}{p}$, the outstanding stocks of government debt and base money representing the heritage of past fiscal and monetary policy; and N , the population. The H -function is homogeneous of degree one in N .

The financing of past government budgets and balances of payments determines the current stocks of financial assets D , consisting of debt (S) and base money (B) held by the public. The real values of these stocks at the start of the period are known. Future increments are unknown and subject to erratic variation.² Rational individuals do not attempt to forecast either the timing or the magnitude of current changes in B and S .

The real stock of debt, $\frac{S}{p}$, substitutes for real capital in portfolios. If government debt displaces private capital, the effect of $\frac{S}{p}$ on y^* is negative.³

Recent work on the role of the government budget implies that increased real indebtedness lowers and increased real base money raises the level of output and real anticipated receipts []. The real value of base money balances also reflects the response to technological changes that affect the payments system. Changes in payments arrangements are a type of disembodied technical change. Neither the current capital stock nor the labor force is affected. But, improvements in payments technology permit agents to reallocate effort from making payments to both employment and leisure. ⁴ Increased productivity of exchange arrangements increases anticipated receipts and the demand for base money. Increases in the demand for base money lower the price level, so the real stock of base money increases. A breakdown of payments arrangements reduces the productivity of exchange arrangements, lowers anticipated receipts and the demand for base money.

Some notable examples of changes in exchange arrangements occurred in this century. The introduction of the Federal Reserve system, the use of the dollar as a principal world money, and the spread of deposit banking are examples of increases in the productivity of monetary arrangements. The breakdown of the gold standard after 1931 is one example of a reduction in the productivity of exchange arrangements.

To incorporate the effects of base money and debt on anticipated receipts and recognize homogeneity in population, N , substitute for $\frac{D}{P}$ and rewrite (3) as

$$(4) \quad y^* = H(K^a, L^b, g^c, \frac{S}{p}^d, e^{kB/p})N \quad a, c, k > 0; b, d < 0$$

Increases in capital, real base money and the demand for labor by government increase anticipated per capita receipts.⁵ Increases in the labor force and debt reduce anticipated receipts. The value of current real receipts is, as before, a random variable

$$(5) \quad y_t = y_t^* \epsilon_{3,t}$$

Equation (5) differs from (2). Agents are permitted more information about the current position of the economy and the effects of the current position on their current receipts. Actual receipts, y , fluctuate around income in much wider swings than around anticipated receipts. The gap between income and receipts, $\epsilon_{1,t}$ of eq. (2), describes the position of the economy in the business cycle. The gap between anticipated and actual receipts, $\epsilon_{3,t}$ in eq. (5) describes the error that agents make in forecasting receipts. These errors are the result of real shocks, the well-known risks inherent in nature and trade, and unpredictable changes in government policies.

In a steady state, income and anticipated receipts are identical. Fluctuations in the economy that create discrepancies between income and receipts cause spending to differ from consumption. Consumption, the rate of use of resources, depends on income; spending, the rate of purchase of goods and services depends on receipts. The steady state path of consumption and income is described by eq. (1). Rational agents base their consumption plans on their income but base planned current spending on anticipated current receipts. When anticipated receipts are above or below income, planned spending is above or below consumption.

The growth rate of planned spending is related to the growth rate of anticipated receipts by (6).

$$(6) \quad \mu + \hat{V}^* = \hat{y}^* + \pi$$

The anticipated rate of inflation, π , equals the anticipated rate of monetary growth, μ , as before, but the anticipated growth of velocity, \hat{V}^* , now depends on anticipated real receipts, \hat{y}^* . When $\hat{y}^* = g$, $\hat{V}^* = \hat{V}_g$.

The current rate of price change is not identical to π , and current spending is not identical to planned spending. Actual spending is MV and actual receipts are the sum of the receipts of individual agents, $py = \sum p_i y_i$. The growth of actual spending and receipts in any year is obtained by taking logarithms of the quantity equation, $MV = py$, and differentiating to obtain (7),

$$(7) \quad \hat{M} + \hat{V} = \hat{y} + \hat{p}$$

where \hat{M} and \hat{V} are the growth rates of money and actual velocity and \hat{p} and \hat{y} are the growth rates of prices and current receipts.

Differences between current and anticipated spending and receipts cause the current rate of price change to differ from the anticipated rate of inflation. Subtracting eq. (7) from eq. (6) and rearranging terms, we obtain an equation for the difference between the actual and anticipated rate of price change.

$$\hat{p} - \pi = \hat{y}^* - \hat{y} + \hat{V} - \hat{V}^* + \hat{M} - \mu$$

By previous assumption, $\mu = \pi$, and from eq. (5) $(\hat{y}^* - \hat{y})$ is the change per period in the error made in forecasting aggregate current receipts. Let

$\Delta \epsilon y$ denote the rate of change of the error. The current rate of price change is then given by (8).

$$(8) \quad \hat{p} = \hat{M} + \hat{V} - \hat{V}^* - \Delta \epsilon y$$

To complete the analysis of the current rate of price change, we must specify the determinants of current and anticipated relative rates of change of velocity. The demand function for money provides the underlying analysis. The current demand for nominal money balances depends on current nominal receipts y_p , nominal stocks of debt and money, S and B , on expected and actual prices, p and p^* , and on the market rate of interest, $r + \pi$.

$$M = L(r + \pi, p, p^*, y_p, S, B) \quad L_1, L_3 < 0$$

$$L_2, L_4, L_5, L_6 > 0$$

The demand function is homogeneous of first degree in prices and the value of financial assets. Much empirical work suggests that the elasticity of the demand for money with respect to current y is less than or equal to unity. If the elasticity is unity, the relative rate of change of current velocity is independent of current real receipts. Velocity, the ratio of real income to real balances is

$$V = V\left(r + \pi, \frac{p^*}{p}, y, \frac{S}{p}, \frac{B}{p}\right) \quad V_1, V_2, V_3 > 0$$

$$V_4, V_5 < 0$$

Differentiating and then multiplying to form elasticities, we can express \hat{V} , the relative rate of change of current velocity in terms of the relative

rates of change of its determinants. Elasticities are denoted ϵ and relative rates of change are shown by $\hat{}$.

$$\hat{V} = \epsilon(V,r)\hat{r} + \epsilon(V,\Pi)\hat{\Pi} + \frac{1}{p} \left[\epsilon(V,p^*)\hat{p}^* + \epsilon(V,S)\hat{S} + \epsilon(V,B)\hat{B} \right] \\ - \epsilon(V,p)\hat{p}\left(\frac{p^*+B+S}{2}\right) + \epsilon(V,y)\hat{y}$$

The real rate of interest is neither constant nor given in the determination of \hat{V} . Real rates fluctuate as the economy fluctuates in response to changes in anticipations of government policies and in their effects on prices and output. The real rate that governs portfolio choice and inter temporal resource allocation in any year is the product of an expected return to capital, e , and the ratio of the price level of current output to the price level of existing assets.⁶ Direct measurement of the price level of existing assets requires information on the replacement cost of a large number of diverse assets. An alternative is to analyze the relation of asset prices to output prices.

Suppose that all reproducible, real assets are valued at expected replacement cost. These costs are not known with certainty. There are often large marginal costs of acquiring information about replacement costs of particular assets. Constructing an index of current replacement costs is a formidable task. Fortunately, there is an alternative. Replacements of capital (or additions to capital) require withdrawals from current production available for consumption. The anticipated price level, p^* , is an index of the anticipated cost of using a unit of current output to replace or increase capital. The real rate of interest, r , is then

$$r = \frac{p}{p^*} e$$

$$e = e(y^*, \frac{B}{p}, \frac{S}{p}, lg) \quad e_1, e_4 > 0$$

$$e_2, e_3 < 0$$

The expected return to capital, e , depends on anticipated output, y^* , the real value of financial assets and the amount of labor absorbed by government. Absorption of labor by government raises the marginal product of capital and the expected return to capital. Issues of base money and debt lower the return to real capital. The response to the base is a familiar result in monetary theory. The response to debt is an implication of the Brunner-Meltzer hypothesis provided government debt and real capital are not close substitutes. [].

Differentiating r and multiplying throughout to express the results as elasticities and relative rates of change yields eq. (9).

$$(9) \quad \hat{r} = \left[1 - \epsilon(e, p) \frac{B+S}{p} \right] \hat{p} - \hat{p}^* + \epsilon(e, y^*) \hat{y}^* + \epsilon(e, lg) \hat{lg} +$$

$$\frac{1}{p} \left[\epsilon(e, B) \hat{B} + \epsilon(e, S) \hat{S} \right]$$

Substituting \hat{r} in the equation for \hat{V} , we obtain

$$\hat{V} = v_0 \hat{p}^* + v_1 \hat{y}^* + v_2 \hat{y} + v_3 \hat{S} + v_4 \hat{B} + v_5 \hat{p} + v_6 \hat{\pi} + v_7 \hat{lg}$$

$$\text{where } v_0 = \epsilon(V, p^*) \frac{1}{p} - \epsilon(V, r) > 0$$

$$v_1 = \epsilon(V, r) \epsilon(e, y^*) > 0$$

$$v_2 = \epsilon(V, y) \geq 0$$

$$v_3 = \frac{1}{p} [\epsilon(V, S) + \epsilon(V, r) \epsilon(e, S)] < 0$$

$$v_4 = \frac{1}{p} [\epsilon(V, B) + \epsilon(V, r) \epsilon(e, B)] - 1 < v_4 < 0$$

$$v_5 = \epsilon(V, p) \frac{(p^* + B + S)}{p^2} + \epsilon(V, r) \left[1 - \epsilon(e, p) \frac{(B + S)}{p^2} \right] < 1$$

$$v_6 = \epsilon(V, \pi) > 0$$

$$v_7 = \epsilon(V, r) \epsilon(e, lg) > 0$$

I have assumed that the sign of v_0 is determined by the first term, and that v_5 may be positive or negative but, if positive, must be less than unity. The restriction of v_4 to the range between 0 and -1 is required to obtain determinate signs in eq. (10) below. The other responses of velocity follow from previous assumptions.

Anticipated velocity, V^* , depends on anticipated spending or receipts, as shown earlier, and on anticipated inflation. Anticipated inflation increases spending at any level of anticipated receipts. The relative rate of change of anticipated velocity is \hat{V}^* .

$$\hat{V}^* = \epsilon(V^*, y^*) \hat{y}^* + \epsilon(V^*, \pi) \hat{\pi}$$

Substituting the equations for \hat{V} and \hat{V}^* in eq. (8) and rearranging terms, we obtain a solution for \hat{p} containing only policy variables, anticipations, and error terms as arguments.

$$(10) \quad \hat{p} = w_0 + w_1 \hat{p}^* + w_2 \hat{B} + w_3 \hat{S} + w_4 \hat{\pi} + w_5 \hat{g} + w_6 \hat{y} + w_7 \hat{y}^* + \epsilon_4$$

the coefficients are:

$$w_1 = v_0 / (1 - v_5) > 0$$

$$w_2 = (1 + v_4) / (1 - v_5) > 0$$

$$w_3 = v_3 / (1 - v_5) < 0$$

$$w_4 = [v_6 - \epsilon(V^*, \pi)] / (1 - v_5) \geq 0$$

$$w_5 = v_7 / (1 - v_5) > 0$$

$$w_6 = (v_2 - 1) / (1 - v_5) < 0$$

$$w_7 = [1 + v_1 - \epsilon(V^*, y^*)] / (1 - v_5) > 0$$

The current rate of monetary expansion is measured by \hat{B} , the current rate of change of the monetary base.

All of the terms containing \hat{y}^* and \hat{y} can be combined by letting

$$- [1 + v_1 + \epsilon(V^*, y^*)] = v_2 - 1$$

In this form, the current rate of price change depends on the error made in forecasting current receipts, $\Delta \epsilon y$. The relation of the rate of price change to $\Delta \epsilon y$ provides evidence on the type of Phillips-curve most relevant for this analysis.

Estimates of Anticipated Inflation and Real Receipts

To test the theory of interest rates and the rate price change developed in the previous section, I require estimates of the anticipated rate of inflation and the rate of change of current real receipts. In this section, the anticipated values are estimated from past data. The main propositions tested here are propositions about error terms and the like. In later sections, I use the estimates developed here to test propositions about interest rates and price changes.

Equations (4) and (5) are a hypothesis about the formation of anticipated current receipts and their relation to observed receipts (measured real ~~output~~). Consistent data for the private capital stock are not available for the entire century, so I have used two sample periods. The first includes the gold standard years, 1901-31. The second includes 1925-40 and 1954-74. Years of price and interest control, 1941-52, are unsuited for the tests of the model of interest rates and rates of price change and are omitted.⁷ Table 1 shows least squares regressions for the equations used to estimate anticipated receipts. An additional equation, estimated for the combined periods, is shown separately for comparison but was not used to generate estimates of y^* and \hat{y}^*

The total labor force is used to measure L in the regressions. Workers have more information about the current labor market than the equation permits, but the information develops at the same time as the estimate of current receipts.⁸ The private sector has little information at the

start of the year about prospective monetary and fiscal policies. The use of lagged debt and base money reflects the lack of information. The use of L, and lagged financial stocks understates available information. The use of lg probably overstates available information.

Table 1
Equations for y^* and \hat{y}^*

ln K	ln L	ln lg	$\ln \frac{S}{p} - 1$	$\frac{B}{p} - 1$	ln N	Constant Dummy	\bar{R}^2/DW
<u>1901-31</u>							
1.27 (2.70)	-2.33 (2.04)	.13 (.98)	.02 (.66)	.09 (2.52)	1.04 (.84)	8.01/-.01	.95/1.74
<u>1925-40 and 1954-74</u>							
1.43 (6.83)	-4.25 (4.75)	.74 (4.06)	-.03 (.28)	.02 (3.33)	1.04 (1.24)	24.90/-.01	.99/1.17
<u>all years combined</u>							
.58 (4.75)	-3.09 (4.91)	-.08 (.80)	-.01 (.57)	.02 (8.46)	4.14 (8.10)	-13.29/.14	.99/1.26

Numbers in parentheses are t-statistics. DW is the Durbin-Watson statistic. A dummy variable (0,1) was used with value 1 in World War I (1917-19) and after the break in the data (1954).

Most of the signs in Table 1 correspond to the hypothesis. An exception is the positive coefficient of $\frac{S}{p}$ in the first sample period. Although the positive response of anticipated output or receipts to improvements in payments arrangements receives support in both sample periods, the expected response to $\frac{S}{p}$ is not well supported. The unit elasticity

of receipts with respect to population implies that \hat{y}^* can be treated as the growth rate of per capita receipts.

A problem with the estimates for the two samples is the very high value of the intercept and the correspondingly large elasticities with respect to K and L. Combining the data for all years (using 1901-24 from the first sample), reduces the intercept and response of output to capital. The equation is now homogeneous of first degree in L and N, but not in N alone.

Anticipations of inflation depend on the prevailing monetary standard. Under a gold standard, anticipated inflation in the gold standard countries depends on the maintained rate of growth of the world gold stock. Domestic rates of inflation differ from the world rate of inflation when domestic monetary growth is maintained at a rate in excess of the growth of the world gold stock -- "world money." Maintained expansion or contraction of domestic money relative to world money requires the expanding or contracting country to pay out or absorb gold or to revalue. Adjustment of domestic gold stocks requires adjustment of the money stock under the gold standard. Maintained growth or contraction of the world gold stock brings inflation or deflation.

The gold standard period ended in the early 'thirties. Britain gave up the standard in 1931 and the United States in 1933. From 1934 to 1940, the United States remained on a gold exchange standard at a higher price of gold. After 1946 much of the world accepted the dollar standard.

The anticipated rate of inflation is not independent of the prevailing monetary standard. Gold movements contain more and different information under a gold standard than under a dollar standard.

A principal difference between the gold and dollar standards affects the formation of price anticipations. Maintained expansion in the U.S. money stock did not set off a process that reduced the growth rate of money. Foreign governments absorbed dollars, permitted their prices to rise and, except in a few cases, did not insist on the convertibility of dollars into gold. When foreign governments chose to reduce inflation, the dollar standard ended.

Rational agents use information about the monetary standard when estimating the anticipated rate of inflation. Estimates for 1900-31 and 1954-74 should conform to the gold standard and the dollar standard respectively. The years 1932 or 1934 to 1940 are a mixture, but I have treated them as gold standard years in my estimates and in all subsequent tests.

A main problem to be resolved before estimating anticipated rates of inflation is the meaning of "maintained" rate of monetary or gold expansion. Instead of relying on one of the many estimates of the lag of prices behind money, I have interpreted "maintained" as a three year, unweighted, moving average of rates of change, lagged one year. The mean lag of two years does not differ markedly from some recent estimates. The anticipated rate of inflation and the anticipated one-year rate of price change are identical.⁹

Table 2 shows least squares regression estimates of equation (11) for three periods. Equation (11) is an operational definition of $\mu = \pi$.

$$(11) \quad \hat{p}_t = a_0 + a_1 \hat{M}_{t-1} + a_2 \hat{M}_{t-1} + a_3 D + \hat{\epsilon}_5$$

- \hat{p}_t is the observed rate of price change;
- \hat{M}_{t-1} is the growth of money in the previous year;
- $\hat{\bar{M}}_{t-1}$ is the average growth rate of world gold ($\hat{\bar{W}G}$) or money in the three previous years;
- D is a dummy variable; and
- ϵ_5 is the difference between anticipated and actual rates of price change

Table 2
Estimating Equations for \hat{p}^*

Variable	1900-31	1900-40	1954-74
\hat{M}_{t-1}	0.67 (4.69)	0.56 (4.80)	-0.23 (1.10)
$\hat{\bar{W}G}_{t-1}$	1.27 (1.26)	1.12 (1.31)	
Dummy for Avg.	3.78 (1.65)	4.11 (1.75)	-0.78 (0.88)
Dummy for Gold Revaluation		-26.63 (1.66)	
$\hat{\bar{M}}_{t-1}$			1.11 (4.09)
Constant	-6.20 (2.02)	-5.19 (1.80)	0.37 (0.58)
\bar{R}^2/DW	.54/1.89	.28/1.21	.60/1.00

A bar over the variable indicates a three-year moving average. t-statistics are shown in parentheses.

A dummy variable, avg. with value 1 in 1917-22 and in 1954-55 and zero elsewhere, is used to separate any special effect of World War I from the effect of the moving average gold stock and to separate any effects of the Korean War on the early postwar rate of inflation from the effect of \hat{M}_{t-1} . A second dummy variable, gold, has a value of 1 in 1934-36 to separate the effect on the rate of price change of the 1934 revaluation of gold from the effect of the moving average of the gold stock. Since the mean gold stock is lagged one year, the dummy affects the rate of price change in 1935-37.

The regressions suggest that, if the anticipations hypothesis is correct, a considerable part of the observed rate of price change is unanticipated. Agents did about as well, on average, anticipating the rate of price change under the gold standard, 1900-31, as under the dollar standard, 1954-74. Although the responses to growth of money and gold are approximately the same in 1900-40 as in 1900-31, the measured rate of price change is much more variable. If agents maintained the "gold standard hypothesis" during the thirties, they experienced substantially larger errors than in the past. The fifty per cent decline in \bar{R}^2 is a measure of increased uncertainty about price changes.

The three periods provide similar estimates of the effect on anticipated inflation of maintained rates of change of money or gold. In each period, the estimated response exceeds unity, suggesting some "overshooting" of anticipations. The departure from proportionality is never significant.

A principal difference between the estimates for years of the gold standard and the dollar standard is in the importance assigned to recent

and maintained average rates of monetary expansion. Under the gold standard, the most recent rate of monetary expansion has a larger and more consistent effect on anticipated inflation. The years of the dollar standard show a negative and much less reliable response to \hat{M}_{t-1} , given the average rate of expansion. This suggests that accelerations and decelerations of the domestic money stock became less important in raising or lowering anticipated inflation under the dollar standard. The reduced importance of acceleration and the increased statistical significance assigned to the moving average of past rates of growth suggest that anticipations of inflation form and decay more slowly under the dollar standard.

Real Rates, Inflation and the Rate of Price Change

The current rate of price change fluctuates around the anticipated rate of inflation whenever there are random or systematic changes in the price level. If the price level does not respond instantly, the measured rate of price change during any finite interval includes the anticipated rate of inflation, unanticipated inflation and any once-and-for-all adjustment that occurs during the time interval. Our estimates of the anticipated rate of inflation permit a test of the effect of anticipated inflation and other variables on the current rate of price change.

Interest rates provide a second test. If anticipated inflation is fully reflected in market rates of interest, our estimate of the anticipated rate of inflation can be subtracted from market rates to obtain

a time series on real rates of interest. In this section, I test the hypotheses relating inflation, money and other variables to the rate of price change and the real rate of interest using data for several sub-periods in this century and for the century to date.

Table 3 shows estimates of two forms of equation (10) for different periods. The measured relative rate of price change in each pre-war and post-war year, under the gold standard and under the dollar standard is shown to fluctuate around the anticipated rate of inflation. With the exception of one short period the results for the two equations are indistinguishable.

[Insert Table 3 about here]

Two forces dominate the current rate of price change: the rate of inflation anticipated at the start of the year, \hat{p}^* , and the current rate of growth of the monetary base, \hat{B} . The hypothesis does not permit us to separate the effect of current monetary growth on currently anticipated inflation, but for present purposes, there is no need to do so. The measure of anticipated inflation depends solely on past monetary growth, so the current rate of price change is dominated by the current and past rates of growth of money, μ and \hat{B} .

Moreover, the combined effects of the anticipated rate of inflation and the current rate of monetary expansion are equal to unity for the period as a whole and remain close to unity in all sub-periods. The dominant, persistent effect of money growth on the observed rate of price change is supported by the data.. There is no evidence that changes in the monetary standard, the growth of unions, increased reliance on fiscal policy, the growth of intermediaries or any of the ever present "special"

Table 3

Period	The Current Rate of Price Change							Intercept / Dummy	\bar{R}^2 / DW
	\hat{p}^*	\hat{B}	\hat{S}	$\hat{\pi}$	\hat{lg}	\hat{y}	\hat{y}^*		
1902-31	.54 (2.09)	.77 (4.71)	-.03 (.66)	-.08 (.64)	.00 (.04)	-.01 (.06)	.05 (.34)	-2.52/6.98	.79/1.78
1902-40	.67 (2.79)	.30 (2.60)	-.10 (1.63)	-.04 (.28)	.12 (1.20)	.05 (.50)	-.13 (.86)	-1.94/23.4	.60/2.04
1956-74	.72 (2.28)	.25 (.98)	-.08 (.66)	-.87 (1.25)	-.18 (1.04)	-.44 (3.30)	.16 (.91)	1.66	.78/1.82
Combined	.76 (4.77)	.27 (3.31)	-.07 (2.70)	-.03 (.28)	.08 (1.66)	.02 (.22)	-.09 (.93)	-1.18/17.7	.62/1.85
	\hat{p}^*	\hat{B}	\hat{S}	$\hat{\pi}$	\hat{lg}	$\Delta\epsilon y$	Intercept / Dummy	\bar{R}^2 / DW	
1902-31	.56 (2.25)	.75 (4.89)	-.04 (.72)	-.08 (.72)	.01 (.10)	-.00 (.05)	-2.42/7.49	.80/1.82	
1902-40	.63 (2.76)	.30 (2.64)	-.09 (1.55)	-.03 (.20)	.10 (1.08)	.06 (.64)	-2.02/22.5	.61/1.99	
1956-74	1.02 (3.92)	.00 (.01)	.02 (.16)	-.98 (1.34)	-.36 (2.61)	-.36 (2.79)	1.26	.76/1.46	
Combined	.75 (4.72)	.26 (3.21)	-.08 (3.02)	-.02 (.18)	.09 (1.68)	.04 (.51)	-1.26/19.11	.62/1.88	

$\Delta\epsilon y$ was computed as $\hat{y} - \hat{y}^*$, so the sign should be negative;
t-statistics in parentheses; dummy variable is used in 1917-19
to hold constant any wartime effect.

factors has changed the magnitude of the response of inflation to monetary growth.

The timing of the response has changed, however. The weights assigned to \hat{p}^* and \hat{B} in the sub-periods place increased weight on past monetary growth, \hat{p}^* , and less weight on current monetary growth, \hat{B} . One estimate for 1956-74 assigns no weight at all to the current rate of monetary expansion. Since the weights are a measure of the average lag of inflation behind money growth, there is evidence of a longer lag. This finding reinforces the earlier finding that increased weight in forming anticipations is now placed on past, as compared to recent, money growth. Prices now respond more slowly to monetary expansion and contraction than under the gold standard. In this sense, recent inflation is "different."

Popular, and some academic, discussion of inflation assigns importance to the growth of monopoly power in product and factor markets. There is no evidence that the rate of price change is now less predictable; the same percentage of the variance is explained in the 1902-31 and 1956-74 samples without allowing for any change in the degree of monopoly. There is, however, some tenuous evidence that the eras of the gold and dollar standard differ. The intercept of the \hat{p} equation shifts from negative to positive. Whether the shift is explained by a bias in the price index or some systematic change has not been studied. It is clear, however, that the shift cannot explain the acceleration of inflation after 1965.

Fiscal variables, \hat{S} and \hat{lg} , have opposite effects on the rate of price change, in the analysis presented above. The growth of debt lowers, and the growth of the government's labor force raises the rate of price change. The data give slightly more support to the response to \hat{S} than to \hat{lg} , but the only exceptions are in the recent, short period, 1956-74, so the disconfirmation is based on a small sample.

The years of the dollar standard, 1956-74, show several departures from the pre-1940 results and from the estimates for the period as a whole. It is the only period exhibiting a large, negative effect of the current rate of increase of output or receipts, \hat{y} , or the error in anticipations, Δey , on \hat{p} . Moreover, it is the only period in which the Phillips-type effects are statistically significant by the usual standards. The importance assigned to the Phillips-curve by Gordon [] and others[] rests heavily on data from recent years. The evidence in Table 3 suggests that unanticipated growth of output lowered prices in the 1956-74, but not in other periods. However, the evidence does not discriminate sharply between alternative explanations assigning greater or lesser weight to past and current monetary expansions (\hat{B} and \hat{p}^*) and to a Phillips-type effects (\hat{y} or Δey). Below, I attempt a comparison.

The 1956-74 period is also characterized by an increase in the effect on \hat{p} of the anticipated rate of price acceleration, $\hat{\pi}$. The negative sign of $\hat{\pi}$, in all periods, suggests that the effect on \hat{V}^* is slightly stronger than the effect on \hat{V} in all periods. The response of \hat{V}^* to price acceleration helps to explain the much discussed decline in the

average rate of change of velocity in recent years. The decline is often described to a change in "trend." Analysis suggests that the relevant "trend" may be the "trend" in the rate of price change.

Current rates of price change are dominated by past and current monetary expansion. Anticipated inflation at the start of any year is the anticipated rate of price change; $\pi = \hat{p}^*$. I have assumed, throughout that $\pi = \mu$, the maintained rate of monetary expansion, and have imposed that assumption on the data by estimating π (or \hat{p}^*) from past monetary expansion.

If my measure of π is an appropriate index of the anticipated rate of inflation, real rates of interest can be computed from observed market rates by subtraction,

$$r = i - \pi,$$

and the way is open to test the hypotheses introduced earlier, eq. (9), relating real rates to p , p^* and the determinants of the expected return to real capital, e . At the same time, we test the hypothesis that anticipated inflation is a monetary phenomenon.¹⁰ Table 4 shows estimates for the periods of the gold and dollar standard and for the combined sample. Since the measured real rate is negative, at times, the regression equation uses r , not $\ln r$, as dependent variable; r is measured as per cent per annum. This explains the size of the coefficients in Table 4.

[Insert Table 4 about here]

Three findings stand out. First the hypothesis explains most of the variation in real rates. This is true for the period as a whole and in each sub-period. There is no evidence that the power of the hypothesis

Table 4
The Real Rate of Interest

Period	ln p	ln p*	ln y*	ln lg	ln B	ln S	Intercept / Dummy	R ² / DW
1902-31	107.8 (24.81)	-103.4 (37.30)	-.11 (.14)	.64 (1.00)	-1.37 (.95)	-.43 (2.56)	-13.48/ -.70	.99/ 1.61
1902-40	109.1 (58.27)	-105.1 (64.53)	-.48 (.72)	.66 (1.30)	-1.20 (2.36)	-.38 (2.61)	-11.0/ -.54	.99/ 1.43
1956-74	129.6 (5.22)	-110.4 (4.78)	3.36 (.55)	-.19 (.03)	-12.80 (2.06)	-6.45 (1.23)	-10.16	.86/ 1.52
Combined	108.4 (38.8)	-102.6 (41.6)	-.47 (.53)	2.47 (3.64)	-2.66 (4.13)	-.70 (4.02)	-28.75/ -1.80	.98/ 1.04

A dummy variable is included for the war years 1917-19.
t-statistics are in parentheses

was poorer in thirties, or under the gold standard than in the period as a whole. Second, the dominant influence on the real rate of interest in all periods is the difference between the anticipated and actual price level. When anticipated and actual prices are equal, the principal cause of changes in real rates is removed. Third, the effects of the principal determinants of real rates are similar in the pre-World War II samples and in the combined sample but differ in the 1956-74 sample. The second and third point merit further discussion.

The relation between anticipated inflation and real rates of interest receives considerable attention in recent theoretical literature. Friedman [] argues that the optimal monetary policy provides a rate of fully anticipated deflation equal to the real rate of interest. Tobin [] develops conditions under which the optimal monetary policy is a positive rate of fully anticipated inflation. Brunner and Meltzer [] show that there is no effect of fully anticipated inflation on the steady state stock of capital for the moderate rates of inflation observed in the United States.

Evidence capable of discriminating between these conclusions has not been developed. A significant exception is Sargent's [1973] analysis of the relation between inflation and a crude measure of the real rate of interest. Sargent found that past rates of inflation are positively related and future rates of inflation are negatively related to real rates of interest. For the period 1871 to 1929, he estimated a mean lag of 12 to 15 years for the response of real rates to inflation.

The responses of r to p and p^* contain information about the effects of anticipated and unanticipated inflation. By construction $p_t^* = p_t + dp^*$,

so the ratio

$$\frac{p}{p^*} = \frac{1}{1+\pi} \quad \text{and for } \pi = \frac{dp}{p}, \frac{dr}{r} = -\frac{1}{p} \epsilon(e,p) \frac{B+S}{p} \pi$$

Interest rates change by the wealth effect on real rates. If B+S grow at the rate π , as would seem required for $\pi = \frac{dp}{p}, \frac{dr}{r} = 0$.

Estimates in Table 4 show the response of r to p and p^* . The response to r is always numerically larger than the response to p^* . The difference in every period is approximately equal to the sum of the coefficients of $\ln B$ and $\ln S$. The remaining difference is small, never more than two ~~basis~~ basis points, and this difference can be reduced to less than one basis point in three of the periods by reestimating the equation to eliminate the "real financial effect" of a price change from the coefficient of p . ¹¹

The conclusion that a fully anticipated inflation has no effect on real rates of interest seems well supported by the data and more strongly so after we allow for the transfer of wealth from owners of financial assets to the government and the effects of these real wealth effects on real rates of return. Real rates of return appear to be independent of fully anticipated inflation to a close first approximation as implied by the Brunner-Meltzer hypothesis. There is no evidence of a ten to fifteen year lag of real rates behind inflation. The mean lag of anticipated inflation behind money growth is at most two years and the mean lag of real rates is about the same.

A strong, positive association between the current price level and the rate of interest has been observed for a century. Keynes called

the relation the Gibson paradox. A large literature attempts to explain the paradox or to account for the observed relation in other ways.

The anticipated price level is measured here as the sum of the current price level and the anticipated price change. Monetary expansion raises the anticipated price level, lowers real rates and expands economic activity. The current rate of price change responds to monetary growth and to the expected rate of price change. The price level rises, after a time, and the real rate rises.

Data for real rates of interest for the century cover a wide range. "Actual" tax-free real rates reach a peak of 12.9% in 1932 and a trough of -8.7% in 1917. The rates implied by the last equation in Table 4 cover a similar range, from 12.1% in 1932 to -8.7% in 1917. Anticipated price increases during World War I, to be precise from 1916 to 1920, and during 1973-74, would account for half of the years in which "actual" real rates are negative. Anticipated reductions in prices would explain the "observed" high real rates of return from 1930 to 1933.

The dominant effect of the difference between actual and anticipated prices on real rates of return suggests that much of the fluctuation in real rates is the result of anticipated price changes. Steady inflation, steady deflation or a constant price level reduces the variability of real

rates by reducing the variability of the price level and the difference between anticipated and actual prices.

In the years of the dollar standard used in the sample, 1956-74, the coefficient of variation for inflation -- the ratio of the standard deviation to the mean -- is about 2/3. For 1902-40 or 1902-31, the coefficient of variation for p is about 4. The mean and standard deviation of twenty-year, tax exempt real rates is shown in Table 5 for several periods. Both are lower from 1955 to 1974 than in the earlier period taken as a whole.

Table 5

Mean and Standard Deviations for Real Rates of Interest
on Tax-Exempt Twenty Year Bonds
(in percent)

Years	Mean	Standard Deviation
1902-11	1.24	2.91
1912-21	-1.14	5.44
1922-31	6.15	2.53
1932-40	3.09	5.84
1955-64	1.42	0.64
1965-74	0.14	0.50
Pre-WW II	2.32	5.02
Post-WW II	0.78	0.86
All Years	1.79	4.16

Table 5 shows some association between price stability and the standard deviation of real returns. The relatively steady increase in the prices from 1955 to 1964 and the more rapid inflation from 1965-74, are periods in which r has low standard deviation. The 1930's and the decade 1912-21 have high price variability and high variability of real returns.

Relatively stable prices from 1922 to 1931, however, did not reduce the standard deviation to the low levels attained in 1956-74. Postwar economic expansion, particularly during 1956 to 1964, appears to have been very different from the prosperity of the twenties. The twenties offered higher but more variable real returns, the postwar lower and more secure returns. The data suggest that these are the only decades in this century during which real returns on average exceed their standard deviation.

Six decadal averages are too few observations to support any firm conclusion about the relation of risk, measured by the variance or standard deviation of real rates, and mean returns. The general tendency for a positive association is evident. Whether real rates change less or more than in proportion to the variance cannot be judged reliably.

A large part of economic theory, and many empirical studies, assume that real rates of return are constant, or nearly so. There is no evidence to support the assumption here. There is, however, some evidence that, over long periods of time, the real rate returns to the range 1.5% to 2.5%, but the variance is large, and the rate remained outside that range during the entire decade 1965-74, and for the prosperous 1920's. Even if we dismiss the 1930's and the wartime experience 1916-20, rates of return move over too wide a range to be regarded as constant for economic analysis or policy.

A long-term tendency for real rates of return to remain constant is, of course, consistent with the estimates in Table 4. Constant terms are small in all periods, and the dominant forces operating on real returns are the price level and the anticipated level. Substantial rates of change in real variables -- lg and y^* -- are required to have a pronounced effect on the mean value of r given the relatively small effect of these variables on r .

A constant, steady state, real rate of interest equal to the growth rate of per capita output is an implication of golden age, neo-classical growth models [Phelps]. Denison [,] reports the growth of real income per person employed as 1.44 to 1.59 for the years 1909-57 and 1.89 for 1929-1969. The growth rate of per capita real income used in this study is 1.86 for 1902-1974. My estimate of the mean real return to capital after taxes, 1.79, suggests that this golden rule condition has been met, on average, during this century.

Equality of growth in per capita income and the real rate of interest satisfies only one of the conditions for optimality. However, the evidence showing that steady state real rates of interest are independent of fully anticipated inflation removes the possibility of changing the steady state rates of interest by inflationary or deflationary policies and enhances the importance of the equality.

Equality of the real rate and the growth of per capita income is not found in the two main sub-periods. From 1902-40, per capita output rose at an average of 1.32% per annum, based on the data in my study. The mean real rate of 2.32% (Table 5) is much too high for optimality. For

1955-74, the mean growth is 2.03%, and the mean after-tax real rate of return is 0.78%, much too low for optimality. The long-term results average the two periods and bring the real rate and the growth rate toward equality. Not much more can be said from the evidence at hand.

Post-war estimates differ from the estimates for the period as a whole and pre-war estimates. The effects of debt and money are substantially larger, and the response to anticipated receipts is positive, as my hypothesis implies. This is, however, the only period in which the response to y^* is positive, and the estimated response is never significant by the usual standards.

Interest rates typically rise in periods of expansion and fall in contraction. The response to y^* is negative in three of the four samples. This suggests, again, that the cyclical pattern in real rates is a response to the price level, the so-called Gibson paradox discussed earlier, and not a response to income as emphasized in Keynesian or IS-IM theory.

Growth of government debt reduces the real rate and reductions in government debt raise real rates. A negative response of r to S is found in each of the sample periods. Although the response is of relatively small magnitude, it is statistically significant in three of the four periods. This finding supports the Brunner-Meltzer hypothesis, particularly the implication that increases in government debt raises asset prices. The finding is contrary to such standard hypotheses as IS-IM exemplified by the classic work of Metzler [].

Tests using the real rate and rate of price change support some principal implication of the theory developed here. Cyclical changes in real rates are mainly a response to current and lagged monetary growth operating on anticipated and actual price levels. Anticipated inflation is a monetary phenomenon, and actual inflation or deflation, too, is almost entirely a response to current and past monetary growth.

Real rates of interest have fluctuated over a wide range during this century. Most of the changes can be explained by the relation Keynes called the Gibson paradox and the delayed response of the price level.

Little evidence has developed to support alternative explanations of price and interest rate changes. The Phillips curve receives little support, and its relevance appears limited to a single period, the postwar. The failure of prices to respond to monetary growth in periods of high unemployment, a point frequently emphasized in recent policy discussions, [Gordon, Modigliani, Tobin], is not supported by our finding that prices responded to current monetary expansion in the thirties. These issues are considered in greater detail in the following section.

FOOTNOTES

- * Much of the work appearing here has developed from the discussions that I have had for many years with Karl Brunner and from our joint work. Brunner's long-time interest in the problems addressed is well known. I am pleased that this attempt at explanation appears as an essay in his honor. As teacher, collaborator and friend, he stimulated my interest in the problems addressed and in the importance of economic analysis and evidence for correct conclusions. I am indebted to the National Science Foundation for continued support and to Malcolm Gray and Walter Dolde for criticisms of an earlier draft.
- 1 To cite a single example, Fisher [,] discusses an eight year cycle following a change in the gold stock.
- 2 This point is emphasized by Friedman, Brunner and Meltzer, Laidler, Parkin and other monetarists. See Mayer [].
- 3 Government debt also finances some accumulation of capital by government. If the governments capital in the form of toll roads, the postal system, courts, schools, etc. increases output and receipts and there is some rough proportionality between government capital and debt, the effect of S/p on y^* may be positive.
- 4 This interpretation of productive monetary arrangements is developed in Brunner and Meltzer [1971]. The contribution of money balances is not as in Sinai and Stokes [] a direct contribution of money balances to output.
- 5 A forthcoming paper by Coulter [] investigates these effects on the labor market more fully. See also Hall [].
- 6 This section follows Brunner and Meltzer [1975] and provides a test of the proposition advanced there. The ratio of output to asset prices is the reciprocal of Tobin's "q." Tobin [1969].
- 7 The use of lagged values of B/p and S/p explain the omission of 1900 and 1953 from the samples.
- 8 The use of labor force data neglects any information that workers have about their prospects for employment and is contrary to the hypothesis that workers use available information to estimate expected employment. I have used the labor force data to avoid either detailed analysis of the expected employment or bias from the use of man-hours (or a similar series) that is affected by current output.

- 9 This is a very restrictive assumption. Agents may anticipate once-and-for-all price changes or distinguish such changes from the rate of inflation. Also, agents may form a term structure of anticipated inflation instead of a mean rate. The mean lag depends on the rate of monetary expansion. Silveira [] has shown that at high rates of inflation in Brazil, anticipations form more rapidly. All such problems are neglected.
- 10 The return on a tax-exempt bond with twenty years to maturity is used as the market rate to reduce the influence of changes in tax rates. Use of a long-term bond with the current expectation of future price levels ignores differences in expected rates of inflation for different periods. A term structure of expected inflation may produce different results.
- 11 See eq. (9) in the text above. The term $\epsilon(e,p) \frac{B+S}{p^2}$ is eliminated by replacing B and S with B/p and S/p. Coefficients are nearly identical for all variables except p, in all periods. The differences, by sample periods, between the positive effect of p and the combined negative effects of p*, B/p and S/p are:

106.00	107.50	108.90	105.00
<u>-105.20</u>	, <u>-106.68</u>	, <u>-128.70</u>	, <u>-105.96</u>
.80	.82	- 19.80	- .96

The effect of lg on r, using the coefficient 2.47 in the last line of Table 4, is to raise real rates by 0.12. This compares to a mean r of 1.78 for the entire period and 0.78 for the postwar. The effect seems neither large nor negligible relative to the mean rate.