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Three Questions Concerning Nominal and Real Interest Rates

Carl E. Walsh*

Do increases in real interest rates tend to be followed by declines? Are market interest rate movements a reflection of variations in expected inflation or expected real rates of return? Are monetary and fiscal policy responsible for the behavior of real rates in the 1980s? These three questions, and their implications for monetary policy, are addressed in this paper.

The 1980s have witnessed unusually high levels of market interest rates relative to measured rates of inflation. The importance of this phenomenon depends critically on the extent to which these high *ex post* real rates have reflected high expected, or *ex ante,* real rates of interest, since it is the expected real return that should affect the savings, investment, and portfolio choices of the public. Because these aspects of economic behavior are related to expected real rates of interest, it is important to gain a fuller understanding of the relationship between market interest rates, expected real rates, and macroeconomic policies.

This paper examines three empirical questions related to the behavior of nominal and expected real interest rates:

Does the real rate of interest have a random walk component? If the real rate does not have such a component, it would tend to revert to a constant average value after any changes, that is, rate changes would be temporary in nature. Deviations of the real rate from its average therefore may provide information about the business cycle that would be useful for the conduct of monetary policy. One could interpret the average value of the real rate as its "equilibrium" value, and indeed several analysts have suggested that monetary policy act to stabilize the real rate around its equilibrium value.[1] If, however, the real rate does not tend to revert to any constant level, then there is no sense in which the real rate has a constant, long-run equilibrium value around which it might be stabilized.

To what extent are unpredicted movements in market interest rates due to movements in real rates as opposed to movements in expected inflation? Using U.S. data from the 1950s and 1960s, Fama (1975) concluded that nominal interest rate movements were consistent with a constant expected real rate of interest and that all market interest rate changes were attributable to changes in expected inflation. More recent U.S. experience suggests that the expected real rate has moved quite sharply, so that nominal rate changes may reflect a more equal balance of movements in the real rate and expected inflation.

Federal Reserve monetary policy has often been characterized as designed to smooth market interest

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rates, and the appropriateness of such a policy depends, in part, on whether movements in market rates tend to be generated by changes in real rates or by inflationary expectations. An expansion in the money supply designed to offset a rise in market rates that originates from expectations of higher inflation may simply fuel an actual increase in inflation.

To what extent are monetary and fiscal policy disturbances responsible for the movements of the real rate, particularly over the last ten years? The initial apparent rise in real rates in the early 1980s has generally been attributed to restrictive monetary policy actions designed to reduce inflation; the continued high level of real rates is often blamed on large federal budget deficits. However, many economists argue that deficits have little impact on interest rates. Decomposing the real rate into components due to monetary policy shocks and fiscal policy shocks may shed light on this debate.

The paper is organized to discuss each question in order. The next section examines the stochastic processes followed by nominal interest rates and inflation to test for whether changes in these variables tend to persist or to be temporary. The results have implications for the existence of a constant average *ex ante* real rate around which the real rate fluctuates. They also are useful in determining the specification of the variables to use in the later empirical analysis.

Section II uses the results from a Vector Autoregression (VAR) to decompose innovations in the nominal rate into *ex ante* real rate innovations and expected inflation revisions. By comparing such decompositions over different sample periods, one can obtain a sense for the changing informational content of nominal rate innovations. Section III presents the decomposition of the real rate into components attributable to monetary and fiscal disturbances, respectively. Conclusions are summarized in Section IV.

I. Does the Real Rate Have a Random Walk Component?

Until relatively recently, economists generally assumed that most macroeconomic variables tended to fluctuate randomly around either a constant average value or around a trend line. When a variable rose above its trend, it was expected subsequently to fall back towards the trend line.

In the last few years, this standard view has been questioned. For example, Nelson and Plosser (1982) argue that most macroeconomic variables are better characterized as having a random walk component to their behavior.[2] A random walk has the property that changes are permanent, that is, if the variable goes up, there is no tendency for it to return to any average or trend value. Thus, shocks to a variable containing a random walk component will have permanent effects on the level of the variable.

A finding that the *ex ante* real rate has a random walk component would have important implications for suggestions that real rates be used to guide the conduct of monetary policy (Jenkins and Walsh 1987). Factors, such as changes in tax policy, that produce persistent shifts in the real rate may call for a different policy response than factors, such as fluctuations in the demand for money, that produce temporary changes in the real rate.

To be more specific, a rise in the demand for money, in the absence of a policy response, would temporarily raise the real rate and contract aggregate demand. Policy might respond by expanding the money supply to keep the real rate from rising. But if the initial rise in the real rate were due to a permanent shift in consumer preferences towards current consumption and away from saving, then no such monetary policy action would be called for. In other cases, it may be less important to respond to temporary movements in the real rate, since the costs of failing to act would presumably be smaller than a failure to respond to more persistent disturbances. At the time the change in the real rate is observed, however, it may be difficult to determine whether permanent or temporary factors are at work.

Testing for a Random Walk

Testing for random walk behavior in the *ex ante* real rate of interest is complex because the expected real rate cannot be observed. Nevertheless, it is possible to draw some conclusions about the real rate process by examining the behavior of the *ex post* real rate and its two components, the nominal interest rate and the rate of inflation.

To define some notation, let i_t denote the nominal interest rate from t to t+1. Let π_{t+1} be the rate of inflation from t to t+1, and let $E_t x_{t+j}$ be the expectation, formed at time t, of a variable x_{t+j}. Then, ignoring taxes, the ex ante real rate, r_t, and the ex post realized real rate, exr_t, are given by equations 1 and 2:

$$r_t = i_t - E_t \pi_{t+1} \quad (1)$$

$$exr_t = i_t - \pi_{t+1}. \quad (2)$$

Equations 1 and 2 imply that

$$r_t = exr_t + (\pi_{t+1} - E_t \pi_{t+1}) \quad (3)$$

so that the *ex ante* real rate and the *ex post* real rate differ by the error made in forecasting future inflation.

Chart 1 plots the nominal interest rate on 3-month Treasury bills and their *ex post* real return. The apparent upward drift in the nominal rate from 1960 to 1981 was primarily a reflection of rising expectations of inflation; the *ex post* real return, far from mirroring this upward trend, remained negative for most of the 1970s. The sharp rise in the *ex post* real rate from 1978 to 1982 was interrupted only during early 1980 by the Federal Reserve's imposition of credit controls.

The realized real rate differs from the expected real rate by the error made in forecasting the rate of inflation. Under any reasonable model of expectations formation, this inflation forecast error should be transitory, or stationary, in nature (that is, have no random walk component). Since the sum of a variable with a random walk component and a variable without one will contain a random walk component, equation 3 shows that r is stationary if and only if exr is stationary. If exr contains a random walk component, then so must r.

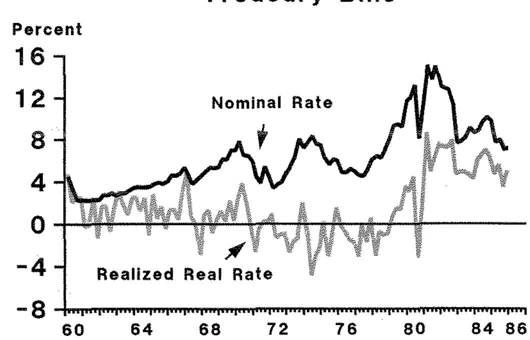
A common test for a random walk is based on the least squares regression of the first difference of a variable on its lagged level and lagged first differences. A constant and a time trend also may be included. The test statistic is simply the standard t-statistic for the coefficient on the lagged level. Under the null hypothesis that the variable has a random walk component, the coefficient on the lagged level should equal zero.[3] A large, negative t-statistic would indicate rejection of the null in favor of the hypothesis that the variable is stationary (perhaps with a trend).

Table 1 presents the results of the test described above. Quarterly data were used, and the nominal interest rate is the daily average of secondary market yield on 3-month Treasury bills for the first month of the quarter. Two price indices were used to calculate π: the GNP Price Deflator and the Consumer Price Index. Results for various sample periods are reported.

The test statistics consistently fail to reject the presence of a random walk term in the real rate. (In no case can the null hypothesis be rejected at the 5 percent level.) Rose (1987) reports similar findings for annual, quarterly, and monthly data for the U.S. He also finds evidence of a random walk component in the real rate for 17 other countries.

Chart 1

Nominal and Realized Real Rate on 3-Month Treasury Bills



The Effect of Taxes

One possible explanation for these results is that exr is the wrong way to combine the nominal rate and realized inflation to obtain a measure of the real rate. Many economists would argue that the relevant real interest rate should be an after-tax real rate. Letting τ denote the marginal tax rate, the *ex post* after-tax real rate is $(1 - \tau)\, i_t - \pi_{t+1}$. When both i and π contain independent random walk elements, the two variables will tend to drift apart over time since there are no forces acting to keep them close together. But if the after-tax real rate tends to fluctuate around a constant value, then i and π cannot drift too far apart. This implies that the random walk elements in i and π must be related.

If the after-tax nominal interest rate and the rate of inflation contain the same random walk component, then when one is subtracted from the other to obtain the after-tax real rate, the random walk components will cancel, leaving an after-tax real rate with no random walk element. If both i and π have random walk components, then exr can also have a random walk component, as indicated by Table 1, even if the after-tax real rate does not.

When two variables contain random walk components but some combination of the two does not, the variables are said to be cointegrated (see Engle and Granger, 1987 and 1986, and Hendry, 1986). The nominal interest rate and the rate of inflation will be cointegrated if they contain the same random walk

TABLE 1

Tests for a Random Walk Component in the Real Rate

A: Reported Test Statistic is the t-statistic on β_1 in the regression

$$x_t - x_{t-1} = \beta_0 + \beta_1 x_{t-1} + \Sigma\, \gamma_j (x_{t-j} - x_{t-1-j})^1$$

Inflation Measure	Sample Period	Test Statistic[2]
GNP Deflator	1961QI-1985QIII	−1.44
GNP Deflator	1961QI-1979QIII	−2.60
GNP Deflator	1970QI-1985QIII	−0.98
CPI	1961QI-1985QIII	−1.42
CPI	1961QI-1979QIII	−1.13
CPI	1970QI-1985QIII	−1.49

B: Results with trend included

Inflation Measure	Sample Period	Test Statistic[3]
GNP Deflator	1961QI-1985QIII	−1.94
GNP Deflator	1961QI-1979QIII	−3.25
GNP Deflator	1970QI-1985QIII	−2.02
CPI	1961QI-1985QIII	−2.03
CPI	1961QI-1979QIII	−2.81
CPI	1970QI-1985QIII	−2.00

* Significant at the 5% level.
1. A lag length of 4 was used.
2. Approximate 5% critical value is −2.9 (Fuller (1976, Table 8.5.2, P.373)).
3. Approximate 5% critical value is −3.47.

component. In this case, there will exist a constant α, called the cointegrating parameter, such that $\alpha i - \pi$ is stationary. If the after-tax expected real rate has no random walk component, then α will just be equal to one minus the marginal tax rate. Tests for cointegration and estimates of α are reported in Part A of the Appendix.

The results from the cointegration tests are mixed. Evidence of cointegration is found for the 1961QI - 1979QIII period, but cointegration is rejected when the sample is extended through 1985QIII. In addition, if the after-tax rate has no random walk component, the cointegrating parameter should equal one minus the marginal tax rate, that is, the estimated value of α should be around 0.6 to 0.7. Unfortunately, the actual estimates generally fail to fall in this range. Hence, the evidence seems to suggest that both the *ex ante* real rate and the after-tax rate contain random walk components.

If this finding were to hold for other real rates, particularly for longer term real interest rates, it would have important implications. For example, most modern macroeconomic theories imply that monetary forces have only temporary effects on real rates of interest. The presence of apparently permanent shifts in the real rate must then be due to nonmonetary phenomena.

However, the evidence of a random walk component in the real rate still leaves unanswered the question of the relative importance of permanent and temporary shocks to the real rate. A finding that the random walk component accounts for almost all the movement in the *ex ante* real rate would suggest monetary disturbances have not been important. Such evidence would support proponents of real business cycle theories, which de-emphasize the importance of money.[4]

Cochrane (1986) has recently proposed a method of measuring the relative importance of the random walk component of an economic time series.[5] Applied to the *ex post* real rate for the period 1961QI to 1985QIV, Cochrane's measure of persistence approaches approximately .12, implying that roughly 12 percent of the total unpredicted change, or innovation, to the *ex post* real rate represents a permanent innovation associated with the random walk component. Cochrane's measure suggests that innovations to the *ex post* real rate are predominantly temporary in nature. Since monetary disturbances have only temporary effects on the real rate, this finding is consistent with the view that monetary disturbances are an important source of real rate movements.

The evidence provided by Cochrane's measure of persistence must be qualified, however, by noting that it has a downward bias when used to measure the importance of the random walk component in the *ex ante* real rate.[6] Thus, the appropriate interpretation is that *at least* 12 percent of real rate shocks have permanent effects.

II. Movements in Real Rates or Expected Inflation?

Central banks have quite frequently relied on nominal interest rates as both instruments of monetary policy and as informational variables to be used as guides in the formulation of monetary policy. However, the use of nominal rates has inherent limitations because of the difficulty of determining whether nominal rate movements reflect movements in expected real rates or in expected inflation. In the 1970s, for example, the Federal Reserve was criticized for failing to allow nominal interest rates to rise sufficiently in the face of inflationary pressures. As a result, it was argued, monetary policy was insufficiently anti-inflationary. More recently, some economists have blamed the Federal Reserve for high real interest rates as nominal rates have, it is argued, fallen less than has expected inflation.[7]

Decomposition

It is possible to use historical data to decompose nominal interest rate movements into expected real rate and expected inflation changes. This allows an assessment to be made of the relative importance of these two components during different sample periods. Of particular interest is the decomposition of the unpredicted changes — or innovations — in the nominal rate. Such innovations are important as they represent "new information" that may be useful for the conduct of monetary policy.

If $E_{t-1}i_t$ is the best linear forecast of the nominal rate i_t based on information available at $t-1$, then the nominal rate innovation, denoted $\hat{i}_t$, is just the forecast error:

$$\hat{i}_t \equiv i_t - E_{t-1}\, i_t. \tag{4}$$

Since $i_t = r_t + E_t\pi_{t+1}$ and $E_{t-1}i_t = E_{t-1}r_t + E_{t-1}\pi_{t+1}$,[8] the nominal rate innovation can be written as the sum of the innovation to the expected real rate and the revision, or innovation, to expected inflation:

$$\begin{aligned} \hat{i}_t &= (r_t - E_{t-1}\, r_t) + (E_t\pi_{t+1} - E_{t-1}\pi_{t+1}) \\ &= \hat{r}_t + E_t\hat{\pi}_{t+1}\,. \end{aligned} \tag{5}$$

Given any two of the three innovations — $\hat{i}_t$, $\hat{r}_t$ and $E_t\hat{\pi}_{t+1}$ — the third can be calculated from equation 5. Armed with estimates of the three innovations, the relative importance of the expected real rate and expected inflation for nominal interest rate innovations can be gauged.[9]

Estimates of both $\hat{i}_t$ and $E_t\hat{\pi}_{t+1}$ were obtained by estimating a six-variable VAR system. The variables included in the VAR were quarterly observations on the three-month Treasury bill rate, the logs of real GNP, the GNP price deflator, M1, the relative price of fuels, and the real value of federal defense purchases. All variables were entered into the VAR in first difference form with a lag length of four.[10] The estimation period was 1961QI to 1984QIV. Data from 1985 to 1986 were dropped because of the apparent shift in the relationship between M1 and other macroeconomic variables that occurred in 1985. Details of the construction of $\hat{i}_t$ and $E_t\hat{\pi}_{t+1}$ can be found in Part B of the Appendix.

The estimation results show expected inflation innovations to have been much more volatile than nominal rate innovations. For the 1961QI - 1984QIII period, the variance of $E_t\hat{\pi}_{t+1}$ was four times that of $\hat{i}_t$ (2.03 versus 0.51). Since the October 1979 change in Fed operating procedures, the variance of $\hat{i}_t$ has risen (to 1.05), while that of $E_t\hat{\pi}_{t+1}$ has fallen (to 1.52), putting the expected inflation innovation variance at less than twice that of $\hat{i}_t$.

The series on $\hat{i}_t$ and $E_t\, \hat{\pi}_{t+1}$ can be used to construct a series on $\hat{r}_t$, the innovation to the ex ante real rate.[11] The results of this decomposition for various subperiods are given in Table 2.

For the entire estimation period (1961QI - 1984QIII), a one percent innovation in the nominal rate reflected, on average, a .56 percent real rate innovation and a .44 percent expected inflation innovation.[12] This division, however, is far from

TABLE 2

Decomposition of Nominal Interest Rate Innovation*

	1961QI-1984QIII	1961QI 1979QIII	1970QI 1984QIII	1979QIV 1984QIII
Variance of Nominal Rate Innovation	.508	.362	.667	1.054
Fraction due to:				
Real Rate Innovations	55.7	36.9	51.1	79.9
Expected Inflation Innovations	44.3	63.1	48.9	20.1

*Based on a VAR estimated over 1961QI-1984QIV period. See text for details.

constant. During the period prior to the Fed's October 1979 change in operating procedures, nominal interest rate innovations appear to have predominately reflected expected inflation innovations. In contrast, nominal rate innovations since the fourth quarter of 1979 have primarily reflected innovations in the real rate. A one percent nominal rate innovation during the period 1979QIV - 1984QIII was equal, on average to a .8 percent real rate innovation and a .2 percent expected inflation innovation.

The decompositions of the nominal rate innovations that are reported in Table 2 are based on a single VAR estimated over the entire 1961QI - 1984QIV period. This has the effect of implying individuals knew the behavior of inflation and nominal interest rates during the 1980s when forming expectations in, say, 1970. Such an implication is not implausible if the underlying structure generating inflation, interest rates, and the other macroeconomic variables had remained unchanged over the entire sample period. However, the increased importance of aggregate supply shocks, such as the oil price increase and oil embargos in the 1970s, the shift in monetary policy procedures in 1979, the rapid decline in inflation in the 1980s, and the historically unprecedented deficits of the Reagan Administration suggest that such an assumption of structural constancy may yield a poor approximation when used to characterize the recent macroeconomic experience of the U.S. Huizinga and Mishkin (1986), for example, present evidence to suggest a shift in the structure in the real rate process in October 1979.

To obtain a rough check on the robustness of the innovation decompositions, the VAR system was re-estimated over two subsamples: 1961QI - 1979QIII and 1970QI - 1984QIV. While the results differed somewhat from those obtained using the entire sample, the basic message was the same. For example, estimates from 1961QI - 1979QIII imply that almost all nominal rate innovations (98 percent in fact) were the result of expected inflation innovations. This is consistent with Fama's assumption that for the post-war period prior to 1972, all nominal interest movements were due to changes in expected inflation (Fama, 1975). When the VAR is estimated over the 1970QI - 1984QIV period, expected inflation innovations are estimated to account for 75 percent of the nominal rate innovations during 1970QI - 1979QIII and only 33 percent during the 1979QIV - 1984QIII period.

Findings

The changing composition of the innovations to the nominal rate reflects the changing relative importance of expected inflation and real rate movements over the last twenty-five years. The late 1960s and most of the 1970s were periods of high and variable rates of inflation. Real rates were far from constant then, and *ex post* real rates were negative during the 1970s (see Wilcox, 1983), but the dramatic increases in inflation appear to have dominated nominal rate innovations. The 1980s have witnessed large movements in both inflation and real interest rates. In a reversal of the 1970s, a falling rate of inflation has been associated with very high ex post real rates. Nominal rates have been much more volatile, and, according to the VAR estimates, nominal rate innovations have predominately reflected innovations to the *ex ante* real rate of interest.

This evidence indicates that monetary policy cannot reliably respond in a simple way to movements in market interest rates. For example, increases in the nominal rate due to upward revisions of expected inflation would, in general, call for a more contractionary monetary policy. If nominal rate changes were always dominated by such expected inflation changes, a simple automatic policy response might be possible. But nominal rate changes are sometimes, as in the 1980s, dominated by real rate changes.

Real rate changes pose more difficult problems for monetary policy. If they were due to money demand shifts, then they should be offset. In contrast, real rate effects due to aggregate spending fluctuations should generally not be offset. The changing informational content of movements in market interest rates means that simple policy rules based on market rates are unlikely to produce a satisfactory monetary policy. Additional information is required to interpret the changing nature of nominal interest rate movements.

The innovation decompositions provide interesting evidence on the information contained in unanticipated movements in nominal rates. Such movements primarily revealed information on expected inflation in the 1970s and expected real rates in the 1980s, although they provide no explanation of the underlying causes of either inflation or expected real rate movements. In the next section, an attempt is made to assess the role of macroeconomic policy shocks in explaining the high real interest rate during the first half of the 1980s.

III. What Raised Real Rates in the 1980s?

A number of alternative explanations have been offered to account for the high real interest rates that the U.S. has experienced during the past eight years. Two of the most prominent attribute high real rates to macroeconomic policies. The first views the rise in the real rate beginning in 1979 (see Chart 1) as a result of a restrictive monetary policy aimed at reducing the rate of inflation. The second attributes the continued high level of real rates, particularly since the 1981-82 recession, to current and expected future federal budget deficits.

A measure of the contribution of monetary and fiscal policy actions to the behavior of the *ex post* real rate can be obtained from the same VAR system used in the previous section to decompose nominal interest rate innovations. The manner in which movements in the *ex post* real rate are attributed to the various disturbances is detailed in Part C of the Appendix. The observed value of the *ex post* real rate is expressed, for each period during the sample, as the sum of six independent terms, one for each of the six disturbances in the VAR system. Since the purpose of this section is to focus on the behavior of the measured real rate during the 1970s and 1980s, the sample period over which the VAR was estimated was shortened by dropping the decade of the 1960s and estimating the system over 1970QI - 1984QIV.

As described in the previous section, the VAR system used to decompose nominal rate movements used real federal defense expenditures as a measure of fiscal policy. It is more common to use either the federal deficit or total government purchases of goods and services as proxies for the impact of fiscal policy. Results will be reported for each of these proxies, but each is an imperfect measure. The deficit, or the deficit corrected for the business cycle (the high employment deficit), implicitly imposes the assumption that expenditures have the same impact on real interest rates as do tax revenues. Yet this is an assumption that macroeconomic theories imply is wrong.

Simple Keynesian models predict that tax changes are partially financed out of both consumption and savings so that the impact of taxes on aggregate demand is less than an equal dollar change in government purchases of goods and services. Other models predict that only government expenditures will affect real rates. According to these models, the impact of current taxes on private spending would be offset by the effect of the accompanying change in future expected taxes when government expenditures are held constant.[13]

Total government purchases of goods and services, however, will not provide a perfect measure of the impact of fiscal policy even when taxes do not matter. To the extent that some government programs (health, public transportation, etc.) substitute for private purchases, a rise in government purchases may produce an offsetting decline in private spending, leading to little net impact on aggregate demand. This possibility suggests that a category of government expenditures for which no close private substitute exists should be used in calculating the impact of government expenditures on real rates. Federal defense expenditures constitute one such category.

In light of these considerations, three fiscal proxies were used: the real federal budget deficit (National Income and Product Account basis), real government purchases of good and services, and real federal defense purchases. The VAR system was estimated using each of the three fiscal proxies in turn. Then, the predicted path of the *ex post* real rate was generated under the assumption that either fiscal or monetary shocks were equal to zero. This assumption yields an estimate of the contribution of each type of shock over the sample period. Unfortunately, the estimated contributions of fiscal and monetary shocks to real rate movements are sensitive to the fiscal proxy used. Table 3 summarizes the results for the period since 1979QIV.

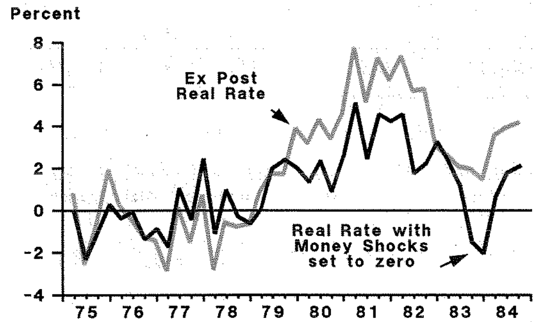
Impacts of Fiscal and Monetary Shocks

The deficit measure (rows 1 and 4 of Table 3) attributes relatively little of the rise in the real rate since 1979 to *either* monetary or fiscal shocks. There is some indication that monetary shocks have contributed less to the level of real rates since the end of the last recession in 1982QIV, whereas fiscal policy has contributed more. This result supports the view advanced by, among others, Cecchetti (1986).

Somewhat similar results were obtained by using defense expenditures, although the absolute contribution of both monetary and fiscal shocks in this case was much larger. Although the impact of monetary shocks falls slightly after the end of 1982, it is estimated to have added more than fiscal shocks to the real rate even in the 1983-1984 period. In marked contrast, the contribution of fiscal shocks is

Chart 2

Impact of Money Supply Shocks on the Real Rate



raised significantly when proxied by total real purchases of goods and services. With that proxy, fiscal shocks are estimated to have added roughly 450 basis points on average to the *ex post* real rate between 1979QIV and 1984QIII.

The time pattern of the impact of fiscal and monetary shocks implied by the estimates using either total purchases or defense purchases are fairly similar. Using the results obtained when defense purchases proxy for fiscal policy, Chart 2 illustrates the role played by M1 shocks on the path of the *ex*

TABLE 3

Fiscal and Monetary Policy Effects on the Ex Post Real Rate

	Fraction of Predicted Real Rate Due to:			
	Monetary Shocks	Fiscal Shocks		
Period		Deficit[1]	Purchases[2]	Defense[3]
1.) 1979QIV-1982QIII	20% (1.09)[4]	*(−.61)		
2.) 1979QIV-1982QIII	29% (2.36)		55% (4.44)	
3.) 1979QIV-1982QIII	48% (2.6)			22% (1.2)
4.) 1982QIV-1984QIII	6% (0.23)	17% (0.63)		
5.) 1982QIV-1984QIII	30% (2.06)		66% (4.59)	
6.) 1982QIV-1987QIII	35% (1.91)			26% (1.4)

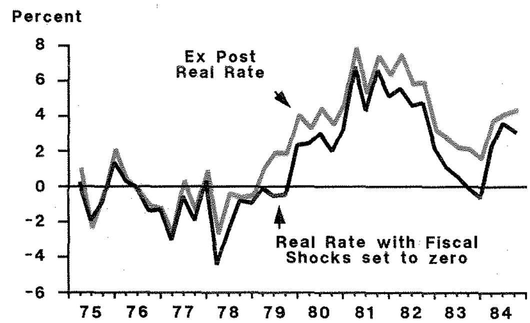
[1]Fiscal policy measured by real federal deficit.
[2]Fiscal policy measured by real federal purchases.
[3]Fiscal policy measured by real federal defense expenditures.
[4]Effect in percentage points is given in parentheses.
*Fiscal policy estimated to have reduced the real rate by an average of 61 basis points during this period.

post real rate. This chart plots the *ex post* real rate[14] and an alternative path, $\widehat{exr}_t$, in which the estimated effects of M1 shocks on exr_t are removed. Whenever exr_t exceeds $\widehat{exr}_t$, money disturbances are estimated to have raised the *ex post* real rate. When exr_t is less than $\widehat{exr}_t$, the net impact of M1 shocks was to lower the *ex post* real rate.

The evidence in Chart 2 appears to agree with other analyses of U.S. real interest rates in the early 1980s (for example, Blanchard and Summers, 1984, and Cecchetti, 1986). If money supply shocks are interpreted as reflecting the impact of monetary policy, the estimated decomposition of the *ex post* real rate suggests that monetary policy began to push up the real rate during the fourth quarter of 1979 and continued to contribute to the high level of exr through 1982. Apparently not until the fourth quarter of 1982 did the net contribution of monetary policy fall to zero. During the three-year period (1979QIV - 1982QIII), monetary policy actions added an estimated 2.6 percentage points to the real rate. To place this in perspective, exr, net of the estimated effects of credit controls, averaged 5.4 percent during this three-year period.

More surprising is the apparent effect of monetary policy in pushing exr above $\widehat{exr}$ during 1983 and 1984. For example, Cecchetti (1986) attributes high real rates in 1984 to fiscal policy (high expected future budget deficits) on the basis of evidence from the term structure of interest rates. From 1982QIV to 1984QIII, exr averaged 2.88 while $\widehat{exr}$ averaged only 0.97. Monetary policy is

Chart 3
Impact of Fiscal Shocks on the Real Rate



therefore estimated to have contributed almost 2 percentage points to exr during this period.

The estimated impact of fiscal policy is shown in Chart 3, where the path of the *ex post* real rate when the effects of defense spending shocks have been removed is shown. Fiscal policy is estimated to have raised exr throughout the 1979-1984 period. This rise reflects the increase in real defense expenditures that began in 1979 under President Carter and that continued under President Reagan. The average effect of fiscal policy during 1979QIV - 1982QIII was to raise exr 1.2 percentage points, roughly half the impact of monetary policy. Since the end of the 1981-82 recession, fiscal policy, as measured by defense spending shocks, has added 1.4 percentage points on average to exr.

V. Conclusions

This paper has attempted to address three empirical questions related to the behavior of nominal and real interest rates. The first asked whether a random walk component plays a role in the *ex ante* real rate of interest. Test results were consistent with the hypothesis that the real rate does contain a random walk component. However, they also indicated that the permanent effect of an unpredicted change in the real rate is probably relatively small, although the results showed that at least 12 percent of an unpredicted change would have a permanent effect on the real rate.

The second question concerned the respective importance of innovations to the expected rate of inflation and the expected real rate in accounting for innovations in the 3-month Treasury bill rate. Test results showed clearly that the division of nominal rate movements between real rate and expected inflation rate movements has changed quite dramatically during the last twenty-five years. In the 1970s, almost all unpredicted nominal rate changes were associated with variation in the expected rate of inflation. In contrast, unpredicted changes in the nominal rate during the first half of the 1980s predominately reflected changes in the expected real rate of interest.

The third question addressed the role of fiscal and monetary shocks in explaining the high real rates of the 1980s. Decomposing the history of the *ex post* real rate into the independent contributions of various shocks provided a means of assessing the impact of monetary and fiscal effects. Using defense purchases by the federal government as a proxy for fiscal policy, the evidence suggests that monetary policy added just over 2 percentage points to the *ex post* real rate between 1979QIV and 1984QIII. Fiscal policy raised the *ex post* real rate on average just over 1 percentage point during this same period.

These results, however, were sensitive to the measure of fiscal policy employed. When total federal purchases of goods and services was used, fiscal policy was estimated to have added 450 basis points on average to the real rate between 1979QIV and 1984QIII. When the federal deficit was used, neither fiscal nor monetary policy was estimated to have contributed much to the behavior of the real rate over the same period.

Appendix

Part A

Table A.1 presents the outcomes of stationarity tests for the 3-month nominal Treasury Bill rate and the two measures of inflation. The test statistics indicate that the random walk hypothesis is not rejected for the nominal interest rate, with one exception: the nominal rate behavior during 1961QI - 1979QIII is consistent with that of a variable stationary around a constant trend. Since both i and π appear nontrend stationary for the sample period as a whole, the hypothesis of cointegration is tested; that is, does there exist some combination of i and π that is stationary? Can we find a constant α such that $\alpha i_t - \pi_{t+1}$ is stationary?

Engle and Granger (1987) propose several tests of cointegration based on the "co-integrating regression" of either i_t on π_{t+1} or π_{t+1} on i_t.[1] If the real after-tax rate of interest is stationary, then the coefficient on i_t in a regression of π_{t+1} on i_t should equal one minus the marginal tax rate. This coefficient should therefore be of the order of magnitude of 0.6 to 0.7. The reverse regression of i_t on π_{t+1}, should yield a consistent estimate of one over one minus the marginal tax rate, which should be in the approximate range 1.4 to 1.7.

1. Barsky [1987] discusses the effects of regressing i_t on lagged π_t's as proxies for $E_t\pi_{t+1}$ when inflation is stationary. However, the results in his Table 2 suggest that π is non-stationary for the 1960-1979 period.

Under the null hypothesis of no cointegration, the residuals from the cointegrating regression should be nonstationary. This implies that the Durbin-Watson statistic will approach zero. Thus, a "large" D-W indicates cointegration. In addition, the residuals can be subjected to standard tests for a random walk. Critical values from a Monte Carlo experiment are reported by Engle and Granger.

Results from the cointegrating regressions are reported in Table A.2. The column labeled CRDW gives the Durbin-Watson statistic, the D-F (for Dickey-Fuller) column gives the t-statistic from a regression of the first difference of the residuals on their lagged level, while the ADF column adds four lagged first differences to the residual regression.

The evidence for cointegration is mixed. For the 1961QI - 1979QIII period, none of the lagged first differences of the residuals is significant, so D-F provides the appropriate test, and both it and CRDW indicate rejection of no cointegration. When the post 1979QIII period is added to the sample, some of the lagged first differences are significant, suggesting the ADF statistic should be used. In all cases, this fails to reject no cointegration. The CRDW statistics rejects no cointegration when π_{t+1} is regressed on i_t but not when i_t is regressed on π_{t+1}. The estimates of the cointegration parameters (reported in the column labeled α) also yield mixed results. The estimated coefficient in all odd numbered regressions should be around 0.7. Only equation 4 comes close.

Part B

The nominal interest rate innovation, $\hat{i}_t$, is simply the one-step ahead forecast error for the nominal bill rate as implied by the estimated VAR. The inflation forecast innovation, $E_t\hat{\pi}_{t+1}$, can also be obtained from the VAR in the following manner. Suppose z_t is the 6x1 vector of the variables in the VAR at time t. The VAR system can be written as

$$z_t = A(L)z_{t-1} + u_t \tag{A.1}$$

where A(L) is a 6x6 matrix of polynomials in the lag operator L (that is, $A(L) = A_0 + A_1L + A_2L^2 + \ldots$ and $L^i x_t = x_{t-i}$), and u_t is the vector of one-step ahead forecast errors. Let s_π be a selection vector such that $s_\pi z_t = \pi_t$ (that is, s_π just picks out π from the list of variables in z). The equation for π_t is given by

$$\pi_t = s_\pi z_t = s_\pi A(L)\, z_{t-1} + s_\pi u_t. \tag{A.2}$$

Equation A-2 can be used to evaluate $E_t\, \hat{\pi}_{t+1}$.

By definition, $E_t\hat{\pi}_{t+1} = E_t\pi_{t+1} - E_{t-1}\pi_{t+1}$. Updating A.2 by one, $\pi_{t+1} = s_\pi A(L)z_t + s_\pi u_{t+1}$ so that $E_t\pi_{t+1} = s_\pi A(L)z_t$. Similarly, $E_{t-1}\pi_{t+1}$ is equal to $s_\pi A_0 E_{t-1}z_t + s_\pi A_1 z_{t-1} + s_\pi A_2 z_{t-2} \ldots$ It follows that

TABLE A.1

Tests for a Random Walk Component in the Nominal Interest Rate and the Rate of Inflation[1]

A: Trend excluded

Variable	Sample Period	Test Statistic
3-month Treasury Rate	1961QI-1985QIII	−1.94
	1961QI-1979QIII	−1.95
	1970QI-1985QIII	−1.73
GNP Deflator	1961QI-1985QIII	−1.92
	1961QI-1979QIII	−1.34
	1970QI-1985QIII	−1.49
CPI	1961QI-1985QIII	−2.05
	1961QI-1979QIII	−0.85
	1970QI-1985QIII	−2.06

B: Trend included

Variable	Sample Period	Test Statistic
3-month Treasury Rate	1961QI-1985QIII	−2.64
	1961QI-1979QIII	−3.84*
	1970QI-1985QIII	−2.15
GNP Deflator	1961QI-1985QIII	−1.26
	1961QI-1979QIII	−2.95
	1970QI-1985QIII	−1.57
CPI	1961QI-1985QIII	−2.05
	1961QI-1979QIII	−3.26
	1970QI-1985QIII	−2.00

* Significant at the 5% level.
1. See notes to Table 1. The rate of inflation is measured as the first difference of the log of the price index.

$$E_t\pi_{t+1} - E_{t-1}\pi_{t+1} = s_\pi A_0 (z_t - E_{t-1}z_t) = s_\pi A_0 u_t \qquad (A.3)$$

Thus, the revision to the inflation forecast is equal to a linear combination of the errors made in forecasting all the elements of z_t. Because $E_t\hat{\pi}_{t+1}$ depends on the one-step ahead forecast errors (u_t) and coefficients from the VAR (A_0), it is easily calculated from the estimated system.

Part C

The decomposition of the *ex post* real rate into components attributable to the various underlying shocks is based on the moving average representation of the VAR system given in equation A.1:

$$z_t = (I - A(L)L)^{-1}u_t = B(L)v_t \qquad (A.3)$$

where $v_t = Gu_t$ is the orthogonalized vector of disturbances obtained from the VAR residual vector u_t, and $B(L) = (I - A(L)L)^{-1}G^{-1}$. Using the selection vector s_π to pick out the equation for π and s_i to pick out the equation for the nominal rate, the *ex post* real rate can be expressed as

$$\begin{aligned} exr_t &= s_i z_t - s_\pi z_{t+1} \\ &= s_i B(L)v_t - s_\pi B(L)v_{t+1} \\ &= \sum_q \sum_j b_{qj}^{(i)} v_{jt-q} - \sum_g \sum_j b_{qj}^{(\pi)} v_{jt+1-q} \end{aligned} \qquad (A.4)$$

where $b_{ij}^{(x)}$ is the coefficient on the i[th] lag of the j[th] shock in $s_x B(L)$, $x = i, \pi$. The contribution of the j[th] shock to exr_t is equal to

$$\sum_q (b_{qj}^{(i)} - b_{qj}^{(\pi)})\, v_{jt-q} - b_{0j}^{(\pi)}\, v_{jt+1}$$

The orthogonalized shocks were obtained using a

TABLE A.2

Tests of Long-Run Relationship Between the Nominal Rate and Inflation

Cointegrating Regression: $y_t = \alpha + \beta x_t$

Sample Period	y_t[1]	x_t	α	Test Statistics: CRDW[2]	D-F[3]	ADF[4]
1961Q1-1985QIII	i_t	π^1_{t+1}	0.54	0.33	−3.03	−1.75
	π^1_{t+1}	i_t	0.44	0.68*	−4.28*	−1.79
	i_t	π^2_{t+1}	0.42	0.40	−3.37*	−1.83
	π^2_{t+1}	i_t	0.60	0.72*	−4.56	−1.87
1961Q1-1979QIII	i_t	π^1_{t+1}	0.49	0.84*	−4.37*	−2.95
	π^1_{t+1}	i_t	1.19	1.23*	−5.57*	−2.97
	i_t	π^2_{t+1}	0.44	1.79*	−5.81*	−2.96
	π^2_{t+1}	i_t	1.64	1.36*	−6.03*	−2.45
1970Q1-1985QIII	i_t	π^1_{t+1}	0.19	0.23	−1.93	−1.56
	π^1_{t+1}	i_t	0.13	0.59*	−3.03	−1.40
	i_t	π^2_{t+1}	0.17	0.29	−2.13	−1.60
	π^2_{t+1}	i_t	0.26	0.68*	−3.54*	−1.76

1. Variables are the 3-month Treasury bill rate (i_t), the first difference of the log of the GNP Price Deflector (π^1_t), and the first difference of the log of the CPI (π^2_t)
2. 5 percent critical value given by Engle and Granger (1987) is 0.39.
3. 5 percent critical value given by Engle and Granger (1987) is 3.37.
4. 5 percent critical value given by Engle and Granger (1987) is 3.17.

Choleski decomposition based on the following ordering of the variables in the VAR: government purchases and defense expenditures were ordered first in their respective VARs, followed by real GNP, M1, the nominal interest rate, the relative price of fuel, and the rate of inflation. When the deficit was used, the ordering was real GNP, M1, the nominal interest rate, the relative price of fuel, the deficit and the rate of inflation.

For each ordering, the hypothesis that a given variable Granger-caused a variable ordered before it could be rejected. Note that when the monetary or fiscal shock is set equal to zero, the predicted path of the money supply or the fiscal variable will still vary endogenously in response to movements in the other variables in the system.

FOOTNOTES

1. See the discussion of real rate targeting in Walsh (1983).

2. By a random walk component I mean that a variable x_t can be written as $y_t + z_t$ where y_t is a stationary random variable and $z_t = z_{t-1} + \varepsilon_t$ when ε_t is a stationary process. Realizations of ε_t have permanent effects on z_t and x_t.

3. The test statistic does not have a standard t-distribution, but the appropriate critical values are given in Fuller (1976).

4. For nontechnical introductions to real business cycle theories, see Walsh (1986, 1987).

5. If all changes in a variable x_t are permanent, then the variance of $x_{t+k} - x_t$ is equal to k times the variance of $x_{t+1} - x_t$. If all changes in x_t are temporary, then the variance of $x_{t+k} - x_t$ should tend to zero for large k. Thus the ratio

$$\sigma_k = \frac{1}{k} \cdot \frac{\text{var}(x_{t+k} - x_t)}{\text{var}(x_{t+1} - x_t)}$$

is a measure of the relative importance of the random walk component. The ratio σ_k equals 1 for a pure random walk and zero if all changes are transitory. Cochran's method is evaluated in Campbell and Mankiw (1987).

6. Because the *ex post* real rate used to construct the measure of persistence is equal to the *ex ante* real rate plus a serially uncorrelated inflation forecast error, Cochrane's measure will yield a value of σ_k less than one for the *ex post* rate even if the *ex ante* rate is a pure random walk.

7. For discussions of the use of the nominal interest rate in the conduct of monetary policy, see Sargent and Wallace (1975), McCallum (1986), and Goodfriend (1987).

8. From the properties of conditional expectations,

$$E_{t-1}(E_t\pi_{t+1}) = E_{t-1}\,\pi_{t+1}.$$

9. See Litterman and Weiss (1985).

10. Dummy variables for 1980QII and 1980QIII were also included to capture the effects of the credit controls in effect at that time. The use of defense expenditures as a proxy for fiscal policy is discussed in Section III; the general conclusions in this section were not affected when other proxies were used.

11. From equation 5, $\hat{r}_t$ is just equal to $\hat{i}_t - E_t\hat{\pi}_{t+1}$. This also implies that var $(\hat{i}_t)$ = cov $(\hat{i}_t, \hat{r}_t)$ + cov $(\hat{i}_t, E_t\hat{\pi}_{t+1})$. The fraction of nominal rate innovation variance associated with real rate innovations can then be estimated by cov $(\hat{i}_t, \hat{r}_t)$ / var $(\hat{r}_t)$. The fraction of var $(\hat{i}_t)$ associated with revisions in expected inflation is thus 1 − cov $(\hat{i}_t, \hat{r}_t)$ / var $(\hat{i}_t)$ = cov $(\hat{r}_t, E_t\hat{\pi}_{t+1})$ / var $(\hat{i}_t)$. Since var $(\hat{i}_t)$ = var $(\hat{r}_t)$ + var $(E_t\hat{\pi}_{t+1})$ + 2 cov $(\hat{r}_t, E_t\hat{\pi}_{t+1})$, the measure used to estimate the fraction of var $(\hat{i}_t)$ associated with $\hat{r}_t$ is not equal to var $(\hat{r}_t)$ / var $(\hat{i}_t)$ unless cov $(\hat{r}_t, E_t\hat{\pi}_{t+1}) = 0$. In fact, cov $(\hat{i}_t, \hat{r}_t)$ = var $(\hat{r}_t)$ + cov $(\hat{r}_t, E_t\hat{\pi}_{t+1})$, so the measure used here is equal to var $(\hat{r}_t)$ / var $(\hat{i}_t)$ + cov $(\hat{r}_t, E_t\hat{\pi}_{t+1})$ / var $(\hat{i}_t)$.

12 Based on a VAR estimated using quarterly data from 1949QII to 1983QII, Litterman and Weiss (1985) report that a 1-percent innovation to the nominal rate was, on average, associated with a .56 percent real rate innovation and a .44 percent expected inflation innovation, exactly the same division reported in Table 2 for the 1961Q1-1984QIII period. Note that, while the actual estimation period runs to 1984QIV, one observation is lost in calculating the realized future rate of inflation needed to form the *ex post* real rate.

13. For a discussion of this view, see Barro (1984, Chapter 15). Some empirical evidence is presented in Motley (1987).

14. The estimated effects of the 1980 credit controls have been subtracted out of the real rate series plotted in both Chart 2 and Chart 3.

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