Monetary Policy and the Behavior of Long-Term Real Interest Rates

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A time-honored description of the "monetary transmission channel"—the set of linkages that run from the instrument that the Federal Reserve controls to its ultimate goals, low unemployment and low, stable inflation—suggests that the Fed controls the federal funds rate, which affects the rates on longer-term credit market instruments, which affect the expected *real* (inflation-adjusted) rates on longer-term instruments, which affect real spending on interest-sensitive goods, which affects unemployment and inflation.[1] This description is used quite widely in commentary on the state of the economy and the appropriate stance of monetary policy. And yet one key link in the chain, the expected real long-term interest rate, is not observable. There is no market in the United States in which participants trade long-term debt contracts that are negotiated in real terms (adjusted for the inflation rates that are expected to prevail over the life of the contracts), and thus we do not directly observe expected long-term real interest rates.[2] One can search all of the available economic data and never find a series with such a description.

This poses an interesting problem for macroeconomic modelers and policymakers. While a vast array of *nominal* yields on financial instruments are available, these yields convey only part of the information necessary to flesh out the conventional transmission channel.[3] Moreover, Bernanke and Blinder (1992) have observed that the federal funds rate, a short-term nominal interest rate, has been very well correlated over the past 30 years with subsequent movements in real activity. Does this empirical observation imply that we can ignore the difficulties inherent in linking short-term nominal rates to expected long-term real rates and posit a simpler "Bernanke–Blinder" transmission channel in which nominal rates directly affect real economic activity? This would be somewhat disconcerting, because most of our theories predict a relationship between longer-term *real* rates and real activity.[4] Or does the correlation between nominal short rates and real output proxy for a more understandable correlation between long real rates and real activity?

This article explores the link between the behavior of monetary policy and inferences about the behavior of the expected long-term real rate of interest. Analysis of this link reveals a reasonable empirical basis for the standard transmission channel, and an explanation of the Bernanke–Blinder observation that is fully consistent with the standard transmission channel.

I. A Simple Framework for Understanding the Link from Monetary Policy to Long-Term Interest Rates[5]

If the description of the transmission channel in the first paragraph of this article is approximately correct, then the behavior of long-term real interest rates will depend importantly on the current and expected behavior of the federal funds rate, and thus on the behavior of the FOMC, the body that sets the funds rate.

Monetary Policy

The starting point for the framework is the description of the behavior of monetary policymakers. Their ultimate goals are a stable and low inflation rate, π_t, and a level of real activity, y_t, that is stable around its "potential." To achieve these goals, the Fed changes the federal funds rate, rff_t, so as to "lean against the wind," raising the funds rate when inflation is above its target, and lowering it when output falls below its potential. It may choose to respond more vigorously to deviations of inflation from its target, or to deviations of output around potential, or equally to both. The vigor with which the Fed responds to deviations of its ultimate concerns from their targets is summarized in the "reaction function" coefficients α_π and α_y in equation (1).[6]

To achieve its goals, the Fed changes the federal funds rate so as to "lean against the wind," raising the funds rate when inflation is above its target, and lowering it when output falls below its potential.

$$rff_t - rff_{t-1} = \alpha_\pi(\pi_t - \bar{\pi}) + \alpha_y(y_t - \bar{y}) \qquad (1)$$

Equation (1) will be the complete description of monetary policy for the purposes of this article. All of the "policy exercises" will involve changes in the emphases on inflation and real activity, α_π and α_y, and in the target inflation rate, $\bar{\pi}$.

The Link from Short to Long Interest Rates

The second component of the framework is the linkage from short-term rates to longer-term rates. It is conventional to assume that, to a first approximation, participants in the bond markets act so as to equalize the real, after-tax, risk-adjusted returns on bonds of different maturities. If this were not so, then investors would buy the low-priced (high-yield) asset and sell the high-priced (low-yield) asset. These relative shifts in demand and supply would drive up the price on the low-priced asset and drive down the price on the high-priced asset until the differences in yields disappeared.[7]

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[1] In fact, the relevant rate is the real, after-tax rate of interest. This article ignores the effects of taxes.

[2] The United Kingdom issues inflation-indexed bonds, which presumably reflect the long-term real rate of interest (and, by comparison with equivalent long-term *nominal* bond yields, the long-term expectations for inflation).

[3] This article will refer to "the transmission channel" of monetary policy. In fact, there are many transmission channels; monetary policy affects different sectors of the economy in different ways. Because the framework exposited below does not distinguish between the different components of real output, it does not distinguish between the different transmission channels. Empirically, this strategy works quite well, as will be shown in the following sections.

[4] There are reasons to believe that nominal rates might affect certain sectors of the economy. For example, some households that are cash-flow constrained may care more about the nominal interest rate on their mortgage, because it determines the monthly cash payment that they must make, than about the real interest rate. Even for this example, however, many of the constrained households would be considering fixed-rate mortgages, and so they care about a *long-term* nominal interest rate, not the federal funds or some other short-term rate.

[5] The framework described here is essentially that of Fuhrer and Moore (1995).

[6] It is assumed here that while the Fed determines the target rate of inflation, $\bar{\pi}$, the Fed cannot influence the level of potential output, $\bar{y}$.

[7] Of course, many caveats can be attached to this simple description of asset markets, including the observation that the presence of transactions costs could explain the persistence of yield differentials.

For our purposes, the yields that we expect to equalize are the real yield on federal funds, $rff_t - E\pi_{t+1}$, and the real yield on a long-term bond, ρ_t. We abstract from both taxes and risk differentials. The simplest way to state the relationship between federal funds and the long bond is that the yields on the two instruments should be such that investors are ambivalent in expectation between holding a long-term bond for its duration and continually rolling over short-term federal funds investments over the same duration as the long-term bond. If the expected real yields do not satisfy this equality, then investors will shift their positions to take advantage of the "better deal," and the yields will adjust accordingly. Equation (2) states this condition algebraically.[8]

When the Fed changes the systematic component of its behavior, it can alter the expectations of future federal funds rates that are assumed to determine the long rate.

$$\rho_t = \sum_{i=0}^{k} \beta_i E_t(rff_{t+i} - \pi_{t+1+i}) \qquad (2)$$

where the symbol E_t indicates the expectation of a variable, given all the information available at the time t that the expectation is made. This equation defines the expected real rate of return on a long-term bond as the weighted average of the expected real returns on federal funds over the life of the bond. This equation also illustrates the unobservability of long-term real rates: Because expectations of the difference between future short rates and inflation are not directly observable, the expected long-term real rate itself is not observable.[9]

Equation (2) makes the link between monetary policy and long rates explicit. When the Fed changes the systematic component of its behavior (changes any of the coefficients in equation (1)), it can alter the expectations of future federal funds rates that are assumed to determine the long rate. However, in order to complete the definition of the expected long-term real interest rate, two more elements are required. The first is a description of the process generating inflation, required both for its direct effect on expected future real funds rates, and for its indirect influence on the expected nominal federal funds rate through the Fed's reaction function. The second is a description of the behavior of real output, required because of its importance as a determinant of inflation and because of its effect on the funds rate (and therefore the expected funds rate) through the reaction function.

Inflation

The behavior of inflation is determined by two defining characteristics:

(1) Inflation is linked to real activity: When output rises above potential, inflation tends to rise, and conversely.

(2) Inflation moves *gradually* in response to changes in output.

The specification of inflation that is used in this paper's framework is motivated by the existence of overlapping nominal wage and price contracts as in Fuhrer and Moore (1995); the details of the specification are discussed in that article. For the present purposes, the most important feature of the specification is that it captures both of the defining characteristics of inflation enumerated above. In that regard, it behaves very much like a conventional Phillips curve.

Real Output

Real output is influenced by its own recent behavior and (negatively) by the level of the expected long-term real interest rate. With this final link, the transmission channel is complete: the funds rate is linked to long-term real rates via equation (2), long-term real rates are linked to real output, and real output influences inflation as described in the preced-

[8] In the original formulation of this link between short-term and long-term rates, the long-term rate is equal to the expected *geometric* average of future short-term rates, so that the summation would be replaced by a product. Equation (2) is an approximation to the multiplicative form that is very accurate for low to moderate real rates.

[9] Some surveys of long-term inflation expectations are available, although not on a continuous basis extending back 30 years or more. The Hoey survey, for example, queries financial market participants on 10-year inflation expectations. In addition to not being available for a long, continuous sample, however, these also are not exactly the inflation expectations that should enter the definition of the long real rate, as equation (2) shows.

ing section. Equation (3) summarizes this final component of the framework.

$$\tilde{y}_t = a_1\tilde{y}_{t-1} + a_2\tilde{y}_{t-2} - b\rho_{t-1} \tag{3}$$

II. Is the Framework a Reasonable Description of the Economy?

If we combine the description of monetary policy, the link from short to long rates, the persistent inflation model, and the real output relationship, we have a model that can be used to examine the behavior of the economy and of expected long-term real rates. A graphical depiction of the basic relationships in the model appears in the diagram. In summary, the model works as follows:

- Expected long-term real rates depend on expectations of future short-term real rates. While these are not observed, the model implies specific forecasts of future short-term interest rates and inflation, and these are used to construct the long-term real rate according to equation (2).
- The federal funds rate depends on inflation and real output.

Basic Relationships in the Model

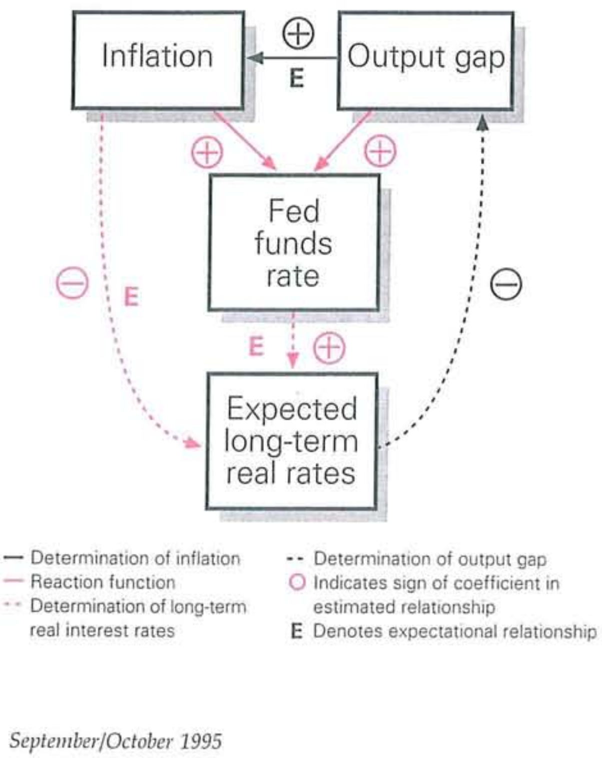


Table 1
Model Variables

Mnemonic	Description
	Data Variables
rff	Federal funds rate, quarterly average of daily effective rates
π	Inflation rate, four times the log change in the GDP deflator
y	Logarithm of GDP per capita, 1987 dollars
$\tilde{y}$	Deviation of logarithm of real per capita GDP from segmented linear time trend, breakpoint in 1973:I
	Model-Defined Variable
ρ	Expected long-term real interest rate

- Inflation is determined by past and expected inflation, and the past and expected output gap.
- The output gap depends on its own history and on expected long-term real rates.

Fuhrer and Moore (1995) estimate the coefficients in this simple model—the responsiveness of the funds rate to inflation and output, the sensitivity of inflation to the real output gap, and the influence of real interest rates on real output. For given coefficients, we can use the model to infer the expected real interest rates that are consistent with the model and the data on the federal funds rate, inflation, and the real output gap. That is, we use the data and the model structure to compute the weighted average of forecasts of short-term real interest rates that are consistent with the model and that define the expected long-term real interest rate. The definitions of model variables are summarized in Table 1.[10]

The solid line in Figure 1 displays the expected long-term real interest rate that is generated in this fashion. As the figure shows, the real rate rises during times that the Fed was widely viewed as pursuing contractionary monetary policy, notably 1981–82 and 1987–89. The model's estimate of the expected real rate peaks in the middle of 1981, when the Fed was

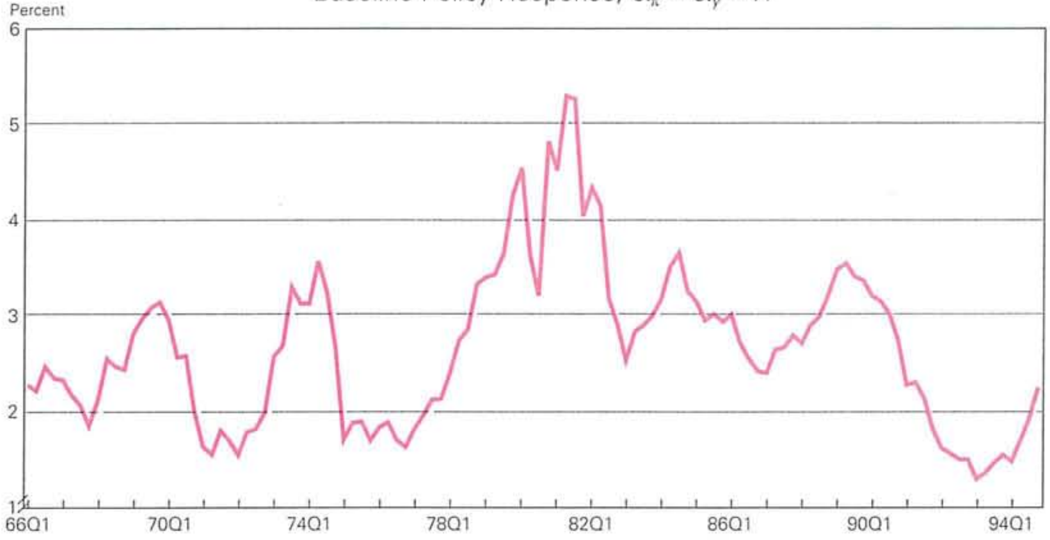
[10] A full set of estimation results is reported in Fuhrer and Moore (1995). Most important for our purposes is the output gap equation, which captures the influence of the model's expected long-term real interest rate on real output. The estimated coefficients for this equation are reported below:

$$\tilde{y}_t = 1.34\tilde{y}_{t-1} - 0.37\tilde{y}_{t-2} - .75(\rho_{t-1} - 2.3)$$

so that real rates exert a depressing effect on output whenever they exceed their long-run equilibrium of 2.3 percent.

Figure 1

Expected Long-Term Real Interest Rate
Baseline Policy Response, $\alpha_\pi = \alpha_y = .1$



Source: Author's calculations.

explicitly engineering a recession to disinflate the economy. How well does a model with these movements in the (unobservable) expected real interest rate describe the behavior of the U.S. economy?

The next figure displays a "dynamic" simulation of the model economy over the important 1981–86 period of the great disinflation. The simulation starts the model off at the actual values for inflation, interest rates, and real output at the end of 1980, and then traces the implications of the model from that time forward, not allowing the model to "see" any actual data during the simulation period.[11] The simulation suggests that the transmission channel described above is a very accurate description of how monetary policy influences the economy.

In the top panel, tight Fed policy results in an expected long-term real rate of 3½ percent in 1981, considerably above its long-run equilibrium level. The result is that the economy slows, output falls well below potential, and inflation falls fairly quickly. As a graphical check on the validity of this simple model, the actual data for the output gap and inflation are included as the black lines in the bottom two panels of the figure (there is, of course, no corresponding "actual" line for the expected real rate). The simple dynamics of this model of the transmission mechanism capture very well the actual paths taken by the key variables in the macroeconomy over one of the most important episodes in the last 30 years. This lends plausibility to the model's estimate of the expected long-term real rate. The next section examines the behavior of the real rate, explaining its movements by reference to the systematic behavior of monetary policy.

III. Explaining the Behavior of the Long-Term Real Rate[12]

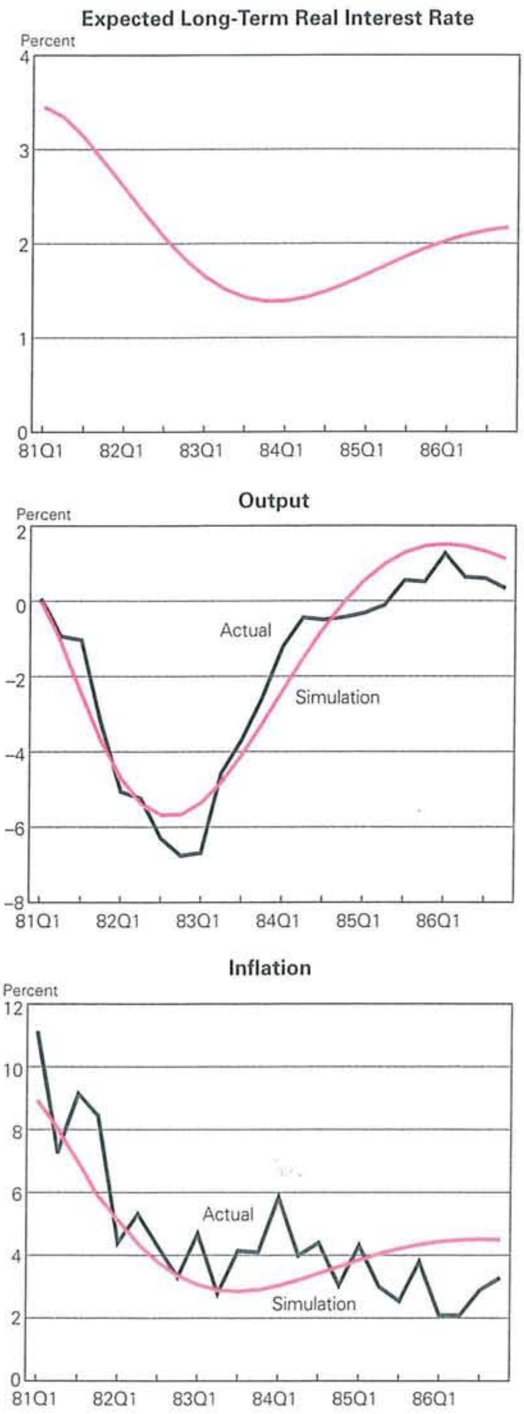
Figure 3 plots the estimated real rate from Figure 1 with the actual federal funds rate. Interestingly,

[11] Note that the model was estimated using data from this period, so that the model has already "seen" some of this data. Thus, this simulation is not an out-of-sample dynamic simulation, but an in-sample dynamic simulation. Still, this is a more difficult test to pass than a "static" simulation that feeds actual values of lagged variables into the simulation path.

[12] The analysis in this section follows closely Fuhrer and Moore (1995).

Figure 2

The Monetary Transmission Channel at Work: The "Great Disinflation" of the 1980s



Source: Expected long-term real interest rate and output and inflation simulations: Author's calculations.
Actual output: Log of real GDP per capita, deviation from segmented trend.
Actual inflation: Log change in the GDP deflator.

although the scales are somewhat different (as they should be—one is a real rate, one a nominal rate), the movements in the expected real rate are mirrored extremely closely by the movements in the funds rate. Thus, this model provides a partially satisfying explanation for the Bernanke–Blinder observation. Real output is actually well correlated with the expected long-term real interest rate, which happened to look like a short-term nominal interest rate for the past 30 years.

While this explanation is satisfying on one level, it leaves much to be desired on another. While we now have a plausible interpretation of the correlation of short rates with real output, the question left unanswered is: Why has the long-term real rate behaved like a short-term nominal rate over recent history? Does the structure of the framework require the two to be tightly linked? Because our framework builds a tight link between monetary policy behavior and long-term rates, the first place to look for an explanation is in a close analysis of the behavior of monetary policy.

How Does the Behavior of Monetary Policy Affect the Long Real Rate?

Monetary policy cannot completely determine the economy's course. Because policy affects the economy with a lag, other economic influences that are "baked in the cake" at the time of policy implementation and influences that arise unexpectedly during the unwinding of the policy transmission channel cannot be completely offset by monetary policy. However, important differences in the systematic response of monetary policy to the state of the economy can yield distinctly different behaviors of the macroeconomy.

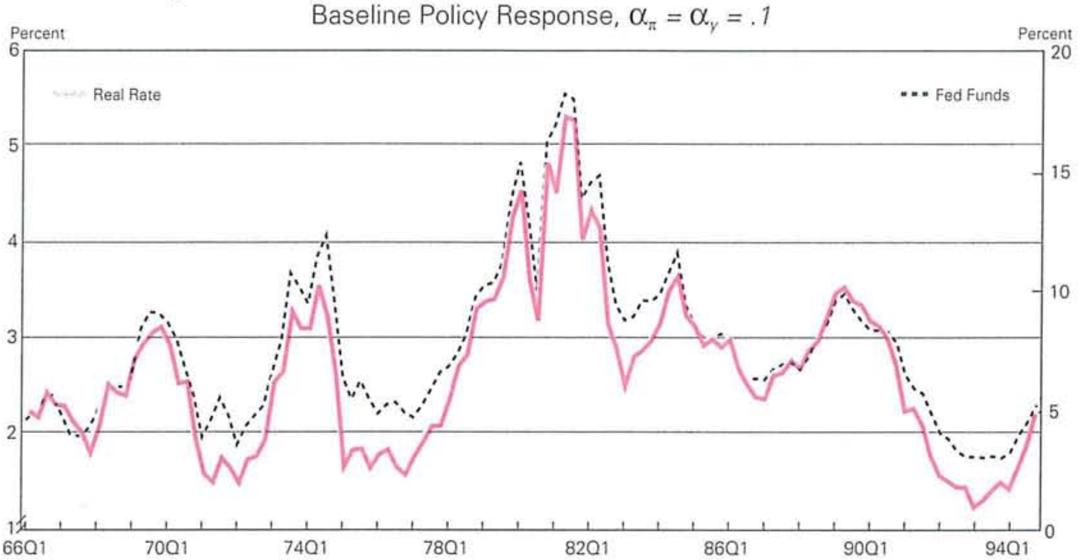
The vector autocorrelation function (VAF) provides one graphical way of summarizing the patterns of behavior in key variables in the economy. The VAF displays the correlations between one variable today and another variable some time in the past. Included in the VAF is the correlation between a variable and itself a fixed number of periods in the past, its "autocorrelation". Thus, the VAF summarizes all of the correlations among a set of variables, both contemporaneously and across time.

An example of a VAF is shown in Figure 4. The figure displays the correlations among inflation, the federal funds rate, and the real output gap, taken from the model that was used to produce the simulation in Figure 2. The policy response is the "baseline" response that sets $\alpha_\pi = \alpha_y = .1$. The autocorrelations for

Figure 3

Expected Long-Term Real Interest Rate vs. Federal Funds Rate

Baseline Policy Response, $\alpha_\pi = \alpha_y = .1$



Source: Real rate: Author's calculations.
Fed funds rate: quarterly average of daily effective rates.

inflation, the funds rate, and the output gap are displayed along the top left to bottom right "diagonal" of the graph. They show that all three of these series are positively correlated with their own past values. If inflation (or the funds rate or the output gap) was higher than average four quarters ago, it is likely to be higher than average today.

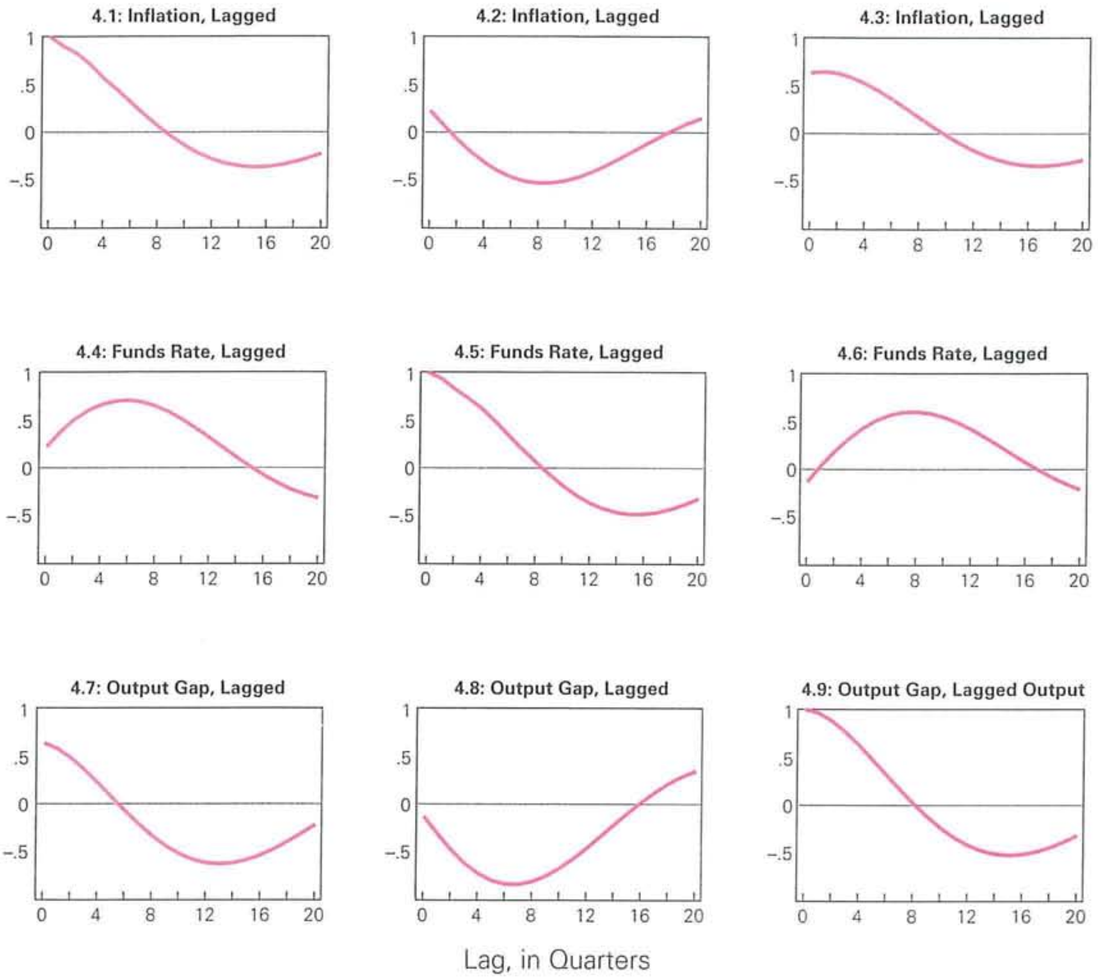
In the "off-diagonal" elements of Figure 4, we can see how interest rates, inflation, and real output interact over time. Panel 4.2 may be translated as "when the federal funds rate was higher than average four to eight quarters ago, inflation tends to be lower than average today." Panel 4.3 captures the Phillips-curve behavior of inflation: When output exceeds potential over the past several quarters, inflation tends to be higher than average today. Panels 4.4 and 4.6 capture the response of the federal funds rate to current and lagged inflation and real output. In both cases, when past inflation and output are higher than normal, the funds rate subsequently tends to be higher than normal. In the last row, panel 4.8 depicts a condensed version of the effect of monetary policy on output: When the federal funds rate was higher than normal four to eight quarters ago, the output gap tends to be negative today. As was demonstrated above, this condensed version proxies for the more conventional link from federal funds to long-term real rates to output.

Thus, these VAFs provide a graphical snapshot of how the important variables in the economy interact over time. One more insight about the VAF will be useful in unraveling the monetary policy–real interest rate connection. Note that the top panels of Figure 4 may be read as reflecting the link either between past variables (inflation, interest rates, and output) and current inflation, or between current variables and future inflation. The correlation holds regardless of the "viewpoint date" assumed.

Understanding the behavior of long-term real rates requires two additional steps. The first will link changes in the systematic behavior of monetary policy to changes in the VAF for the variables in the economy. The second will link observations about the correlations among the variables in the economy, particularly about the correlations over time between the funds rate and inflation, to explanations of the behavior of long-term real interest rates.

Figure 4

Vector Autocorrelation Function for Baseline Monetary Policy
$\alpha_{\pi} = \alpha_{y} = .1$



Source: Author's calculations.

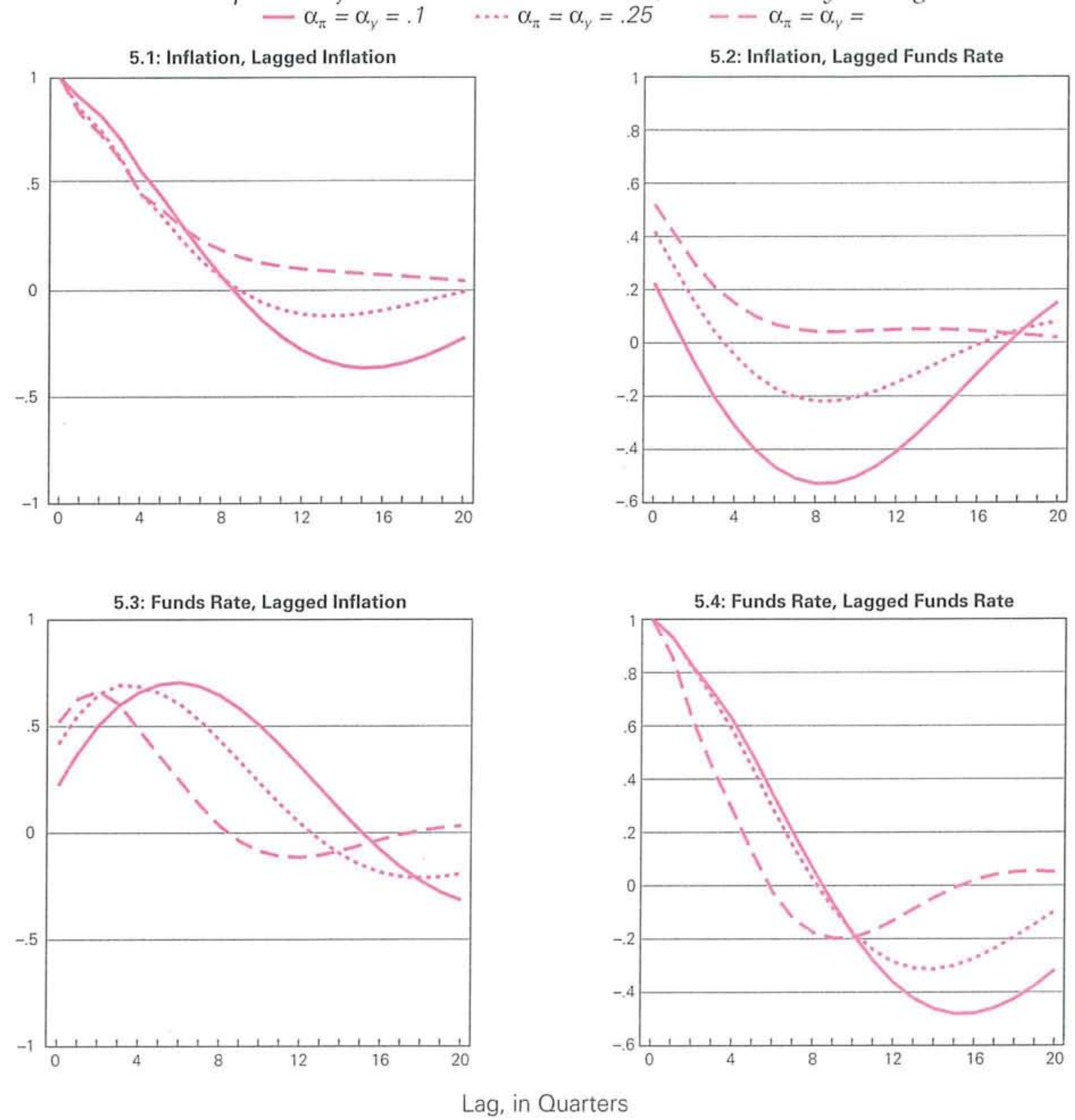
The Effect of Monetary Policy on Correlations Between Interest Rates and Inflation

Changes in the way the Fed sets the funds rate in response to deviations of inflation from its target can alter the correlation over time between short-term interest rates and inflation. In one sense, one could view the long-term mission of monetary policy as the desire to influence this correlation. A successful inflation-fighting policy will entail vigorously raising the short-term interest rate in order to subsequently lower the inflation rate. Thus, a negative correlation between past interest rates and current inflation rates, as in panel 4.2 of Figure 4, can be interpreted as evidence of an inflation-fighting monetary policy.

Figure 5 displays the VAFs associated with several different monetary policy regimes, focusing only on the relationship between inflation and the funds rate. Each regime is characterized by its reaction function coefficients (the responses to inflation and the

Figure 5

Comparison of Autocorrelation Functions, Various Policy Settings



Source: Author's calculations

output gap in equation (1) above). Note that for moderate inflation-fighting policies—policies with coefficients of 0.1 or 0.25 in the reaction function—the correlation between past funds rates and current inflation, displayed in panel 5.2, is predominantly negative for the first five years or so. In all cases, current inflation is positively correlated with lagged inflation, at least for the first eight quarters, and often for longer, as shown in panel 5.1. This is an indication of the inherent persistence in the rate of inflation. Regardless of the monetary policy pursued, inflation will exhibit considerable persistence.[13]

A monetary policy that responds quite strongly to inflation and output—as in the long-dashed lines in Figure 5, which set both policy responses to 1—yields a *positive* correlation between past funds rates and current inflation. The Fed moves the federal funds rate up rapidly to push inflation down when inflation is above its desired level, for example, and drops the funds rate just as quickly when output falls below potential and inflation drops to its new, lower target. This aggressive policy moves inflation and real output monotonically toward their targets. As a result, high past funds rates will be associated with current inflation rates that are above their desired level. Thus, the positive correlations indicated in the long-dashed line in panel 5.2 are caused by a strong policy response to both inflation and output.

Different monetary policies can imply very different correlations over time between inflation and interest rates.

In addition, the weaker the inflation and the output responses, the more negative the autocorrelation of inflation turns over time, as shown in panel 5.1. If monetary policy does not vigorously force inflation towards its target, then inflation will gradually move towards and subsequently "overshoot" its target. Above-normal inflation rates three years ago will be associated with below-normal inflation rates today. This overshooting behavior is indicated by the negative autocorrelations of inflation at lags 12 to 20, displayed in the solid and short-dashed lines in panel 5.1.

Thus, different monetary policies can imply very different correlations over time between inflation and interest rates. How do these correlations explain the behavior of long-term real rates?

The Link between Long-Term Expectations and the VAF

Recall that the expected long-term real interest rate is equal to the weighted average of expected short-term real interest rates, where the short-term real rate is defined as the difference between the expected short-term nominal rate and the expected rate of inflation. Thus, we can think of expected long-term real rates in this model as composed of the difference between the expected long-term nominal rate, R_t, and the expected long-term rate of inflation, Π_t, or

$$\begin{aligned} \rho_t &= \sum_{i=0}^{m} E_t rff_{t+1} - \sum_{i=0}^{m} E_t \pi_{t+1+i} \qquad (4) \\ &= R_t \qquad\qquad - \Pi_t \end{aligned}$$

Ultimately, the *expectations* of any variables in the model, which are not observable, must be based upon things that are observable, such as the quarterly observations on inflation, interest rates, and output. Thus, in the framework that we are currently using, we must be able to express R_t and Π_t in terms of these variables. How these expectations depend on observable macro variables will be the final key to understanding long real rates.

Consider the expected long-term nominal rate R_t. What should be the relationship between the expected long-term nominal rate and the short-term nominal rate? The VAF suggests that, at the baseline policy parameters used to generate Figure 4, the relationship should be *positive*, consistent with the persistence of the federal funds rate displayed in panel 4.5 of Figure 4. The correlation between R_t and inflation can be inferred from panel 4.4 of Figure 4: Current inflation should be *positively* correlated with future (expected) federal funds rates and thus with R_t. Thus, the expected long-term nominal rate should be positively related to both the funds rate and inflation.

By similar reasoning, at the baseline policy parameters, the long-term expected inflation rate should be *positively* correlated with current inflation. This is a direct implication of panel 4.1 of Figure 4: Current inflation is positively correlated with future (expected) inflation, but therefore it must be positively correlated with long-term expected inflation. Finally, long-term expected inflation should be *negatively* correlated with the current funds rate; this relationship is implied by panel 4.2 of Figure 4. The current funds rate is negatively correlated with future (expected) inflation rates, so it must be negatively correlated with expected long-term inflation.

[13] Fuhrer (1995) examines the persistence of inflation in detail.

Table 2
The Components of the Expected Long-Term Real Rate

Component	Relationship to: Short-term nominal rate	Inflation rate
Baseline Policy Parameters ($\alpha_\pi = \alpha_y = 0.1$)		
Long-term nominal rate (R_t)	positive	positive
minus	–	–
Expected long-term inflation (Π_t)	negative	positive
equals	=	=
Expected long-term real rate (ρ_t)	positive	zero
Vigorous Policy Response ($\alpha_\pi = \alpha_y = 1.0$)		
Long-term nominal rate (R_t)	positive	positive
minus	–	–
Expected long-term inflation (Π_t)	positive	positive
equals	=	=
Expected long-term real rate (ρ_t)	?	?

Turning back to equation (4), we can now see why the baseline monetary policy has produced an expected long-term real rate that behaves like a short-term nominal rate. Table 2 summarizes the relationships between the expected long-term nominal rate and expected inflation and the funds rate and inflation, in the context of the definition of the long-term real rate. The positive correlations between the long-term nominal rate and inflation and between long-term inflation and inflation are essentially equal, so they cancel out in the definition of expected long-term real rates. However, the positive correlation between long-term nominal rates and short-term nominal rates is reinforced by the negative correlation between long-term inflation and short-term nominal rates. As a result, only the short-term nominal rate provides a significant net contribution to the definition of expected long-term real rates.

Thus, the close correspondence between short-term nominal rates and output may be interpreted as a close correspondence between long-term expected real rates and output. The reason is that long-term expected real rates behave very much like short-term nominal rates. This similarity depends critically, however, on the behavior of monetary policy.

The Effect of a Change in Monetary Policy on the Behavior of Real Rates

What happens to the correspondence between short nominal rates and long real rates when monetary policy behaves differently than it has in recent history? Consider the long-dashed lines in Figure 5. These correlations are generated by a policy that aggressively targets both inflation and real output. Now the negative correlation between the funds rate and future inflation in the solid line in panel 5.2 has turned positive. The difference between the expected long-term nominal rate and long-term expected inflation, as depicted in Table 2, no longer yields a long real rate with an unambiguous relationship to the funds rate.

Figure 6 displays the expected long-term real rate that is consistent with this aggressive monetary policy response.[14] As the figure shows, the real rate no longer mimics the behavior of the short nominal rate (the correlation between the real rate and the funds rate here is about 0.5, as compared with 0.96 in Figure 3). The more vigorous policy response implies markedly different correlations between inflation and the funds rate, implying a different pattern of expectations for short-term real rates, and thus a different expected long-term real rate.

This exercise shows that in this framework the behavior of the expected long-term real rate, including its reduced-form correlation with the short nominal rate and inflation, depends importantly upon the behavior of monetary policy. A shift from less vigorous to more vigorous inflation and output targeting can alter the *sign* of the dynamic correlations between inflation and the short rate. Thus, the behavior of real rates implied by this framework will not be stable across changes in the monetary policy regime.

IV. Some Revealing Disinflation Simulations

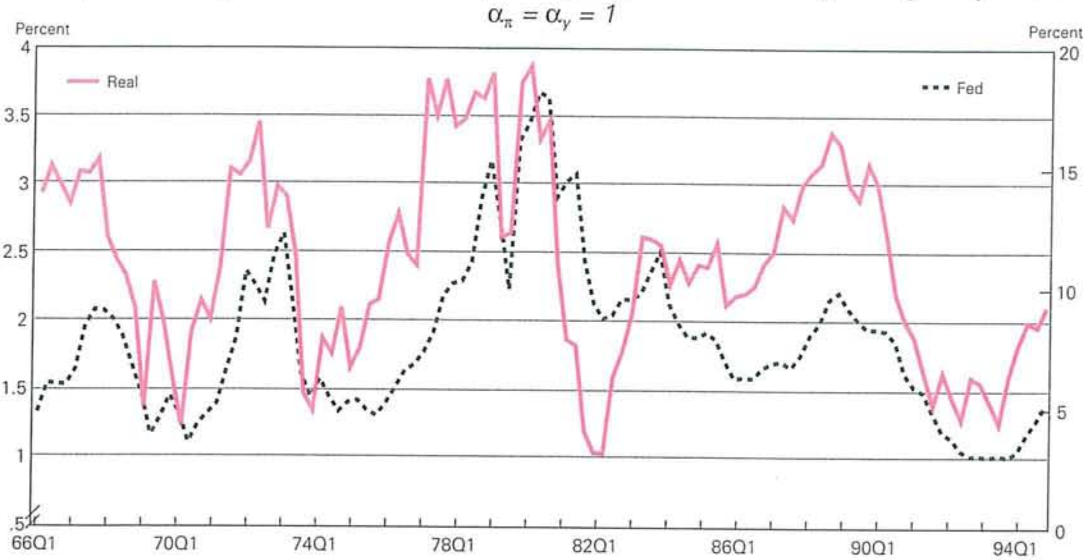
Much of the correspondence between the autocorrelation information in Figures 4 and 5 and the systematic behavior of monetary policy can be illustrated in a somewhat more digestible form by simulating a disinflation for a particular policy setting from the figures. Figure 7 displays two disinflation simulations,

[14] The expected long-term real rate is generated by dynamically simulating the model with the vigorous monetary policy response over the data from 1966 to 1994.

Figure 6

Expected Long-Term Real Rate Implied by Vigorous Monetary Policy Responses

$\alpha_\pi = \alpha_y = 1$



Source: Real rate: Author's calculations.
Federal funds rate: quarterly average of daily effective rates.

one for the baseline policy setting $\alpha_\pi = \alpha_y = 0.1$ (the top panel), and one for the vigorous policy response $\alpha_\pi = \alpha_y = 1.0$ (the lower panel). In each case, the economy begins at an initial point with the output gap equal to zero, inflation at its initial target rate of 3 percent, the expected real rate of interest at its long-run equilibrium value (2 percent), and the federal funds rate at the sum of the equilibrium real rate and the target inflation rate.[15] At the beginning of the simulation, the target inflation rate is dropped 3 percentage points to zero, and all the variables in the model respond as dictated by the relationships specified in equations (1) to (3).

Under the baseline policy response, the funds rate rises modestly at the onset of the disinflation, raising expected long-term real rates and depressing output below potential, and inflation begins to fall. As the output gap turns decidedly negative, the funds rate responds moderately, dropping slowly below its new long-run equilibrium (2 percent) and not quickly enough to prevent slack demand from pulling inflation below its new target.

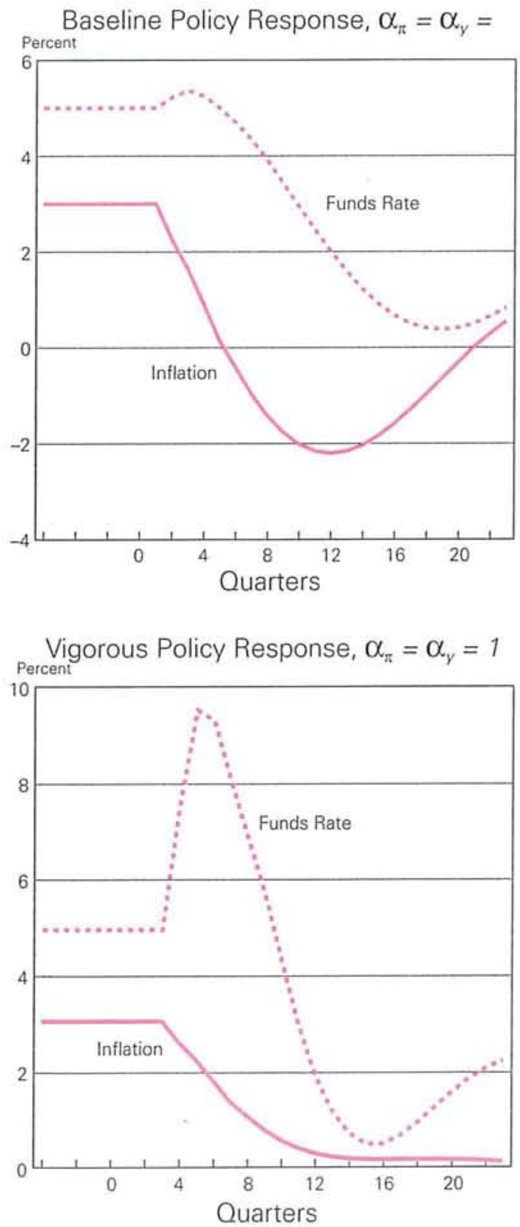
One can read the dynamic correlations between inflation and the funds rate directly from this disinflation simulation. Higher-than-normal initial federal funds rates are followed by lower-than-target inflation rates 5 to 16 quarters later. This is exactly the negative correlation displayed in panel 4.2 of Figure 4. Similarly, higher-than-target inflation rates at the beginning of the disinflation are followed by higher-than-normal federal funds rates for the ensuing 12 quarters. This positive correlation of current inflation with future funds rates is mirrored in panel 4.4 in Figure 4.

The first of these two dynamic correlations shifts dramatically under the vigorous policy response in the disinflation depicted in the bottom panel of Figure 7. With an initial output gap of zero, and an "inflation gap" (the difference between the inflation rate and its target rate of zero) of 3 percent, the Fed quickly raises the federal funds rate, raising expected real rates and depressing output, thus lowering the inflation rate. As the output gap turns more and more negative, the Fed

[15] The equilibrium real rate of 2 percent is consistent with the estimated coefficient values for the real output gap equation (3), reported in footnote 10.

Figure 7

Disinflation Simulation



Source: Author's calculations.

quickly lowers the funds rate, avoiding a more serious downturn in real activity and avoiding the "overshooting" of inflation that takes place under the baseline policy response. The more vigorous monetary policy yields a milder "recession" (a smaller negative output gap) than the baseline policy and a smaller variation of inflation about its target, due to the absence of inflation overshooting. Thus, one key lesson that can be drawn from this simulation comparison is that a more vigorous monetary policy is more "efficient" in this framework, achieving better outcomes for *both* inflation and real output.

Once again, the dynamic correlations between inflation and the funds rate are apparent from the simulation. Higher-than-normal funds rates at the beginning of the disinflation are followed by higher-than-target inflation rates throughout the disinflation. Thus the combination of more vigorous inflation and

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output targeting has reversed the sign of the correlation between the current funds rate and future inflation rates. As before, higher-than-target inflation rates at the beginning of the disinflation are associated with higher-than-normal funds rates for the next eight quarters. Thus, the disinflation simulations essentially articulate the pattern of correlations over time between inflation and the funds rate that are implied by a particular monetary policy response.

V. Conclusions

This article provides empirical support, originally documented in Fuhrer and Moore (1995), for a standard description of the monetary policy transmission channel. According to this view, the Fed sets the federal funds rate in response to deviations of inflation and real output from their desired values. Credit market participants take this systematic behavior into account in forming their expectations of future federal funds rates, and so their expectations of long-term real interest rates reflect the stance of Federal Reserve policy. Long-term real interest rates in turn influence real economic activity, which in turn influences the rate of inflation. This characterization of the economy and of the Fed's role in it appears to match the behavior of the actual economy quite well.

As monetary policy alters its systematic response to inflation and real activity, credit market participants' expectations of future funds rates will also shift, inducing changes in the behavior of expected long-term real rates. This article illustrates the link between the behavior of monetary policy and the behavior of long-term real rates, tracing the link from a particular policy response to its implications for the expected interaction between the federal funds rate and inflation over time. In addition, the paper provides an explanation for the widely documented correlation between short-term nominal rates and real activity (see, for example, Bernanke and Blinder (1992)), arguing that this correlation may be interpreted as the outcome of an underlying correlation between expected long-term real rates and real activity.

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