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# Can the Fed Control Real Interest Rates?

Robert J. Shiller

## Introduction

One contribution that the recent literature on “rational expectations” in macroeconomic models<sup>1</sup> has to make to the older literature on the neutrality of money is to suggest a definition of the real interest rate in a stochastic environment and to suggest senses in which it may or may not be controllable by the monetary authority (or “Fed”). The new definition takes the “rationally expected real rate of interest” as the nominal or “money” interest rate (as quoted in financial markets or perhaps as an after-tax interest rate) minus the *optimally forecasted* inflation rate. The senses in which it may or may not be controlled are described in terms of the nature of the influence of chosen parameters of the Fed *policy rule* on the stochastic properties (and relation to other variables) of the real rate so defined.

There are at least three distinct hypotheses concerning the Fed’s influence over rationally expected real interest rates that seem to be suggested in recent discussions of monetary policy. We will give a brief statement of them here subject to clarification below. We will disregard at this point whether we wish to use an “after-tax real rate.” It is assumed throughout that Fed policy takes the form only of open market operations and that the interest rate is a short-term one. In order of decreasing stringency and testability, these nested hypotheses are:

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1. This literature is surveyed by Poole 1976 and Shiller 1978.

*Hypothesis 1.* The form the Fed policy rule takes, whether deterministic or random, has no effect on the behavior of rationally expected real interest rates. That is, the Fed has no ability to shock rationally expected real interest rates at all in the short run or long run. This hypothesis has apparently never been asserted outright in the published literature but does seem implicit in many discussions. The hypothesis seems to be suggested by those who would try to explain interest rates in terms of inflationary expectations without apparent regard to the form monetary policy has taken. Fama, in his well-known article on interest rates as predictors of inflation (1975), seems to suggest this hypothesis when he extends his own hypothesis that one-month real rates are constant to periods when the Fed apparently caused a credit crunch, but at another point he also appears to deny explicitly that the Fed has no influence at all over real interest rates.<sup>2</sup>

*Hypothesis 2.* The Fed can shock rationally expected real interest rates, but only by taking policy actions other than the actions the public supposes they are taking. That is, if Fed policy on a particular day is known by the public on that day, it will have no effect on real rates.

Hypothesis 2 has some important implications. First, it implies that the Fed's ability to affect real interest rates relies essentially on secrecy. If the Fed opened up all of its internal discussion to public scrutiny without time lag, it would then lose any ability to affect real interest rates. Second, the hypothesis implies that even if the Fed is allowed to maintain secrecy, then still the *systematic* (i.e., nonrandom) part of its policy rule is without effect on real interest rates. That is, if the Fed attempts consistently to pursue any "sensible" or "purposeful" policy then its policy behavior will bear some consistent relation to business conditions and will become predictable by economic agents outside the Fed. This assumes that the Fed has no secrets about business conditions, that is, does not have any "information advantage" over the public.

Hypothesis 2 would appear to be suggested by many models that incorporate the Lucas-Sargent-Wallace aggregate supply relation (see, for example, Lucas 1973), or variations on it, and is specifically an implication of the macroeconomic model of Sargent and Wallace (1975).

*Hypothesis 3.* Any policy action by the Fed that is known by the public sufficiently far in advance will have no effect on rationally expected real interest rates. That is, we could in principle identify a "policy effectiveness interval," which might be as short as a few days or as long as many years. If the Fed policy rule depends only on information known

2. Data before 1951 is not usable, Fama (1975) said, because "in effect a rich and obstinate investor (i.e., the Fed) saw to it that Treasury bill rates did not adjust to predictable changes in inflation rates."

earlier by this time interval, then the form the rule takes will have no effect on the behavior of real interest rates.

The implications of hypothesis 3 depend on the length of the policy effectiveness interval. If the interval is years long, then the Fed may have substantial scope for systematic countercyclical monetary policy. Since the business "cycle" is not rigidly periodic, it cannot be forecasted years in advance, and so even if the Fed policy rule follows a consistent or systematic relation to business conditions, the public will still not have enough advance notice of the policy to react in such a way that real rates become uncontrollable. But if the interval is very short, then there may not be an important difference between hypothesis 3 and hypothesis 2. We will speak of this hypothesis as implying generally a policy effectiveness interval of, say, at least a number of months, but less than a number of years.

Hypothesis 3 seems to be suggested in many discussions. It is specifically a consequence of a model by Phelps and Taylor (1977) and would appear to be implied (though not explicitly in his model) by Fischer (1977). These models connected the policy effectiveness interval with the length of time prices are rigid (Phelps and Taylor) or the length of time labor contracts run (Fischer).<sup>3</sup>

All of our hypotheses are meant to characterize economies in "expectations equilibria," and in the literature that suggested them, "rational expectations equilibria." By an expectations equilibrium we mean merely a situation in which economic agents have *unchanging* subjective probability distributions for all stochastic variables in the economy. If this equilibrium is rational, these subjective distributions are correct. In such an equilibrium, then, economic agents have a correct understanding, to the extent that it will ever be understandable, of the Fed policy rule. What economic agents do not understand is represented as a stochastic term with known properties. Our hypotheses 2 and 3 concern comparative expectations equilibria, that is, what changes in the behavior of economic variables will occur when the parameters of the policy rule are changed *after* the public fully appreciates the systematic nature of the change. In understanding hypotheses 2 or 3, it is particularly important to bear this in mind. If the Fed changes its policy rule (e.g., changes the way the money growth rate responds to unemployment), then there will no doubt be a transition period before a new rational

3. In Phelps and Taylor 1977, prices are assumed to be fixed by firms one period in advance and the money supply fixed by the Fed based on information *not* known one period in advance. If Fed policy were known one period in advance, then taking expectations of their expression (8) based on information known at time  $t-1$  and using their expression (6), one finds that the money stock drops out of the real part of their model altogether.

expectations equilibrium is reached.<sup>4</sup> The length of this transition period is not to be confused with the policy effectiveness interval.

These hypotheses would seem in principle to be subject to some form of empirical verification. The concepts of a “rationally expected real interest rate” and of a “Federal Reserve policy rule” and changes thereof are sufficiently slippery, however, to make it difficult to bring empirical evidence to bear on *any* of these hypotheses, as we shall discuss in the next section of this paper. It is perhaps for this reason that the literature relating to these hypotheses is almost exclusively theoretical. Empirical literature on the real interest rate (e.g., the Fama 1975 article mentioned above), while perhaps relevant to our evaluation of these hypotheses, does not explicitly consider them.

At the same time, there are some who have asserted, on the basis of their observations of real world phenomena, that certain of these hypotheses are highly “implausible.” It is apparently a useful exercise, therefore, to discuss ways in which empirical evidence (qualitative as well as quantitative) might be brought to bear on them, if at all.

Our purpose in this paper is (a) to discuss the definitions of “rationally expected real interest rates” and “Fed policy rule” and the meaning of the three hypotheses described above, (b) to discuss the kind of subjective beliefs that must be added before these hypotheses have any testable implications, and (c) to look at the data and empirical literature in monetary economics to see if there are any clues to the plausibility of the hypotheses when they are given “reasonable” interpretations.

Some will perhaps argue that the abstract models that yielded these hypotheses are not to be taken literally, that they are intended as abstract possibilities that suggest a change in our methods of monetary policy evaluation. Nonetheless, people *have* applied them to discussions of historical experience and will no doubt be inclined to do so in the future. We think, then, that it is not premature to discuss whether these hypotheses might be considered useful in understanding historical experience. Needless to say, our examination of these hypotheses should not be interpreted as an evaluation of the contribution to the history of economic thought of the abstract models that gave rise to them.

## **Definition and Measurement of Real Interest Rates and Fed Policy Rule**

### **The Real Rate of Interest**

A number of different definitions have been applied to the term “real interest rate.” For simplicity, we will at this point disregard tax considerations in defining them.

4. The economy may never reach a new rational expectations equilibrium, or may never be in one. These are important theoretical possibilities that lessen the appeal of models that assume rational expectations equilibria (see Shiller 1978).

First, the  $m$ -period real interest rate at time  $t$  has been defined as the money or “nominal” interest rate (the usual rate quoted at time  $t$  in financial markets) minus the actual inflation rate from time  $t$  to time  $t + m$ .<sup>5</sup> Since the inflation rate is not known with certainty, the real interest rate by this definition is not known at time  $t$ , and hence we will refer to this as the *ex post* real interest rate. By this definition the real interest rate is readily measured *ex post*, at least insofar as inflation can be measured.

Second, the  $m$ -period real interest rate at time  $t$  has been defined as the nominal interest rate minus the average inflation rate forecast by professional forecasters as quoted in the news media. Readers of business periodicals are regularly supplied with inflation forecasts by the major consulting firms that specialize in macroeconomic forecasting. It has been argued that, realistically, no one in the public has any significant information advantage over these professional forecasters and that it would seem rational to base decision making on these forecasts. These consensus forecasts, while not market determined, are the result of intense discussion in a sort of intellectual “marketplace,” especially in more recent years. We will call this the *consensus* real interest rate. The consensus real interest rate is readily measured with a slight lag, which is a publication lag. Since inflation forecasts usually move slowly, this lag is generally not important, but is *potentially* important in some hypothetical circumstances.

Third, the  $m$ -period real interest rate at time  $t$  has been defined as the rate quoted at time  $t$  on an  $m$ -period index bond. An  $m$ -period index bond is a bond whose coupons or principal due at maturity at time  $t + m$  are guaranteed in *real* terms, that is, they are escalated by a price index. We will call this the *market* real interest rate. The market real interest rate is readily measurable at time  $t$ , since it is a rate quoted on financial markets. Unfortunately, a market for such index bonds does not yet exist in the United States.

We will digress for a moment to consider whether the Fed might control the real interest rate by any of these definitions. The *ex post* real rate is obviously not fully controllable, since inflation cannot be fully forecasted. Clearly, however, the Fed can always control the consensus real interest rate as it desires (so long, at least, as this is consistent with a positive nominal rate) if it is willing to accept the economic consequences of the control. The Fed can choose a real interest rate, add to that the latest consensus inflation forecast, and then “peg” the nominal rate at their sum. If we abstract from current institutional details, the

5. Slight variations in the definition arise because of different ways of handling compounding. For example, we might define the real interest rate as one plus the nominal rate divided by one plus the rate of inflation. We disregard the differences among these definitions in what follows.

owner of the "printing press" could announce that it stands ready to borrow and lend unlimited amounts at this nominal rate, and then no one would borrow from another person at a higher rate nor would one lend to another at a lower rate. If the Fed can print nominal bonds as well as money in unlimited amounts, there is no limit to its ability to do this (or to repay the principal on the nominal bonds when they come due). One might question, however, whether it is really of interest that the Fed can do this. If the Fed, in its control of consensus real interest rates, were to cause rapid economic changes, then the publication lag might make the consensus forecast unimportant to economic decisions. Should markets not all clear, the inflation rate based on quoted prices might become less relevant to economic decision making. A hyperinflation might ensue if the Fed tried to peg rates too low or if it consistently followed certain policy rules which would ultimately cause money to be abandoned as the medium of exchange. A deflation might ensue if the Fed tried to peg rates too high; this might cause nominal rates to hit zero, ending the Fed's latitude for control.

It would seem highly plausible a priori that at any moment of time there is nonzero range over which the Fed can influence consensus real interest rates. Efforts to peg such real interest rates do not create unlimited riskless profit opportunities. In contrast, suppose (to take a simple extreme example) the Fed tried to establish different borrowing and lending (nominal) rates and offered to lend, say, at 3% and borrow at an incrementally higher rate. It would thereby create an unlimited riskless profit opportunity. Individuals would borrow from the Fed and use the proceeds to lend to the Fed and would reap a profit with certainty. It is realistic to suppose that if the Fed really announced this, however small the increment, it would quickly find an infinite supply of both lenders and borrowers. If, however, the Fed announced a reduction of the consensus real interest rate from 2%, say, to 1%, it seems hard to imagine that anything really dramatic would happen and historical experience appears to confirm this. The question, then, is how far and for how long it can reduce or raise the consensus real interest rate.

The Fed would seem to have the same sort of potential control over market real interest rates with one modification. It could announce a market real interest rate and offer to buy unlimited quantities of index bonds at this rate, but it cannot sell unlimited quantities of index bonds. While it can promise to deliver unlimited quantities of money in the future, it cannot promise to deliver unlimited quantities of real goods in the future. There are limits to the Fed's ability to command real resources through inflationary finance. Hence it would seem that the Fed could *depress* market real interest rates as it pleases, but there are limits to its ability to elevate them. A hyperinflation is, of course, a possi-

ble consequence of depressing the market real interest rates too far or for too long.

The  $m$ -period *rationally expected* real interest rate at time  $t$ , which is defined as the  $m$ -period nominal rate quoted at time  $t$  minus the optimal forecast of the inflation between time  $t$  and time  $t + m$ , is not so readily observed either ex ante or ex post. The rationally expected real rate of interest is not necessarily equal to the consensus real rate of interest or market real rate of interest. In fact, the rationally expected real rate of interest is undefined unless economic variables are stochastic processes whose random properties are given. Such a definition thus makes sense only when the Fed's behavior itself can be described as a stochastic process or policy rule related to other economic variables. The question then is, can the Fed, in deciding on its policy rule, choose a rational expectations equilibrium characterized by a desired behavior of the rationally expected real interest rate?

Such a definition of the real rate of interest is inherently academic, and at the same time a rather elusive concept. It is academic because in a world that is enormously complex and constantly changing, there is no way to define an optimal forecast without some assertion of faith in a model of some sort. Economic agents clearly have diverse models and forecasts. We can estimate empirical forecasting equations, but these will differ depending on the structure we assume, the explanatory variables we include, and the sample period we choose. The concept is also elusive when applied to the present issue for a couple of reasons. First, monetary authorities do not think of themselves as outcomes of stochastic processes and tend to think of themselves as exercising free will. If they must be described in terms of a reaction function, it would be logical to ask whether they can even choose parameters of this function. Second, it is no longer possible to speak of the Fed as defining its policy rule as a function of an observed real interest rate or observed expected rate of inflation, since these depend on the policy rule. That is, the Fed cannot announce that it will buy and sell bonds at 2% plus the optimally forecasted rate of inflation, since it does not know what this will become upon announcement. A rational expectations theorist might be able, given a complete model of the economy, to find an "inflationary expectation" as a function of observable variables predetermined at time  $t$ , so that if the Fed pegs nominal rates at the desired real rate plus this inflationary expectation, then this inflationary expectation will be an optimal forecast of the resulting inflation. But it is not obvious that we know the model that might enable rational expectations theorists to do this. It is also conceivable that no such rational expectations equilibrium at the desired real rate of interest exists or that, even if it might exist, there may be no path of economic variables that makes a transition from the

present equilibrium to the alternative equilibrium. It may be, for example, that an announced policy of pegging the real yield of an index bond may not cause the economy to converge on a rational expectations equilibrium at all, because the price level may explode to infinity.

In this sense, then, models in which the indefinite fixing of market real yields at some announced function of state variables will result in unstable price behavior might be described as models in which the rationally expected real rate is absolutely uncontrollable.

Given the difficulties with the concept of a rationally expected real rate of interest, a practical control theorist might conclude that there is no point even in considering the concept. One might wish to define the structure of the economy in terms of observable variables. Yet it may be, as rational expectations theorists have argued, that the true structure of the economy is not comprehensible unless such variables are included in our model.

#### Tax Law and the Definitions of the Real Interest Rate

For an individual or corporation in marginal income or corporate profits tax bracket  $\tau$  the after-tax ex post real rate of interest is found by subtracting the inflation rate from  $(1 - \tau)$  times the nominal rate. This is the rate of increase in real after-tax buying power. Definitions of consensus real rates and rationally expected real rates may also be put on after-tax basis by replacing the nominal rate in the definition by  $(1 - \tau)$  times the nominal rate. Now, we have not a single after-tax real interest rate but an array of such rates, one for each tax bracket.

It has been suggested (Darby 1975, Feldstein 1976) that hypotheses such as ours should refer not to the simple real interest rate but to the after-tax real rate for some "representative" tax bracket or for the corporate tax rate paid by large corporations. There is a sort of intuitive plausibility to this suggestion. Consider two individuals in the same tax bracket who wish to make a three-month loan between them. No net taxes are paid by the two of them considered together since the borrower deducts interest paid equal to the amount declared as income by the lender. In effect, the government refunds  $\tau$  times the interest rate from the lender to the borrower. In the face of inflation, if the individuals wish to keep the amount of real resources transferred in the terms of the loan the same as without inflation, they need only mark up their nominal rate by the inflation rate times  $1/(1 - \tau)$ .

If our tax system were neutral to inflation in other ways, and if all individuals paid the same marginal tax rate, then it would seem quite plausible that our hypotheses should refer to the after-tax real rate. The problem is that our tax system is not neutral in other ways to inflation. If the borrower in our example above wishes to use the funds to

purchase physical assets for speculative purposes, then he will not be happy with an arrangement that keeps his real after-tax interest paid constant in the face of inflation, since he will be taxed on the inflation of the price of his investment. Indeed, with such short-term speculation for which gains are taxed as ordinary income, his profits after tax will remain constant in the face of inflation only if the simple (not after-tax) real rate is kept constant. The lender may then also be indifferent to either making the loan or investing in the physical asset himself. But if the borrower wishes to spend the money on a vacation (and the lender views the opportunity cost of the loan as a vacation foregone), then he may be happy with the constant after-tax real rate, precisely since he is not taxed on the “psychic” income from an investment in a vacation and hence inflation does not affect him in the same way. It is clear, then, that inflation affects taxes of individuals in different circumstances in different ways, and so it is not likely that hypotheses 1 through 3 above could be given a simple rationale in terms of any particular definition of the real interest rate.

One possible conclusion of our consideration of tax effects is that our empirical work should concentrate on the period before World War II, when income taxes were relatively negligible. Postwar monetary policy is not really “pure” monetary policy since it affects real taxes. If we are interested in the ability of “pure” monetary policy to affect real interest rates, then we had best confine our attention to the period when such policy was practiced. Our approach here is instead to consider both periods in terms of the simple real interest rate even though for the postwar period the hypotheses may be of less interest.

### The Federal Reserve Policy Rule and Hypothesis Testing

We will suppose first that all relevant possible Federal Reserve policy rules can be summarized and indexed in terms of a parameter vector  $\beta$  in the form:

$$(1) \quad f(r_t, M_t, \beta, \mathbf{I}_t, \phi_t) = 0,$$

where  $r_t$  is the interest rate,  $M_t$  is the log of high-powered money,  $\mathbf{I}_t$  is a vector of state variables or information at time  $t$  which characterizes the economy before the Fed acts at time  $t$  and is known to the public as well as the Fed, and  $\phi_t$  is an innovation in Fed policy that cannot be forecast by the public, that is, it is independent of the information vector  $\mathbf{I}_t$ . We have written the function in implicit form to allow for both interest rate rules and money stock rules or for combination rules.

The Fed confronts a public demand for high-powered money function, which we will write as:

$$(2) \quad g(r_t, M_t, \mathbf{I}_t, \beta, \gamma, \delta_t) = 0,$$

where  $\gamma$  is a vector of parameters and  $\delta_t$  is a vector of innovations in public behavior. Public behavior depends on  $\beta$  through their reaction to the Fed policy rule. Equation (2) is a reduced form equation for the rest of the macroeconomic model, taking either  $r_t$  or  $M_t$  as exogenous.

Equations (1) and (2) represent a two-equation model in two unknowns,  $r_t$  and  $M_t$ . The solution to the model, or reduced form is:

$$(3) \quad r_t = h_1(\beta, \mathbf{I}_t, \phi_t, \gamma, \delta_t)$$

$$(4) \quad M_t = h_2(\beta, \mathbf{I}_t, \phi_t, \gamma, \delta_t).$$

Another reduced form equation from the macroeconomic model gives the price level:

$$(5) \quad P_t = h_3(\beta, \mathbf{I}_t, \phi_t, \gamma, \delta_t),$$

and from this equation we can derive the expected rate of inflation  $E_t(P_{t+1} - P_t)$  and hence the rationally expected real interest rate:

$$(6) \quad r_t - E_t(P_{t+1} - P_t) = h_4(\beta, \mathbf{I}_t, \phi_t, \gamma, \delta_t).$$

Hypotheses 2 and 3 concern the way this reduced form equation derived from the structural equations of our model depends on  $\beta$ .

One fundamental problem we face in explaining such models econometrically is finding identifying restrictions. One must find certain exogenous variables that we know shock equation (2) without shocking equation (1) and may be used as instruments to estimate (1) consistently and other exogenous variables that we know shock equation (1) without shocking equation (2) and may be used to estimate equation (2) consistently. The problem is that it is difficult to find *any* variable that we can be confident shocks one equation without shocking the other. When expectations are involved in the behavior that underlies (1) and (2), then *anything* that is publicly known might in principle affect both equations.

There is a literature on estimation of the demand for money and a smaller literature on the estimation of Fed reaction functions, which might be used to try to examine some of the hypotheses. We do not believe, however, that estimates are trustworthy for this purpose. One reason is that this literature generally does not handle the simultaneous equations estimation problem well. When instrumental variables are used there is generally no discussion, let alone a convincing one, to justify the assumption that the exclusion restrictions and exogeneity assumptions are justified. This defect is compounded by the fact that with slow-moving variables and short samples the small sample properties of the K-class estimators may differ widely from those predicted by the usual asymptotic sampling theory.

For the purpose of formulating policy, we need to know the model. For the purpose of evaluating the hypotheses noted in the introduction, however, it may not be necessary to estimate the model. It may instead be necessary to find some change in  $\beta$ .

The first hypothesis noted in the introduction asserts that the structure of the economy is such that  $r_t - E_t(P_{t+1} - P_t)$  is independent of either the Federal Reserve parameter vector  $\beta$  or the random variable  $\phi_t$ . If we can find  $\phi_t$  or a change in  $\beta$ , then the real rate should be uncorrelated with it.

The second hypothesis implies that if  $\phi_t = 0$  (i.e., the Fed is completely predictable), then  $r_t - E_t(P_{t+1}) + E_t(P_t)$  is independent of  $\beta$ . Changes in the parameter  $\beta$  of the policy rule should not affect the random properties of the real rate. If  $\phi_t$  is random, then this hypothesis has no unambiguous interpretation with a model of this generality. The division of Fed policy into "predictable" or "unpredictable" components might be achieved, for example, by positing a money stock rule of the form

$$(7) \quad M_t = f_2(\mathbf{I}_t, \beta) + \phi_t,$$

and then we might interpret the hypothesis to mean that the behavior of real interest rates is independent of  $\beta$ .

The third hypothesis, like the second, cannot be defined unambiguously until we decide how to divide Fed behavior into components that were and others that were not predictable in advance by the policy effectiveness interval. If we write:

$$(7') \quad M_t = f_3(\mathbf{I}_{t-k}, \beta) + g_3(\mathbf{I}_t, \phi_t),$$

so that  $f_3(\mathbf{I}_{t-k}, \beta)$  is the component of Fed policy known in advance by the policy effectiveness interval  $k$ , then the hypotheses might be interpreted to imply that the interest rate is independent of  $\beta$ .

Unfortunately, although in casual discussions it is often assumed that the hypotheses are well defined, alternative interpretations are possible which would be represented by different versions of (7) or (7') and would in turn be subject to different approaches for testing them. For example, we might break down money into *multiplicative* predictable and unpredictable components, we might allow  $f_3$  in (7') to be multiplied by a function of  $\mathbf{I}_t$ , or we might break down an *interest rate rule* into predictable and unpredictable components.

The only way we can discuss direct verification of the second or third hypothesis cited in the introduction to this paper is to identify periods during which the Fed policy rule had a stable, repetitive nature and also to identify the time when the transitions between these periods occurred (i.e., where  $\beta$  changed). Our guide in identifying changes in the policy

rule will be to look only for changes that were announced by the Fed and well understood by the public. It is inherently a highly subjective business to try to identify periods in which the Fed policy rule might be described as repetitive and when it changed. To evaluate hypothesis 2 or 3 based on statistical analysis, however, we have no alternative but to try.

### Measures of Real Interest Rates

As we have noted, it is impossible to measure the rationally expected real interest rate without a statement of faith in a model and, if there are unknown parameters in the model, an identification of a sample period of some length when the model held. If we take the model above, then, before looking at the data, we begin with prior distributions for the parameters  $\beta$  and  $\gamma$  and for the parameters of the distributions of  $\phi$  and  $\delta$ . We might then in principle update the priors with the data over a period when the policy rule was stable to get a joint posterior distribution of  $\beta$  and  $\gamma$  and other parameters. This distribution might then be used to produce a predictive distribution for the ex post real rate conditional on historical data:  $f(r_t - \Delta P_{t+1} | \mathbf{I}_t)$ , and we might define the rationally expected real rate as the expected value of  $r_t - \Delta P_{t+1}$  from this predictive distribution.

This approach suffers from the problem of describing our uncertainty about the nature and structure of the model. A more parsimonious way to proceed is to seek a simple empirical forecasting relation by finding the optimal linear forecast of  $r_t - \Delta P_{t+1}$  based on some small subset  $\mathbf{I}_{0,t}$  of  $\mathbf{I}_t$  which seems particularly likely to be important in determining the predictive distribution  $f(r_t - \Delta P_{t+1} | \mathbf{I}_t)$ . For example, we might regress  $r_t - \Delta P_{t+1}$  on its own lagged value to produce an autoregressive forecasting relation. We will call the fitted values of such a regression based on the subset of information and regression coefficients the optimal linear forecast and denote it by  $L(r_t - \Delta P_{t+1} | \mathbf{I}_{0,t})$ . Now one property of such optimal linear forecasts is that  $L(r_t - \Delta P_{t+1} | \mathbf{I}_{0,t}) = L(E(r_t - \Delta P_{t+1} | \mathbf{I}_t) | \mathbf{I}_{0,t})$ ; that is, the optimal linear forecast of the ex post real rate is the same as the optimal linear forecast of the true (unobserved) rationally expected real interest rate (see for example Shiller 1978).

It is a property of optimal linear forecasts that the variance of the forecast is less than or equal to the variance of the variable forecasted (i.e.,  $R^2 \leq 1$ ). If we know the optimal linear forecast variance, we can put bounds on the variance of the true rationally expected real interest rate, i.e., its variance must lie *between* the variance of the optimal linear forecast and the variance of the ex post real rate.

The essential point for our purposes is the following: if we can estab-

lish that the Fed can control the optimal linear forecast of the ex post real rate in the sense of one of our hypotheses (e.g., that it can, by changing  $\beta$ , and without relying on unforeseen shocks  $\phi_t$ , affect the random properties of the optimal linear forecast), then it can affect the random properties of the true unobserved rationally expected real interest rate. Since the projection of the optimal linear forecast on  $\mathbf{I}_{0,t}$  is the same as the projection of the true rationally expected real interest rate on  $\mathbf{I}_{0,t}$ , one cannot change the one without changing the other and hence one concludes that one *must* have changed at least the relationship of the rationally expected real interest rate with  $\mathbf{I}_0$ .

### **Empirical Verification Hypotheses**

#### **General Approach**

Now we will explore interpretations and tests of the three hypotheses along the lines suggested above. We will consider whether the hypotheses are plausible in view of the observed behavior of nominal rates coupled with the fact that the precise timing and magnitude of Fed actions are probably exogenous and unforecastable. We will also consider the fact that the Fed apparently can (and *has*) pegged nominal rates, which means that there was a sharp reduction, to zero, in exogenous shocks to monetary policy at this time.

Next we will consider whether the history of the Federal Reserve system can be broken down into subperiods in which the policy rule showed a distinctly different stochastic behavior. The subperiods must be long enough so that it makes sense to try to identify the policy rule from the data. We will argue that there is some reason to divide the monetary history of the twentieth century into three long periods: the period 1900 to 1913, before the Fed was founded, the period 1914 to 1950 of early monetary policy (which was unfortunately disrupted by two world wars and a major depression), and the period 1951 to the present, when modern monetary policy was practiced.

Finally, we will consider Granger-Sims causality tests between real interest rates and money growth rates and Barro unanticipated money tests as ways of evaluating these hypotheses.

#### **Behavior of Nominal Interest Rates**

Members of the Federal Reserve Board—and of the Trading Desk at New York—have the distinct impression that they can, whenever they wish, influence nominal interest rates in a downward direction by increasing high-powered money and in an upward direction by decreasing high-powered money. This impression is very strong because they have

seen it happen with great reliability. Moreover, since they were involved in the decision relating to the conduct of monetary policy, they have a clear idea whether their policy might be considered caused by economic circumstances and to what extent their policy might be viewed as a controlled experiment. Certainly the precise timing of their policy is determined by their own choices, and if interest rates immediately respond reliably when they do intervene, it is hard to question that they can control nominal interest rates in this manner.

If we accept, then, that when the Fed decides to intervene in the open market by increasing high-powered money the nominal interest rate declines, it would appear that the Fed must have some influence over real interest rates, and hypothesis 1 must be wrong. We usually think that increasing high-powered money is, if anything, a signal of higher inflation. It would seem implausible, then, that these lower interest rates are due to lower inflationary expectations. It is conceivable that exogenous increases in the money stock might be a sign of lower inflation over a certain time horizon if the parameters of our model were just right. But it seems inconceivable that such an explanation would reliably hold true for bonds of all maturities for the history of all monetary authorities for hundreds of years.

Even though the Fed knows it can drive the real interest rate at any moment in a desired direction, it does not follow that it can exert any *systematic* control over real interest rates; that is, hypothesis 2 or 3 may still be valid. To see how this might be the case, we may hypothesize a demand for high-powered money function of a form somewhat less general than expression (2) above:

$$(8) \quad M_t = M_{t-1} + \mu(M^*_t - M_{t-1}) + \eta_t$$

$$0 < \mu \leq 1$$

where

$$(9) \quad M^*_t = P_t + m_1 Y_t - m_2 r_t - m_3 (E_t(P_{t+1} - P_t)) + m_4 Z_t$$

and all coefficients  $m_1$ ,  $m_2$ ,  $m_3$ , and  $m_4$  are greater than zero. The term  $\eta_t$  is an unforecastable error. Here we have assumed a simple stock adjustment model although more general adjustment models would not affect the basic conclusions. The desired log money stock  $M^*_t$  is a function of the log price level  $P_t$ , a measure of aggregate economic activity  $Y_t$ , the nominal short interest rate  $r_t$ , the expected inflation rate, and other exogenous real variables  $Z_t$ . Substituting (9) into (8) and using  $r_t = \rho_t + E_t(P_{t+1} - P_t)$ , we get:

$$(10) \quad M_t = (1 - \mu)M_{t-1} + \mu P_t + \mu m_1 Y_t - \mu m_2 \rho_t \\ - \mu(m_2 + m_3)E_t(P_{t+1} - P_t) + \mu m_4 Z_t + \eta_t.$$

Taking expectations conditional on information at time  $t$  and solving for  $E_t P_t$ , we get:

$$(11) \quad E_t P_t = (1 - \lambda) E_t J_t + \lambda E_t P_{t+1}$$

where

$$J_t \equiv \Delta M_t / \mu + M_{t-1} - m_1 Y_t + m_2 \rho_t - m_4 Z_t - \eta_t / \mu$$

$$\lambda = (m_2 + m_3) / (1 + m_2 + m_3)$$

$$0 < \lambda < 1.$$

If we then solve this rational expectations equation and assume stable price behavior, that is, a price level that does not diverge to infinity unless the money stock is increased to infinity as suggested in the rational expectations literature, or in this specific context by Sargent and Wallace (1975), we find:

$$(12) \quad E_t P_t = (1 - \lambda) \sum_{i=0}^{\infty} \lambda^i E_t J_{t+i}$$

and

$$(13) \quad r_t = \rho_t + E_t(P_{t+1} - P_t) = \rho_t \\ + (1 - \lambda) \sum_{i=0}^{\infty} \lambda^i E_t(\Delta J_{t+i+1}).$$

The model thus implies that the price level, as well as the nominal interest rate, embodies optimal forecasts of  $\Delta J_{t+1}$ ,  $i = 0, 1, \dots$ . We can thus see how it is that the Fed may have the *impression* that it influences the real rate and could do so systematically when in fact it cannot. Suppose we hypothesize a money stock rule of the form (7) above. Although the Fed may not be aware of it, the public has divided its behavior into two components: a predictable and an unpredictable component. The public has already formed anticipations of all future movements in the money stock based on information about Fed policy that has unfolded to that point in time. If the public anticipates a policy of greater increases in the money supply, then nominal interest rates will by (13) rise as soon as the public begins to collect information which enables it to anticipate this. If, on the one hand, the Fed *delays* expanding the money stock longer than the public expected, then interest rates may rise further still because of the effect on real interest rates of this "surprise" until the date when the Fed does intervene, when interest rates may drop

back to the level given by (13).<sup>6</sup> If, on the other hand, the Fed increases the money growth rates *sooner* than the public expected, then interest rates may fall when they do this and may rise back to the level given by (13) when the Fed is on target again.

Whenever the Fed has the sense that its actions are volitional, that is, could not have been predicted by the market, it observes the customary negative relation between real rates and high-powered money. The Fed knows these shocks are exogenous and thus *knows* it has influence over real rates. But the Fed rarely observes the effect of its changes in its policy *rule* and, if it does not look deep into history, has no information on its *systematic* ability to control real interest rates.

This analysis does not necessarily suggest a scenario in which, as described, for example, by Friedman (1968), increases in high-powered money cause a decline in interest rates for a certain interval of time (the “liquidity effect” period) followed by a *rise* in interest rates above its former level due to engendered inflationary expectations. Friedman’s scenario might come about if unforeseen shocks constituted evidence that further money growth rates would be higher, in which case inflationary expectations would be immediately adjusted upward, and if temporary effects on real interest rates were sufficient to offset the rise in inflationary expectations.

The crucial behavioral relation that gives the result that the Fed has no systematic influence over real interest rates is embodied in expression (12), coupled with hypothesis 2, which implies that the real variables in  $J_t$  are not subject to systematic Fed control. Expression (12) then says that the *price level* incorporates all information currently available about future money supplies. Without this relation, the Fed must be able to control real rates or the price level must be explosive, even with stable monetary policy. As an illustration, suppose the Fed announces that the money stock today will be decreased by 3% below what the public had expected, but that all future money growth rates will be unchanged. By (12), and hypothesis 2, and assuming for simplicity that  $\mu = m_3 = m_4 = 0$ , the price level must drop immediately, and by (13) the nominal rate will be unchanged. It seems unlikely that the price level would drop immediately by 3%, however. If the price level is sluggish, can we retain hypothesis 2? To retain it would mean that the real money stock falls and hence, by the money demand equation (9), that the nominal rates  $r_t$  must increase. If the real rate is constant, this must imply that expected inflation will increase. If this expected inflation is rational, then it must be the case that actual inflation increases, at least on average. Thus, the price level

6. If monetary shocks show persistence, i.e., serially uncorrelated movements in  $\phi$  create serially correlated movements in the real rate, as represented, for example, in expression (14') below, then the real rate will not return to “target” immediately.

tends to increase in the following period, rather than decrease, which throws the system further out of equilibrium. By the same reasoning the price level is expected to increase even faster during the following period, and, by induction, must explode to infinity even with a stable money supply.

If we assume only hypothesis 3, then (12) still must hold, but now we have lost the proposition that the future real rate and future real income terms in  $J_{t+i}$ ,  $i = 0, \dots, \infty$  are independent of the entire systematic component of monetary policy. Since our hypothesis then does not constrain these  $y$  and  $\rho$  terms in  $J$ , it says nothing about how the price level responds to current information about Fed policy, and so (12) has itself no content in this regard. Hypothesis 3 does imply that real variables are independent of information about monetary policy known earlier by the policy effectiveness interval. The price level, today, optimally incorporates all information about future monetary policy that was known then.

While this behavioral assumption in (12) may be plausible for prices of speculative commodities, this seems improbable for the *aggregate* price level judging from the way many prices are actually set. It is not just that prices are “sticky” or “sluggish,” but that they are not set in anticipation of future monetary policy. It might not be too unreasonable to suppose that the prices of speculative commodities take into account a very simple, repetitive seasonal pattern in money growth rates. It is also conceivable that if the money stock has a simple predictable pattern over the business cycle, then the prices of certain speculative commodities might in effect incorporate this information. But will wages be set in this way? Will the price of haircuts? It seems likely that at least some modification of equation (12) is called for to allow for other factors that help determine the aggregate price level, and this will then invalidate hypotheses 2 and 3.

One reason that (12) and our hypotheses seem implausible is that the public is certainly not consciously aware of it. News reports routinely ascribe movements in the stock market indices to new information, but changes in aggregate price indices, while a subject of great public interest, seem *never* to be ascribed to new information about future monetary policy. Hypothesis 2 requires that if the Fed announces a change in its long-run target, the announcement itself (if credible, and not already discounted by the public) should have an immediate effect on the price level and on the nominal interest rate. Judging casually from the lack of public awareness of such an effect, we think that the effect is certainly not likely to be a very striking one.

Further evidence on the plausibility of (12) and (13) can be obtained by considering the effects of the Fed’s announcing that interest

rates will be pegged at a certain level. Before we consider this, we must point out that this has actually happened.

At the end of April 1942 the Federal Open Market Committee directed the twelve Federal Reserve Banks to purchase all treasury bills offered at a discount rate of  $\frac{3}{8}$  of 1% and in August directed the Federal Reserve Banks to give the seller an option to repurchase bills of the same maturity at the same rate. An ascending rate structure on government bonds was also pegged, peaking at 2.5% for the longest bonds. A demand for short-term bills persisted for a while with this structure, but, as confidence grew that the Fed would continue to peg long rates at this level, it evaporated. In July 1947, the Fed thus ended the peg on treasury bills. In December 1947 the Fed also lowered its buying price to near par on long-term bonds which, with the fixed rate structure, had come to sell above par, but felt obligated not to let bond prices fall below par, until after the Accord in March 1951. Some variation in long-term interest rates was allowed; in particular, the Fed allowed prices of long-term bonds to rise *above* the pegged price, which happened briefly in early 1946.

Price controls were also first imposed in April 1942, with the General Maximum Price Regulation and were finally lifted with the expiration of the Price Control Act on 1 July 1946. Price controls were not reimposed until the Korean conflict, when in January 1951 an official freeze on most prices and wages was announced. In the intervening period the only important efforts to control the aggregate price level were voluntary: the Economic Stabilization Agency efforts just before the price freeze with the Korean conflict, and the voluntary credit restraint program. We thus have a period of 4.5 years in which prices were free and long-term interest rates pegged and a one-year period in which prices were free and short-term interest rates were pegged. This time interval, moreover, came immediately after a four-year period which, although under price controls, was characterized by a development of "pent-up inflation" in the sense that the money supply increased dramatically under the pegged interest rate.

What does the model predict about the effects of an announcement by the Fed that interest rates are to be pegged at a certain level? Here we are confronted with a basic problem of the transition from one rational expectations equilibrium to another for which rational expectations models are no guide. Sargent and Wallace (1975) highlighted this problem when they pointed out that in their model, for which  $\mu = 1$ , the interest rate is related only to future *changes* in money; hence the money stock and price level are not determined by the fixing of the interest rate. Although in our model  $\mu \neq 1$  so that a lagged money stock enters, it is unclear what relevance the money stock before the interest rate peg was announced has to the ultimate rational expectations equilibrium. The

price level after a rational expectations equilibrium is reached is still not determined by the model.

If a rational expectations equilibrium is attained under hypothesis 2, then we do know that expression (13) must hold with  $r_t$  at the pegged rate, and this means that expected future changes in the money stock must move in such a way as to cause inflationary expectations to move opposite to the real rate. If, let us suppose, the real rate and exogenous factors are nearly constant, then the appropriate monetary policy is essentially to keep all changes in  $M$  at the appropriate level, equal to the pegged rate minus the real rate. The Fed, to keep interest rates low, essentially must merely keep money growth rates low. Fed policy must be to set an example with small money growth rates, rather than, as was actually the case, to conduct massive open market purchases when rates started to rise. The Fed does not try to offset movements in interest rates in the usual way; rather, it sets a monetary policy which implies deflation (and hence deflationary expectations) whenever the real rate is shocked upward, so that the public prevents the nominal rate from ever moving. Clearly, the Fed was not doing the right thing to cause the economy to converge on a rational expectations equilibrium with stable prices at the pegged rate, as they essentially said (though not in these words) in their arguments with the Treasury. We may say that the economy was not in a rational expectations equilibrium of the kind with stable prices, as described by (12) or (13). But it was not in an *unstable* rational expectations equilibrium either. When price controls were lifted in July 1946, we saw not a one-shot big increase in the price level but (after a relatively modest immediate jump in prices) a serially correlated smooth increase in prices (see fig. 4.5 below). This means that very negative real interest rates, apparently caused by monetary phenomena, could be *forecasted* during this transition period. This situation persisted for a while and then the economy settled in, not to a hyperinflation, but an ordinary recession.

### Founding of the Federal Reserve System

In the original Federal Reserve Act of 1913 the first purpose of the Federal Reserve system defined in the opening paragraph is “to provide an elastic currency,” and “to accommodate commerce and business” (section 14). From the discussion of the time there is at least one unambiguous implication of this purpose: namely, to provide a larger supply of currency toward the end of the year when the demand for currency was higher, in part because of the crop harvest and Christmas shopping.<sup>7</sup>

7. In its first annual report to Congress (1915), the Federal Reserve Board seems to say, in clear language, that it will mitigate seasonal fluctuations in interest rates: “It should not, however, be assumed that because a bank is a Reserve Bank its resources should be kept idle for use only in times of difficulty, or, if used at all

Under the national banking system, this higher demand for currency was not accommodated, and the result was pronounced seasonality of nominal interest rates. This seasonality in *nominal* interest rates apparently vanished after the establishment of the Federal Reserve system and was apparently replaced by a seasonality in currency in circulation as documented by Macaulay (1938). Carter Glass (1927) listed the elimination of this seasonality as one of the major achievements of his Federal Reserve Act.

The pronounced decline in seasonality in nominal interest rates after the founding of the Federal Reserve at the end of 1913 can be seen clearly in figure 4.1. An additive seasonal factor (plotted with the same scale as the nominal interest rate above) computed with the Census X-11 program is shown. This seasonal factor is computed as a  $3 \times 3$  moving average of the difference of the corrected series from a 13-month average. This implies a triangular moving average extending over nearly 6 years. Thus, the fact that the seasonality does not disappear immediately in 1914 is mainly due to an artifact of the Census X-11 program. The seasonal pattern *does* show a marked decline about as soon as it could.

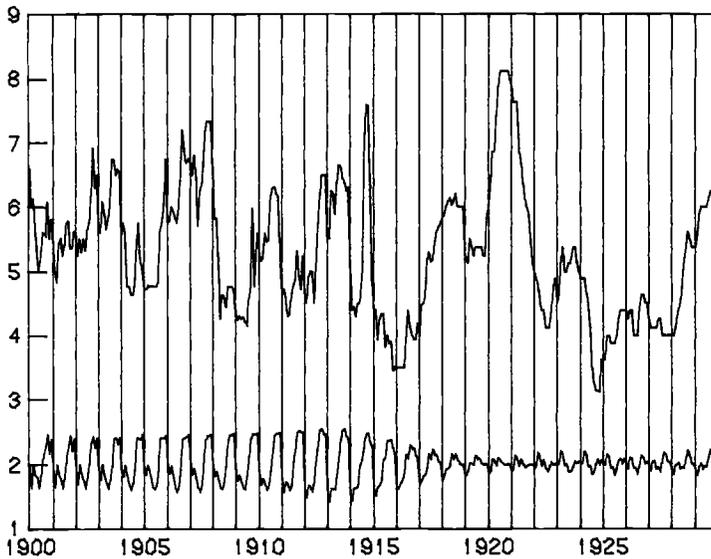
The question that apparently never occurred to anyone then was whether the Fed had, by adopting the announced policy of eliminating seasonal variations, eliminated a seasonal pattern in *real* interest rates. A stable seasonal pattern in *ex post* rates implies a seasonal pattern in *ex ante* rates since seasonal factors are forecastable. All our hypotheses may be taken to imply that the elimination of the seasonal factor in nominal rates should have changed the seasonal pattern in inflation rates so that the seasonal pattern in real interest rates should remain unchanged.

When we look at the seasonal pattern of the *ex post* real interest rates (fig. 4.2), we see an apparent disruption<sup>8</sup> in the seasonal pattern of real

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in ordinary times, used reluctantly and sparingly. . . . Time and experience will show what the seasonal variation in the credit demands and facilities in each of the Reserve Banks of the several districts will be and when and to what extent a Reserve Bank may, without violating its special function as a guardian of banking reserves, engage in banking and credit operations. . . . There will be times when the great weight of their influence and resources should be exerted to secure a freer extension of credit and an easing of rates in order that the borrowing community shall be able to obtain accommodations at the lowest rates warranted by existing conditions and be adequately protected against exorbitant rates of interest. There will just as certainly, however, be times when prudence and a proper regard for the common good will require that an opposite course be pursued and accommodations curtailed." The Board said it gave "certain assurance that whatever funds might be necessary for the gradual and orderly marketing of the cotton crop would be available at moderate rates."

8. The disruption is not due to the spectacular deflation of 1920, since the Census X-11 program automatically excludes such outliers. The Census X-11 is still capable of producing spurious seasonal factors. Sargent (1971) demonstrated the existence

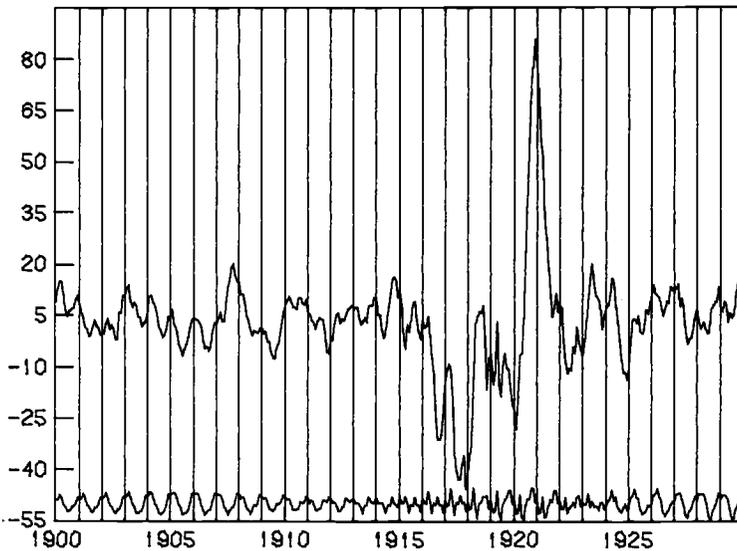


**Fig. 4.1** Four-to-six-month prime commercial paper rate (above) and additive Census X-11 seasonal factors (below), monthly data. Vertical lines correspond to January of the year noted directly below. Source of prime rate series: 1900–1924, *Banking and Monetary Statistics, 1914–41*, Board of Governors of the Federal Reserve system 1943, table 120; 1925–29, Macro Data Library, Board of Governors of the Federal Reserve system.

interest rates after the founding of the Federal Reserve, but a reassertion of the seasonal pattern roughly as strong as before. One is tempted to interpret this disrupted period as a transitional period when the economy converged on a new rational expectations equilibrium in accordance with hypothesis 2. There is potentially an element of truth to this story; however, we note that the seasonal pattern in inflation rates had substantially greater amplitude than that in nominal interest rates, and so it is better to say that the seasonal pattern in inflation rates drowned rather than offset the declining seasonal pattern in nominal rates. All that we can conclude from this data is that we *can't* say with any confidence whether a policy of eliminating the seasonal pattern in nominal rates reduced the seasonal pattern in real rates. The seasonal pattern in inflation rates is so much bigger, and rather unstable itself, that we cannot find any

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of a pre-1913 seasonal factor (as well as a post-World War II seasonal factor) in short-term interest rates with spectral analysis.



**Fig. 4.2**

Ex post real interest rate, the 4–6-month prime commercial paper rate minus the 5-month inflation rate based on the BLS wholesale price index of all commodities (above) and additive Census X-11 seasonal factors (below). Vertical lines correspond to January of the year noted directly below. Source of price series: Bureau of Labor Statistics, 1900–1913, *Bulletin* no. 149 (1914); 1913–19, *Bulletin* no. 269; 1920–29, Macro Data Library, Board of Governors of the Federal Reserve system.

evidence here contrary to the hypotheses. Carter Glass was too quick to congratulate himself on the real consequences of his Federal Reserve Act.<sup>9</sup>

#### A Policy Rule Change Marked by the Accord

It is commonly asserted that the Accord of March 1951 marked an abrupt change in Fed policy. This was the date that the Fed was freed

9. The seasonal pattern in real interest rates may be spurious. Since nominal rates showed less pronounced seasonality than inflation rates, there was an incentive in the fall, when agricultural prices were low, for farmers to hold their crops off the market and borrow at the nominal rate. Their efforts to do so were apparently hampered by credit rationing by the banks. It is possible that there was no seasonal factor in real rates actually available to farmers.

One effect of Fed policy not shown in the data may be the reduction of credit rationing in the fall. Hypothesis 2 would then suggest that the seasonal pattern in inflation should disappear, making for a spurious apparent reduction in real rate seasonality, which we do not observe. Instead, this interpretation suggests the Fed may have *introduced* a seasonal factor in real rates that did not exist before.

from the obligation to peg interest rates and a time of new-found concern with monetary aggregates and countercyclical monetary policy. One can see from figure 4.3 that the rate of growth of the money supply (M-1) before the Accord was less strongly seasonal and more distinctly marked by erratic longer-term movements. After the Accord (actually, after the war) the growth of the money stock was dominated much more by a very strong seasonal factor. The strong seasonal factor in the money stock, incidentally, first appeared around 1942, when interest rates were pegged and, of course, what seasonality in nominal interest rates still remained was then totally eliminated. It appears that the Fed revised its seasonal adjustment factors at this time and then, following the Accord, became concerned that the seasonally adjusted money stock should grow smoothly. In so doing, the Fed perpetuated the seasonal movements in the money stock that were appropriate to a short-term interest rate with no seasonal pattern for the period 1942–50. Subsequent estimates of

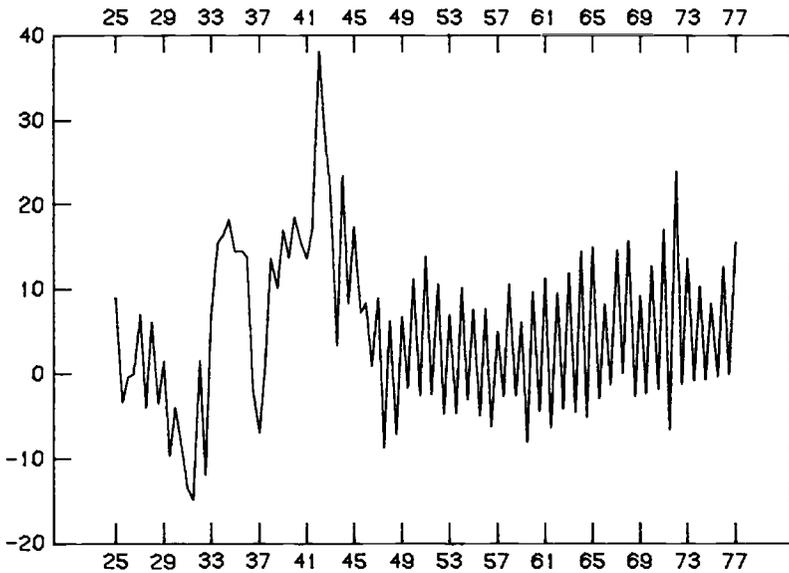


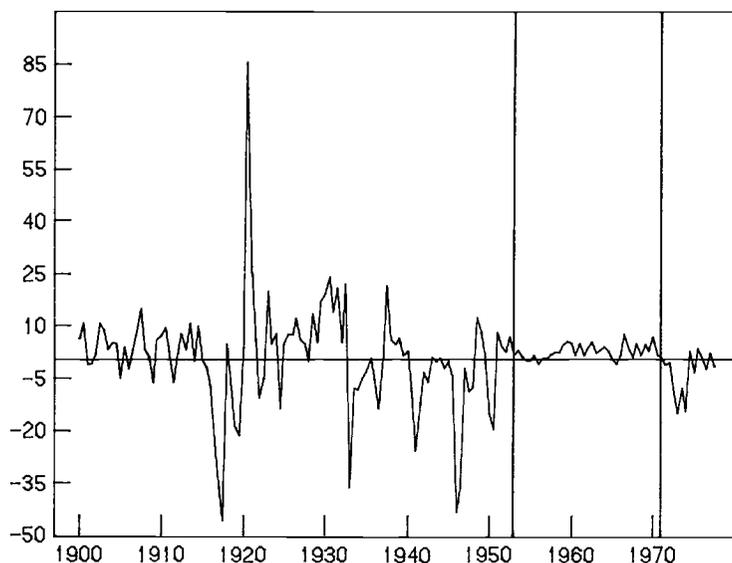
Fig. 4.3

Money growth rates before seasonal adjustment, 6-month percentage change in M-1 over succeeding 6-month period at annual rates, 1925–77, semiannually (June and December). Marks on horizontal axis correspond to June figure. Source: 1925–40, *Banking and Monetary Statistics, 1914–41*, Board of Governors of the Federal Reserve system, 1943, table 9; 1941–70, *Banking and Monetary Statistics, 1941–70*, Board of Governors of the Federal Reserve system, 1976, p. 5 and table 1.1; 1971–77, *Federal Reserve Bulletin*, passim.

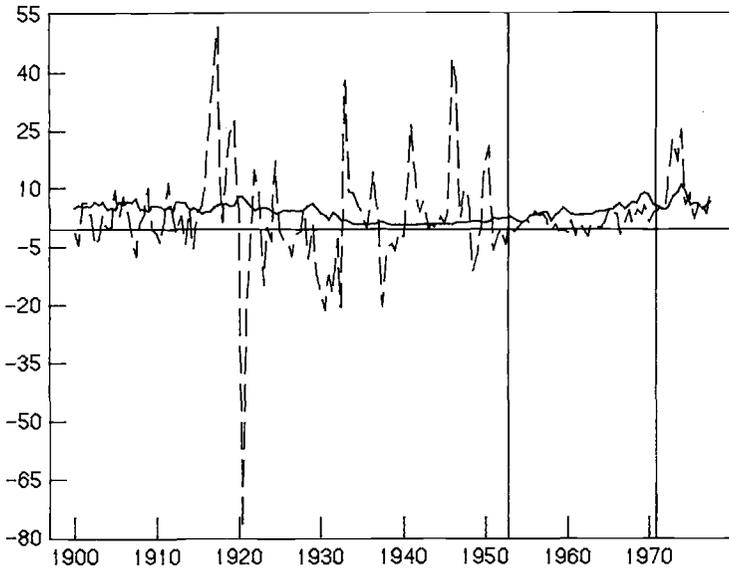
seasonal factors would tend to remain unchanged as long as the Fed perpetuates this seasonal pattern. Apparently, the seasonal pattern in money demand became more pronounced after the war, and so a seasonal pattern in nominal rates has reappeared, as documented by Diller (1971) and Sargent (1971).

It appears, then, that there was a substantial change in the Fed policy rule after World War II. If we can assume that the stochastic structure of the rest of the economy did not show an equally substantial change following the war, then we can look at the behavior of the real interest rate and perhaps find some disconfirmation of our hypotheses if the behavior of real rates changes.

A plot of the ex post real short-term interest rate (the 4–6 month commercial paper rate minus the succeeding 5-month change in the wholesale price index) appears in figure 4.4 and the interest rates and inflation rates in figure 4.5. Indeed, there is a striking change at the time of the Accord. The last big movement downward in the real interest rate was due to the surge in inflation at the end of 1950 which provoked the Accord, as well as the price controls of the Korean conflict. After that, there was never again such a big movement in ex post real interest rates.



**Fig. 4.4** Ex post real rate of interest, 1900:I to 1977:II, June and December, equal to the interest rate minus the inflation rate plotted in fig. 4.5. Marks on the horizontal axis correspond to the June figure. Fama's sample period is enclosed between vertical lines.



**Fig. 4.5**

Annualized percent change in the wholesale price index over succeeding 5 months (dotted line) and 4–6-month prime commercial paper rate (solid line), 1900:I to 1977:II, June and December. Marks on the horizontal axis correspond to the June figure. Fama's sample period is enclosed by vertical lines. Source of wholesale price index: Bureau of Labor Statistics, 1900–1913 *Bulletin* no. 149 (1914); 1913–19, *Bulletin* no. 269; 1920–77, Macro Data Library, Board of Governors of the Federal Reserve system. Source of prime commercial paper rate: 1900–1924, *Banking and Monetary Statistics, 1914–41*, Board of Governors of the Federal Reserve system, 1943; 1925–77, Macro Data Library, Board of Governors of the Federal Reserve System.

These ex post movements in the real interest rate before the Accord are not an indication of movements in rationally expected real interest rates unless they are forecastable. The apparent serial correlation in figure 4.4 suggests that they are, and this is confirmed by the simple autoregressions in table 4.1. The F tests indicate significant coefficients except for the period immediately after the founding of the Fed. The standard deviation of the fitted value (the lower figure in the last column) which is a measure of the standard deviation of the true rationally expected real interest rate is much higher before 1951 than after.

To the extent that we are willing to assume that the structure of the rest of the economy was the same before and after the Accord, these results clearly provide further disconfirmation of hypothesis 1. It is true

**Table 4.1 Ex Post Real Rate Autoregressions**

Time Period	Coefficient of				$R^2$ $t_{next}$	$F$ Sig( $F$ )	$\sigma$ (RESID) $\sigma$ (FITTED)
	Const	Seasonal	Dep <sub>-1</sub>	Dep <sub>-2</sub>			
1901:II to 1913:I	1.73 (1.08)	4.79 (2.35)	.383 (2.02)	-.482 (-2.59)	.244 (-1.48)	3.47 3.54	4.56 2.59
1915:II to 1929:II	.620 (.107)	1.48 (.184)	.493 (2.49)	-.186 (-.942)	.104 (-.416)	2.08 12.87	21.6 7.36
1901:II to 1929:II	.236 (.081)	3.62 (.884)	.481 (3.55)	-.185 (-.137)	.151 (-.679)	4.31 .859	15.33 6.45
1915:II to 1950:II	-2.66 (-.926)	4.33 (1.07)	.493 (4.04)	-.116 (-.950)	.172 (-.327)	5.85 .131	16.9 7.71
1952:II to 1977:II	.100 (.135)	.375 (.369)	.324 (2.38)	.394 (2.91)	.360 (-1.01)	10.4 .002	3.59 2.69

**NOTE**

Dependent variable is the ex post real rate (i.e., the 4–6 month prime commercial paper rate minus the succeeding actual 5-month inflation rate computed from the wholesale price index) as shown in fig. 4.4. Data is semiannual, for June and December. Seasonal dummy is zero in June, 1 in December. Numbers in parentheses

are  $t$ -statistics,  $t_{next}$  is  $t$ -statistic of dependent variable lagged one more time in a different regression (presented here instead of a Durbin-Watson statistic). The term  $\sigma$ (RESID) is standard error of regression;  $\sigma$ (FITTED) is estimated standard deviation of fitted values, equal to  $\sigma$ (RESID)( $R^2/(1-R^2)$ )<sup>1/2</sup>.

that the period before 1951 was characterized by bigger wars than the period after. The depression also came before (although it is less clear that this represents a change in structure of the economy). Nonetheless, the change in the stochastic behavior of real rates with the Accord is so striking that one is tempted to conclude that the change in monetary policy had something to do with it.

Whether or not the change also disconfirms hypothesis 2 is not something we can say with any assurance. Indeed, given that the monetary policy is not deterministic, and cannot be described in terms of just a money stock rule or just an interest rate rule, then we have not given the hypothesis a precise enough definition to evaluate it formally.

One might attribute the greater movements in the real rate before the Accord merely to greater unforecastable monetary shocks before the Accord. By the same token the relatively low variance of real rates before the founding of the Fed might be ascribed to a more predictable monetary rule under the National Banking System. This argument would not apply to the pegged rate period, between 1942–51, when monetary policy was quite forecastable.

It is not obvious whether Fed policy was less predictable in the twenties, say, as compared with the sixties. One must remember that big movements in the money stock are no indication of unpredictability since presumably they were triggered primarily by economic conditions in a way that may well have been understood by businessmen at the time. Monetary policy actions need not be known in advance for there to be predictability in the sense of hypothesis 2 as long as these are revealed by public information before they take place.

We do know that a change in the policy rule occurred after the Accord. It would not be unreasonable to attribute the change in the behavior of real interest rates to the observed change in the systematic policy rule, and thus consider this change as evidence against hypothesis 2. Unfortunately, we cannot feel very comfortable in our assurance that this is so. We are left, then, with only a suggestion that hypothesis 2 might be misguided. Barring a controlled experiment contrasting alternative deterministic, announced policy rules, we are unlikely ever to find better information concerning the direct empirical implications of hypothesis 2.

Before we conclude, however, we note that recent literature on nominal interest rates for the period 1953–71 alone might seem to lead us to a different evaluation of the hypotheses. This literature, which was initiated by Fama (1975), has confined attention to this period because, it is claimed, it represents the only available time period in which the data on inflation rates are good and in which prices are uncontrolled. Fama said that to study real rates before 1953 is “meaningless” because the Bureau of Labor Statistics used poorer sampling techniques before 1953 in

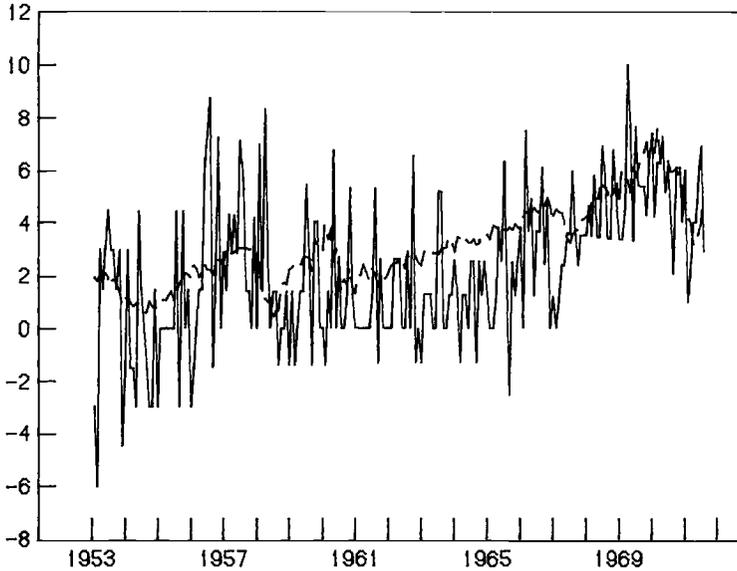
computing the consumer price index (which Fama used), in that it sampled more items on a three-month basis than it does today. If one looks at figure 4.4, one notes that this period (marked off between parallel lines) shows remarkable stability of the real rate of interest.<sup>10</sup> This was also a period when the Fed apparently *thought* it was conducting countercyclical monetary policy and is usually described as having caused at least one credit crunch. Fama's evidence appears then to be evidence which makes us less sure of our dismissal of hypothesis 1, that the Fed cannot influence real rates at all.

In his paper, Fama showed two remarkable results about short-term interest rates and prices for this sample period, both of which are consistent with his joint hypothesis that *ex ante* real rates of interest are constant and expectations are rational. First, while both short-term interest rates and inflation rates show significant autocorrelation, *ex post* real rates do not. This result can be seen again by looking at Fama's monthly data on one-month treasury bill rates and one-month inflation rates (fig. 4.6). The inflation rate appears approximately as white noise superimposed on the interest rate series, except for the period 1960–66, when the short rate shows a trend not matched by a trend in inflation rates. The serial correlation we observed in table 4.1 came about, apparently, from post-1971 data and perhaps also from our use of five-month inflation data, which is smoother than one-month data. Second, Fama showed that if inflation rates are regressed on interest rates the coefficient of the interest rate is nearly one ( $.97$ ,  $t = 10.0$ , with his data) and then, when the lagged price level is added as a second explanatory variable, the coefficient of the interest rate remains near one ( $.87$ ,  $t = 7.2$ ) while the lagged inflation rate has a small coefficient ( $.11$ ,  $t = 1.6$ ) which is insignificant.

10. This figure shows the inflation as measured by the wholesale, rather than consumer price index, but the plots using the consumer price index, for the period for which it is available, look similar.

That Fama's hypothesis did not hold before is certainly well known. The famous "Gibson paradox," noted as early as 1884, was a positive correlation between interest rates and price *levels*, not rates of change of prices. While the correlation is most pronounced for long-term interest rates, it was also present with short-term rates for British data in the century before World War II, and over this period there was really no correlation between short rates and inflation rates (Shiller and Siegel 1977).

A plot of an *ex post* real British consol rate (subject to an arbitrary assumption about inflation rates past 1977 which makes the more recent real rates unreliable) from 1729 to the present appears in Shiller and Siegel 1977. This real long-term interest rate is very volatile and at times negative. It was found that nominal long-term rates over this period moved in such a way as to exacerbate, rather than mitigate, the effects of inflation on long-term real rates, i.e., nominal long rates were *negatively* correlated with the appropriately defined long-term inflation rate.



**Fig. 4.6** Fama's data, February 1953 to July 1971. Solid line is inflation rate, equal to  $-1200 \Delta_t$  and dotted line is one-month treasury bill rate, equal to  $1200 R_t$  where  $\Delta_t$  and  $R_t$  are defined in Fama 1975. Division marks on the horizontal axis correspond to the first month of the year numbered directly below. Data courtesy of E. Fama.

nificant.<sup>11</sup> It seems at first remarkable that the lagged inflation rate should be of so little benefit in forecasting inflation, but when one looks at the data one sees why this is the case. There is a great deal of month-to-month noise in the consumer price index, and so the lagged inflation rate is a poor indicator of current inflation. What is more remarkable is that the coefficient of the interest rate should come out so close to one, which is its theoretical value if the ex ante real interest rate is constant and inflation anticipations are true mathematical expectations.

It should be pointed out that under Fama's hypothesis residuals are serially uncorrelated, and if we wished to estimate the coefficient of the interest rate, then ordinary least squares is appropriate and the standard errors not compromised by possible serial correlation. If our theory is

11. Fama used the rate of change of the purchasing power of money as his dependent variable; i.e., his dependent variable is  $\Delta_t = -(P_t - P_{t-1})/P_t$  rather than  $(P_t - P_{t-1})/P_{t-1}$ . When we used his data, we multiplied  $\Delta_t$  by  $-1200$  and called this the inflation rate. We have reserved the sign of his coefficient to accord with our definition.

that the after-tax real rate is constant, then this coefficient is an estimate of  $1 - \tau$ , where  $\tau$  is the marginal tax bracket of the "representative investor." If we assume normal residuals, then ordinary least squares is clearly the appropriate procedure under Fama's hypothesis to estimate the coefficient in the regression.<sup>12</sup> Fama's regression of inflation on interest rates alone provided an estimate of  $1 - \tau$  so close to one as to imply that the "representative tax bracket" is zero. Feldstein and Summers (1978a) concluded that the after-tax real interest rate relevant to the typical investment decision should be computed with, in effect,  $(1 - \tau)$  roughly in the vicinity of .8 to 1.0, depending on depreciation and equity yields.<sup>13</sup> Fama's estimate of .87 with the inflation variable in the regression is dominated by the previous estimate, since by Fama's theory the inflation rate is an extraneous variable in the regression.

If, however, we are more interested in an alternative hypothesis that makes inflation rates unrelated to interest rates and serially correlated, then the ordinary *t*-test on the coefficient is not valid. The *t*-test is a likelihood ratio test in which the universe does not include the possibility of serially correlated residuals. Thus, we do not know from Fama's highly significant coefficient on the interest rate whether or not the observed relation between interest and inflation might easily have come about by a "trend" or "long cycle" or other low-frequency component in the interest rate which by sheer chance happened to be correlated with a similar component in the inflation series. Fama's good Durbin-Watson statistic is no assurance, as Granger and Newbold (1977) have pointed out, that this is not a problem. One can get some impression of the likelihood of such an alternative explanation of the correlation between interest and inflation by looking at figure 4.6. Clearly, the short-run movements in the price level are not explained by the interest rates. This impression is confirmed by running Fama's regression with the dependent variable lagged or led, to throw it out of alignment with his interest rate data. The fit of his equation is hardly changed. The  $R^2$  rises from .29 in Fama's regression to .30 with a led inflation rate as the dependent variable and falls to .27 with a lagged inflation rate as the dependent variable.<sup>14</sup> In any event, the alignment is not really correct with Fama's regression either. Fama's interest rate data are based on midpoints of bid-asked

12. The residuals do, however, fail the David-Hartley-Pearson studentized range test of normality at the 5% level. The studentized range in the residuals regression of inflation on a constant and the interest rate for the full sample period is 6.42, and the Durbin-Watson statistic is 1.77.

13. Feldstein and Summers' arguments applied to long-term interest rates, which might be connected, via term structure phenomena, to short rates.

14. These statistics refer to a regression of the inflation rate on a constant and the interest rate over the longest possible sample with the data series shown in fig. 4.6.

spreads for the last day of the preceding month. The Bureau of Labor Statistics (1971) reports that it collects food prices on three consecutive days early in the month. Thus food prices, which in 1971 had a total weight of .224 in the consumer price index, are nearly 30 days out of alignment.<sup>15</sup> Rents and items for which prices are obtained by mail, in contrast, are reported as of the fifteenth of the month, and the pricing of other items priced monthly extends over the entire calendar month. Many items are still priced only every three months. We thus could not hope with such data to find a short-run (or high-frequency) relationship, and it is hardly appropriate to dismiss results based on earlier data for this reason.

The explanatory power in the interest rate series does not come about from a simple trend either. If one runs Fama's regression with a linear time trend term added, this variable does not come in as significant. The explanatory power instead comes primarily from a couple of humps in the interest and inflation series. The first hump begins at the bottom of the recession that occurred in 1954 and ends at the bottom of the recession that occurred in 1958. The other hump starts after the credit crunch of 1966 and ends in the recession of 1971. Some explanatory power also appears to reside in the downturn of interest rates in the recession of 1953–54, at the very beginning of the sample. In contrast, the period between 1958 and 1966 shows an upward trend in interest rates with no matching upward trend in inflation rates. Carlson (1977) showed that Fama's regression fits very poorly over this sample period, and the hypothesis that the coefficient is 1 can be rejected.

The remarkable thing about Fama's paper cannot be seen in the paper itself but in the fact that his critics did not find any regression results over the entire sample which strongly contradicted his. One would think that someone through data dredging could come up with another variable which dominated the interest rate as a predictor of inflation, but that appears not to be the case. Nelson and Schwert (1977) and Hess and Bicksler (1975) used the highly regarded Box-Jenkins forecasting techniques to produce a forecast of future inflation based on lagged inflation rates. When Nelson and Schwert added this forecast to Fama's regression of inflation on interest rates over the entire sample period (1953–71),

15. Fama's inflation rate is computed as  $\Delta_t = (P_{t-1} - P_t)/P_t$ , so the food price component of the change applies to the period from the beginning of the preceding month to the beginning of the current month. The interest rate series gives the treasury bill rate at the end of the preceding month, which matures over the current month.

The monthly change in the food price index is more volatile than other components and had a correlation of .71 with the monthly change in the consumer price index over Fama's sample period. Thus, the led inflation rate may be the more appropriate dependent variable.

the  $R^2$  was increased only to .31 from .29. The coefficient of the interest rate fell from .97 in Fama's regression to .65, and the Box-Jenkins forecast had a coefficient of only .38. The coefficient of the Box-Jenkins forecast was significant (with a  $t$ -statistic of 2.4, in contrast to the  $t$  of 1.6 for the lagged inflation rate alone) and so Nelson and Schwert concluded that they had rejected Fama's hypothesis, but they were also forced to conclude that the interest rate carried additional information not in the Box-Jenkins forecast. Other critics were able to find other forecasting variables that pushed up the  $R^2$  a little more. Carlson (1977) added the employment/population ratio to Fama's regression; this variable was highly significant and boosted the  $R^2$  to .36. Still, the coefficient of the interest rate was .64. Joines (1977) added the three lagged values of the wholesale price index to Fama's regression, which were also highly significant, boosting the  $R^2$  another increment up to .37, but still the coefficient of the interest rate remained at .77.

We thus concur with Fama that his results and the results of his critics do suggest that most of the variation in nominal short rates in his sample period can be attributed to inflationary expectations. Fama's results must give pause to those who believe that inflationary expectations are highly sluggish or follow a trend and that medium-run movements in short-term interest rates are movements in *ex ante* real rates.

It is possible to get an estimate of the variance of the *ex ante* real interest rate from Fama's regression of inflation on interest if one is willing to assume that the real rate of interest is uncorrelated with the predicted inflation rate. It is easy to see this as an application of the well-known theorem which states that, in a simple regression, if there is a measurement error in the independent variable, the probability limit of the estimated coefficient is biased downward by a factor which is the ratio of the variance of the true independent variable to the variance of the measured independent variable. Here, we take the variation in the real interest rate as the "measurement error." If we ascribe all of the deviation of the estimated coefficient of the interest rate from 1 to this source, then this implies that with an estimated coefficient of .98, the variance of the real rate is only about 2% of the variance of the observed interest rate, which implies that the standard deviation of the real rate is about 20 basis points. Nelson and Schwert used this kind of argument to arrive at an estimate of the variance of the real rate of interest, but they based their estimate on a different regression: of the change in the rate of inflation on the difference between the interest rate and the lagged inflation rate which produced a smaller coefficient (equal to .89). Under Fama's hypothesis, the coefficient should again be 1. If we take the real rate of interest again as the "measurement error" of a true independent variable which is the inflation forecast minus the lagged actual inflation rate and if we assume that the measurement error is uncorrelated with

the true independent variable, then by the same reasoning we come up with an estimate of the variance of the real rate of interest which is  $1 - .89 = .11$  times the variance of the interest rate minus the lagged inflation rate, which then implies a standard deviation for the real rate of 80 basis points.

These estimates of the variance are suggestive, although they must have substantial sampling error (not discussed by Nelson and Schwert). They do suggest smaller movements in real interest rates than many people expected to see.

#### Time Series Analysis of Real Rate and Money Stock Data

From the sound of the hypotheses, it would appear that a Granger or Sims test of causality (see Sims 1978) from money to real interest rates and a test of the effects of anticipated versus unanticipated money on real rates along lines suggested by Barro (1978), would be relevant to their evaluation.

Granger and Sims tests of causality from the change in the log of the money stock to ex post real interest rates as shown in figure 4.4 appear in table 4.2. Seasonality was handled in two ways. In some regressions, a seasonal dummy was added to the regression. For other regressions the data were first Fourier transformed, both real and imaginary parts were then set to zero in a band of width  $\pi/12$  around the seasonal frequency and the series were then inverse Fourier transformed to produce a de-seasonalized series. Data for the Sims tests was also quasi-first differenced with filter  $(1 - .75L)^2$ .

The results of these causality tests are that, for the postwar period, money unambiguously causes real rates. Clearly the stochastic structure of the series has changed since the Accord, since no causality is found for the pre-Accord period.

Barro tests reported in table 4.3 use data series DM (change in the log money stock), DMR (Barro's estimate of the public's forecast error at time  $t$  for the change in the log money stock at time  $t$ ), and  $G/y$  (real government expenditure over real GNP) from Barro (1978, tables 1 and 2). The dependent variable is the one-year (annual average) treasury bill rate or the rate on the treasury bill whose maturity is closest to one year minus the lead one-year inflation rate DP from Barro (1978, table 2). Neither the DM nor the DMR terms are significant in these regressions, which seems odd, since the Granger and Sims tests found, with different data, that money causes real rates. The  $F$  statistic is, however, nearly significant at the 10% level in the last regression. An interesting observation that arises here is that in the regression in which DM is excluded, all variables have the sign we would expect. All DMR terms have negative coefficients and  $G/y$  has a positive coefficient.

**Table 4.2** Granger-Sims Causality Tests

Sample	Type	Seasonal Dummy	F Statistic	Degrees of Freedom
1928:II to 1977:II	Granger	No	3.09*	5, 87
1928:II to 1977:II	Granger	Yes	1.40	5, 86
1929:II to 1975:II	Sims	No	1.71	4, 80
1928:II to 1950:II	Granger	No	1.55	5, 33
1928:II to 1950:II	Granger	Yes	1.14	5, 32
1929:II to 1948:II	Sims	No	0.58	4, 26
1955:II to 1977:II	Granger	No	5.22**	5, 33
1955:II to 1977:II	Granger	Yes	3.05*	5, 32
1957:II to 1977:II	Sims	No	18.9**	4, 28

## NOTES

Tests indicate whether the change in the log of the money supply (from time series illustrated in fig. 4.3) causes real rates (from series shown in fig. 4.4). Data is seasonally adjusted unless seasonal dummy appears. For Sims tests, data is quasi first differenced with filter  $(1 - .75L)^2$ . Ex post real rate based on nominal rate in a given quarter is considered contemporaneous with the change in the log of the money stock from the preceding quarter to the given quarter. Granger tests involve regressing real rate on five lagged values of the real rate and money variable, a constant, a linear time trend and, if noted, a seasonal dummy. *F* statistic is test of hypothesis that all lagged money coefficients are zero. Sims tests involve regressing the money variable on 4 lead, a contemporaneous and 6 lagged real rate variables, as well as a constant and linear time trend. *F* statistic is test of the hypothesis that all lead real rate coefficients are zero.

\*Significant at 5% level.

\*\*Significant at 1% level.

What do these results mean? One interpretation along lines suggested by the literature on rational expectations and the natural rate of unemployment hypotheses follows from the assumption of a structural relation implying that real interest rates respond *linearly* to the change in the log money stock and expectations of future changes in log money stocks:

$$(14) \quad \rho_t = \zeta_t + \sum_{i=0}^{n_1} \phi_i \Delta m_{t-1} + \sum_{i=0}^{n_2} \sum_{j=0}^{n_3} \psi_{ij} E_{t-i}(\Delta m_{t-i+j}),$$

**Table 4.3** Barro Type Regressions

Const	Coefficient of									Time	G/y	R <sup>2</sup>	D.W.	S.E.	F	F <sub>b</sub>
	DMR	DMR <sub>-1</sub>	DMR <sub>-2</sub>	DMR <sub>-3</sub>	DM	DM <sub>-1</sub>	DM <sub>-2</sub>	DM <sub>-3</sub>								
.372 (.627)	-23.8 (-1.22)	-7.15 (-.371)	-17.0 (-.900)	-29.3 (-1.55)	—	—	—	—	.023 (.582)	—	.218	1.46	1.28	1.06	—	
-7.64 (-1.93)	-27.0 (-1.48)	-9.45 (-.52)	-31.7 (-1.68)	-38.2 (-2.13*)	—	—	—	—	.191 (2.12*)	46.9 (2.04)	.366	1.82	1.18	1.73	—	
2.93 (2.53*)	11.4 (.192)	87.7 (1.40)	-30.2 (-0.50)	68.5 (1.87)	-39.8 (-.74)	-75.4 (-1.20)	36.9 (.572)	-96.0 (-2.30*)	.251 (2.87*)	—	.550	1.82	1.10	2.03	2.75	
-2.95 (-0.60)	17.6 (.300)	85.0 (1.38)	-42.2 (-.694)	55.2 (1.46)	-52.4 (-.971)	-74.9 (-1.22)	46.2 (.723)	-79.1 (-1.83)	.353 (2.96*)	34.4 (1.23)	.594	2.04	1.08	2.04	1.96	

**NOTES**

Dependent variable is the annual average monthly one-year treasury bill rate series (or 9-12-month rate series when 12-month rate is unavailable) from *Banking and Monetary Statistics 1941-70*, Board of Governors of the Federal Reserve System, 1976, and *Federal Reserve Bulletin* minus 100 times Barro's 1978 inflation variable (DP) for the following year. All other data are from Barro 1978. DM is the change in the log of the money stock, DMR is

the residual in Barro's DM forecasting equation, G/y is real government expenditure over real GNP. Time is 1 in 1952 and 25 in 1976. Sample period is 1952-76. F<sub>b</sub> is F statistic to test hypothesis that coefficients of all DM terms are zero. The t statistics are in parentheses.

\*Significant at 5% level.

where  $\rho_t$  is the rationally expected real interest rate,  $m_t$  is the log money stock,  $\zeta_t$  is a stochastic process representing the real forces that cause movements in the real rate even when the money stock is predictably growing along a constant growth path,  $\phi_i$  and  $\psi_{ij}$  are coefficients, and  $E_{t-i}$  denotes expectation conditional on information available at time  $t - i$ .

The ex post real rate  $r_t - p_{t+1} + p_t$  equals the rationally expected real interest rate plus an error term:  $r_t - p_{t+1} + p_t = \rho_t + \eta_{t+1}$ , where the error term is uncorrelated with all data known at time  $t$  and hence is itself serially uncorrelated but may be correlated with information acquired between  $t$  and  $t + 1$ .

In terms of this formulation, hypothesis 1 may be interpreted to mean that  $\phi_i$  and  $\psi_{ij}$  are all zero, so that  $\rho_t = \zeta_t$  and  $r_t - p_{t+1} + p_t = \zeta_t + \eta_t$ . We shall assume for the moment that  $\zeta_t$  is constant. Then, Fama's tests are appropriate and Barro's tests should find all DM and DMR terms insignificant (as we in fact found) although a  $DMR_{t+1}$  term may be significant insofar as it affects  $\eta_{t+1}$ . Granger or Sims tests should show that money does not cause real rates, since, as Fama noted, ex post real rates will be unforecastable white noise.

Hypothesis 2 may be interpreted as a restriction on the coefficients of (14), namely:

$$(14') \quad \rho_t = \zeta_t + \sum_{i=0}^n a_i (\Delta m_{t-i} - E_{t-i}(\Delta m_{t-i})),$$

so that only surprises in monetary policy  $\Delta m_t - E_t \Delta m_t$  affect real rates. The lagged terms are included to allow for persistence in the effects of these surprises. Now, Fama's tests are no longer appropriate even if  $\zeta_t$  is constant. The Barro type tests should show all DM terms insignificant, but the DMR terms, which are supposed to represent  $\Delta m_t - E_t(\Delta m_t)$ , might now be significant. Since  $\rho_t$  is a simple moving average process whose innovation  $m_t - E_t m_t$  is uncorrelated with past data, a Sims or Granger test using the true  $\rho_t$  would show that money does not cause  $\rho_t$ , that is,  $\rho_{t-1}, \rho_{t-2}, \dots$  contain all information available for forecasting  $\rho_t$  and hence further information in terms of lagged  $m$  is of no value.

Hypothesis 3 might be interpreted as a less stringent restriction on (14):

$$(14'') \quad \begin{aligned} \rho_t = \zeta_t + & \sum_{i=0}^n a_{0,i} (\Delta m_{t-i} - E_{t-i}(\Delta m_{t-i})) \\ & + \sum_{i=0}^n a_{1,i} (\Delta m_{t-i} - E_{t-i-1}(\Delta m_{t-i})) \\ & + \dots + \sum_{i=0}^n a_{s,i} (\Delta m_{t-i} - E_{t-i-s}(\Delta m_{t-i})) \end{aligned}$$

where  $s$  is the policy effectiveness interval. The restriction imposed by this hypothesis is that long-term forecast errors (i.e., for a forecast horizon greater than  $s$ ) have in themselves no effect on  $\rho$ . This hypothesis now implies nothing for any of the tests we have examined. One might have thought that it would perhaps imply that, with a Granger causality test, money terms lagged more than  $s$  periods would have no effect, but this is not the case. The only test that seems immediately suggested by it would be an extension of the Barro test found by estimating a battery of 0-period, 1-period, 2-period, and so on, forecasting equations, and then taking their residuals as estimates of the terms  $\Delta m_t - E_t(\Delta m_t)$ ,  $\Delta m_t - E_{t-1}(\Delta m_t)$ , and so on. One could then estimate (14'') using for  $\rho$  the ex post real interest rate. Hypothesis 3 would then imply that coefficients of  $\Delta m_t - E_{t-j}(\Delta m_t)$ ,  $j > s$  should be zero, which is in principle testable.

While the above analysis seems to suggest that Granger, Sims, or Barro tests, or extensions thereof, might well be used to examine the hypotheses, it is useful to bear in mind the stringent assumptions that must be made. These assumptions have for the most part already been pointed out in different contexts by, for example, Sargent (1976) and Sims (1977), so we will cite them only briefly here.

We have assumed first that  $\zeta_t$  is constant. In fact, it is plausible that real factors have had an impact on real interest rates and that the forecast of  $\zeta_t$  may be related to lagged money. For example, wartime increases in government expenditure may themselves influence  $\zeta_t$  and are also correlated with the wartime increases in money. On the one hand, this may mean that Barro, Granger, or Sims tests would find that money has an effect on real rates even if hypothesis 1 or 2 is true. Barro's contemporaneous  $G/y$  term may well fail to correct for such effects. On the other hand, even if all the hypotheses are false, it is possible, as Sims (1977) has pointed out in a more general context, that if the Fed has been trying to stabilize real interest rates, that is, offset  $\zeta_t$ , causality tests might lead one to conclude that money has no effect on real interest rates. These problems seriously limit the usefulness of the above tests for the purpose of examining our hypotheses.

Another problem with the Granger or Sims tests in this context is that our hypotheses relate to unobservable rationally expected real rates and we use in the tests the ex post real rates. With either the Granger or Sims tests the real rate must appear on the right-hand side of the equation, so we have an errors in variables problem (which is not completely solved by using some other estimate of the rationally expected real rates). Then, even if hypothesis 2 is true,  $m$  may appear to cause real rates, since lagged  $\Delta m$  may provide information about  $\Delta m_{t-i} - E_{t-i}\Delta m_{t-i}$  not obtainable from the lagged real rate.

This problem would not arise if we were willing to assume in hypothesis 2 that there is no persistence in the effects of monetary surprises on real interest rates, that is,  $a_i = 0$ ,  $i \geq 1$ . Then (so long as problems of time variation in  $\zeta_t$  do not arise) we could test the hypothesis by checking whether ex post real rates can be forecasted. In effect, we could eliminate the lagged real rate terms from the Granger test by theoretical considerations. Similarly, if the summations in (14'') are known to contain only the first term (i.e.,  $a_{ji} = 0$ ,  $i \geq 1$ , all  $j$ ) then hypothesis 3 could be tested merely by regressing ex post real rates on information known  $s$  periods earlier, which should not contribute to a forecast of real rates. However, those who have suggested our hypotheses have made it clear that they are not willing to rule out persistence, so these tests cannot be used.

Another problem with the Barro tests is that it is perhaps not possible to identify the contemporaneous forecast errors, since these rely necessarily on an arbitrary characterization of the forecasting relation and information set of the public. His forecasting equation depends on one contemporaneous variable (a government expenditure term) which appears no more likely to be known at any point of time than is the money stock itself. This term is essential to the model, since without it his forecasting relation would be autoregressive, in which case the DM terms would be linear combinations of lagged DMR terms and hence not distinguishable in the regression.

Finally, whatever we learn about (14) under one policy rule, we do not necessarily know that (14) is a structural relation which is invariant under alternative policy rules, as Sargent (1976) has emphasized.

## Conclusion

We will conclude here by listing the salient facts that seem relevant to each of the three hypotheses. Since the hypotheses are nested, evidence against any hypothesis also serves as evidence against the hypotheses preceding it.

*Hypothesis 1.* The Federal Open Market Committee knows it can influence nominal rates because it has conducted what Friedman and Schwartz (1963) called "quasi-controlled experiments"; that is, it has moved the money stock in ways and at times that could not be ascribed to reverse causality from economic variables to the money stock. It seems highly improbable that the outcome could be explained in terms of the reaction of inflationary expectations to the shock. We thus feel we can safely say that hypothesis one is wrong.

Fama's evidence serves principally to cast substantial doubt on the conventional argument that medium-run movements in nominal rates

must be due primarily to movements in *ex ante* real rates since inflationary expectations are very sluggish. The correspondence of movements in post-Accord nominal rates and the optimally forecasted inflation rates is fairly impressive. One must bear in mind that really short-run movements in nominal rates did not occur enough in the sample period for us to say anything about these movements in nominal interest rates. Fama probably exaggerates the problems with earlier data and our results with these incline us to the conclusion that the relative constancy of real rates in his sample is due to Fed behavior, not the inability of the Fed to shock them. An interesting unanswered question is: Why did the Fed behave so as to keep the pretax real rate constant? Was this behavior due to their concern with some other variable which responds reliably to this rate?

*Hypothesis 2.* Direct evidence against this weaker hypothesis can be found only if we can find policy rule changes which affect the predictable component of monetary policy. Barro claims to have decomposed changes in the money stock into predicted versus unpredicted components for the postwar period, but his claim is not terribly convincing and in any event he assumed a constant policy rule. Granger or Sims causality tests are suitable as tests of this hypothesis only under some artificial assumptions.

One policy change that appears to relate to the way the Fed reacts to public information is marked by the Accord in 1951. This change was a once-and-for-all change ascribable largely to factors whose origin lay in politics and theoretical economics, and in this sense it too was exogenous. There is a dramatic change in the behavior of real interest rates that seems, looking at the data, to coincide with the Accord. Unfortunately, we do not know for sure that this change is due to a change in the systematic policy rule or just a change in the magnitude of the random components. It is also possible, moreover, that other changing variables were responsible for the change in the real rate's behavior. We also saw, for example, a dramatic rise in income tax rates dating from World War II, and although this change does not coincide with the change in real rate behavior, one could not rule out that the two are related. Paradoxically, pretax real interest rates were more stable *after* the tax rates were increased, when the theoretical case for constant pretax real rates was apparently weakened.

*Hypothesis 3.* Direct evidence against this yet weaker hypothesis can be found only if we can discover changes in the monetary policy rule which relate to information known in advance for a length of time exceeding the policy effectiveness interval. We considered one such shock to policy which relates to information forecastable into the indefinite future; that is, the seasonal factor. At the time it was founded, the Fed

announced a policy of reducing the seasonal shock in nominal rates. The Fed succeeded in reducing it, but there is no evidence that it affected the seasonal factor in real rates.

The most important potential source of evidence against this hypothesis, as well as hypothesis 2, comes not from the macroeconomic data but from other considerations. If we combine hypothesis 3 with a demand for money equation and a stability condition, then we are led to the conclusion that the price level bears a certain relationship to information about monetary policy known in advance by more than the policy effectiveness interval. While it is plausible that in some alternative steady states characterized by, say, different money growth rates, this might work out to be true, it does not seem likely that new information about discrete Fed policy actions would become optimally incorporated in the price level over any policy effectiveness interval. Most prices do not seem to be set that way.

We conclude that none of the hypotheses is likely to be so strictly correct as to rule out completely a predictable effect of systematic monetary policy on expected real interest rates. This does not by itself establish that there is a role for monetary policy in improving economic welfare. This conclusion, moreover, rests on our impression of how prices are set and not on any formal statistical evidence, which cannot be effectively brought to bear either for or against our conclusion. We hope, however, to have clarified why the complete noncontrollability of expected real interest rates should not be, as many seem to have concluded recently, a cornerstone for macroeconomic modelling.

## Comment Phillip Cagan

Economists have long assigned to monetary changes an effect on the real rate of interest. In a famous passage Ricardo stated that changes in the money stock would not affect interest rates in the long run, because price increases would take the economy to the same equilibrium in real terms that it started from.<sup>16</sup> I interpret the word “permanently” in Ricardo’s statement to mean that monetary increases temporarily depress interest rates (both real and nominal—though such a distinction was not typically

16. “The interest for money is not regulated by the rate at which the [central] Bank will lend, whether it be 5, 4, or 3 per cent; but by the rate of profits, which can be made by the employment of capital, and which is totally independent of the quantity, or of the value of money. Whether a bank lent one million, ten millions, or a hundred millions, they would not *permanently* alter the market rate of interest; they would alter only the value of the money which they thus issued” (Ricardo 1817, Everyman’s Edition, p. 246; italics added).

made in the classical literature). Mill alludes to an effect which was apparently widely accepted at the time and was later elaborated and made famous by Wicksell (1898, 1906) as an effect of "cumulative inflation."<sup>17</sup> Wicksell considered a continual increase in the money stock through bank expansion (either by a falling reserve ratio or growth of the monetary base). Since the new money enters the economy through credit markets and is assumed initially to augment the supply of loanable funds, the real rate of interest is reduced. Although the inflation that ensues reduces the purchasing power of all money, the inflow of new money continues to command resources and can be viewed as a continual addition to bank loans in real terms. Unlike Ricardo's proposition, the Wicksell effect does not pass away but holds the real rate of interest lower so long as the money supply increases. The Wicksell effect involves a redistribution of spending in the economy; most recent models of the economy and Shiller's review of them put aside distributional effects of money creation and so neglect this effect.

Recent contributions to monetary theory clarify the assumptions underlying these earlier propositions. If we assume, contrary to the classical economists, that prices are perfectly flexible and expectations are rational, Ricardo's long-run equilibrium is achieved very rapidly and, in so far as changes in the money stock are anticipated, immediately. Hence, in some recent models, as Shiller explains, changes in prices nullify the potential real effects of monetary changes, and the short-run changes implied by Ricardo's statement cited above never occur.

Price flexibility and rational expectations do not dispose of the Wicksell effect, however, since its redistributive effect is not eliminated in real terms by price increases. In an earlier work I analyzed the Wicksell effect as a situation in which *all* the revenue from money creation was used by the issuers to increase their saving to acquire more assets (Cagan 1972). Such a lopsided disposition of the income from money creation is questionable and not the most plausible assumption. If bank owners treat such income as they do all other income, I showed that the Wicksell effect disappears. It can sneak back in, however, if bank owners save a high proportion of income from money creation because it is unanticipated or uncertain or if the Federal Reserve deliberately uses its revenue from money creation to retire the national debt. We can still cut off this last effect if, as suggested by Ricardo (1817) and Barro (1974), we treat the public as knowledgeable stockholders of the government and

17. "The paper currency in common use, being a currency provided by bankers, is all issued in the way of loans, except the part employed in the purchase of gold and silver. The same operation, therefore, which adds to the currency also adds to the loans: the whole increase of currency in the first instance swells the loan market. Considered as an addition to loans it tends to lower interest" (Mill 1865, p. 646).

assume that individuals privately offset whatever saving the Federal Reserve does on their behalf.

To the question, Can the Fed control real interest rates? a broadly accepted answer in the profession even today would be that, for the short-run impact, yes; but that over time the effect diminishes to zero (ignoring second-order effects on the capital stock); and the more monetary actions are anticipated and adjusted to, the smaller the effect, while in some cases perhaps these adjustments make it zero in the short run. (This says nothing about the desirability of having the Fed use this capability.)

Shiller appears to share this general view. But he asks an auxiliary question, What solid evidence do we really have that the Fed affects real rates? Given the difficulties of testing rational expectations and whether policy actions are anticipated, the evidence must be examined with considerable sophistication. This Shiller does, and his paper is very good from this point of view. The counterpart to being sophisticated is that straightforward statistical evidence is slim, and in that respect his paper makes only a limited case for the affirmative view that the Fed affects real rates. Yet Shiller analyzes some qualitative empirical evidence that is of special interest in answering the question even if it does not resolve all the issues raised. He looks at some extreme cases most likely to provide evidence for the affirmative. These are pegging of interest rates during World War II and after, the decline in seasonal variation of nominal interest rates after the founding of the Federal Reserve system, and the decline in the variance of monetary growth and real interest rates since World War II. (As Shiller notes, the fact that nominal rates adjust to expected inflation does not mean that monetary changes have not produced changes in real rates.)

To use these facts to derive an affirmative answer to the question of his paper, it is necessary to conclude that the changes in behavior of nominal rates also produced changes in real rates and that the changes reflected a change in Federal Reserve behavior. Shiller has done a better job of persuading me (who needed little) than himself. But he is right to be careful, because rigorous statistical evidence on the real rate to support the affirmative position is not easy to establish. I am persuaded more by what I know of those events from historical research on monetary developments.

Consider the pegging episode, in which the Federal Reserve held nominal interest rates at a low level. If expected real rates were not also reduced by that action, the expected rate of change of prices had to be negative, which meant that expected monetary growth had to be reduced appreciably. It is difficult to interpret the pegging period as conforming to that scenario. As a matter of fact, the period appears to conform to the

Wicksell scenario, in which the rate of monetary growth is increased by the pegging, prices rise, and the real rate of interest is reduced. Surely most of these changes were widely expected. Indeed, it is difficult to see how the economy, given the pegging policy, could have avoided this outcome.

A similar interpretation can be applied to the reduction of seasonal variations in nominal interest rates, which the Federal Reserve engineered and claimed credit for (one of the limited number of cases in which its claim to have contributed to the stability of something appears valid, though whether the policy was desirable or not is debatable). Although Shiller finds that the effect on seasonal variations in real rates of interest is unclear, it seems to me that they, too, were probably reduced and were expected to be. The Federal Reserve operated by increasing monetary growth in the autumn and Christmas season, supplying seasonal increases in currency and credit in order to hold down the traditional second-half rise in nominal rates. This certainly facilitated the corresponding variation in trade; whether prices also increased seasonally is unclear, but it is likely that they did. If so, nominal rates rose less in the second half and prices more, or at least not less; hence real rates rose less or fell as a result of the Fed's policy.

As possible counter evidence to the affirmative view, Shiller notes that the quarter century since World War II displays an increasing correspondence between nominal interest rates and the rate of change of prices; that is, real rates have risen and fluctuated much less than have nominal rates. To be sure, based on the reduced variations in monetary growth over the same period, this suggests that monetary policy influenced real rates. But it can also be viewed as evidence that real rates are often independent of monetary developments. There is disagreement in the literature on whether real rates can be viewed as constant over this period and what it would mean if they have been constant. In any event, I would not take this as evidence against the affirmative view. The statistical relationship between nominal interest rates and the rate of inflation pertains mainly to the long-run movement; none of it shows that real rates did not fluctuate over the business cycle or that all the fluctuations were unrelated to monetary developments. The financial stringencies of 1966 and 1969 were "real" enough, and the evidence that they were engineered by monetary restraint is very persuasive to me.

I grant that these stringencies may have been largely unanticipated, and that our world is changing. As Friedman and Schwartz (1976) note, financial markets are *learning* to conform to the "Fisher effect" (with due regard for taxes, of course).

The duration of monetary effects on real rates of interest is therefore a crucial consideration. While the long-run effect never existed or is now

disappearing, the short-run effect appears strong and, for the present at least, long enough to make monetary policy and how it is conducted a very serious matter.

## Comment Charles R. Nelson

Robert Shiller has undertaken a particularly difficult but correspondingly important task in trying to shed some light on the question of whether the Federal Reserve can control real interest rates. Shiller begins by providing three specific hypotheses to be considered. Briefly, they are: (1) the Fed cannot affect expected real rates at all; (2) the Fed can affect real rates only through surprise moves in policy; and (3) Fed policies known far enough in advance will have no effect on expected real rates. To this list I would add another hypothesis, which turns out to be surprisingly difficult to reject, namely, that there is no variation whatever in expected real interest rates. Shiller's paper is primarily concerned with reviewing the evidence in favor of or contrary to these hypotheses including some which are relevant to the last hypothesis.

The essence of the problem is, of course, that the *ex ante* real rate is not generally observed. An exception would be the case of index bonds, which are not traded in the U.S. Shiller argues that if index bonds did exist, then the Fed could control their price and therefore their (real) yield simply by standing ready to buy or sell at a target level. In a world of rational expectations, however, it is not at all clear that the Fed would not face a perfectly elastic supply of such bonds since the implications of its actions for the rate of inflation would be immediately and completely understood. Thus, an attempt to depress the yield on index bonds would raise both the expected rate of inflation and *nominal* discount rates by the same amount, making market participants unwilling to hold *any* index bonds at anything less than the initial equilibrium real yield.

Shiller also discusses the possibility of controlling the real rate measured with respect to the consensus of published inflation forecasts and argues that the Fed "can choose a real interest rate, add to that the latest consensus inflation forecast, and then 'peg' the nominal rate at their sum." If I understand this sequence of events correctly, namely, that this real rate is measured relative to a *given* prior forecast, the ability to control it would appear to be of as little interest as the ability to control *ex post* realized real rates.

The important question, of course, is whether the Fed can affect or control real rates measured relative to rationally expected inflation. After reviewing the difficulties of addressing this question in the context of an explicit model, Shiller turns to the possibilities for deriving implied be-

havior in observable magnitudes, in particular the behavior of the ex post realized real rate. For example, Shiller shows that the variance over time in the linear forecast of realized rates based on past realized rates places a lower bound on the variance of the true rationally expected ex ante real rate. Similarly, Fama (1975) has argued that autocorrelation in realized rates would constitute evidence of variation in ex ante real rates since the pure forecast error on inflation must be serially random if expectations are rational. In principle, then, the impact of changes in the regime of monetary policy on the behavior of ex ante real rates may have observable implications. Unfortunately, as Nelson and Schwert (1977) have demonstrated, the very large variance of inflation forecast errors makes it difficult to reject any plausible hypothesis about the behavior of ex ante real rates on the basis of realized rates of return. For example, Fama was unable to reject the hypothesis that ex ante real rates are constant. Although Nelson and Schwert were able to reject this extreme null hypothesis using more refined tests, the basic problem of inferring the behavior of a signal buried in substantial noise remains. This also answers the question posed by Shiller about why Fama's critics did not find some variable that would dominate in an  $R^2$  sense the nominal interest rate as a predictor of inflation. Similar limitations crop up in Shiller's intriguing examination of whether the Fed altered the seasonal pattern in real rates when it moved soon after its establishment to eliminate the seasonal in nominal interest rates. When Shiller applies tests for autocorrelation analogous to Fama's for the period before the Accord, clear evidence of autocorrelation in realized rates and therefore variation in ex ante real rates seems to be indicated. But the inflation measure used is the wholesale price index and the well-known shortcomings of that index in reflecting list rather than transaction prices make the presence of autocorrelation in realized returns less convincing evidence of movements in ex ante rates. Interestingly enough, the empirical evidence would not seem to be nearly so ambiguous in the case of real returns on common stocks. Nelson (1976) and others have presented strong evidence that both ex post and ex ante returns on common stocks are negatively related to inflation.

Shiller also discusses the available "experimental evidence" on the ability of the Fed to influence real rates. Evidently, the Trading Desk can in fact drive down nominal short-term rates on any given day by buying bills. Since such an increase in high-powered money could hardly be construed as diminishing expected inflation, the clear implication is that the Fed can, at will, drive down the real rate at least temporarily. Shiller makes it clear that in a rational expectations context the Fed may well be able to engineer such movements in real rates by surprising the market, but that *systematic* control is by no means implied by this evidence. Empirical tests to distinguish the impact of expected as opposed

to unexpected open market actions by the Fed on short-term rates designed along the lines of analogous work by Robert Barro (1977) relating to unemployment and monetary policy have been made by Shiller, but of course are subject to the same statistical problems that have been raised by discussants of Barro's paper at this conference.

## Comment James L. Pierce

Bob Shiller is to be congratulated for having written yet another highly informative and interesting paper. The paper uses the recent literature on rational expectations as a basis for examining the question of whether or not the Federal Reserve can control rationally expected real interest rates. Shiller points out that it is difficult to convert much of the discussion about real interest rates into testable hypotheses. His development of the various hypotheses and his discussion of the difficulty in testing them is, in itself, a valuable contribution.

After developing a simple model to determine the nominal interest rate and rationally expected inflation in which policy, and the public's response to it, are endogenous, Shiller spends most of his efforts in searching for data that will provide identifying restrictions for the model. He has to find exogenous shocks that affect the Fed while leaving the public unaffected. The trick is to find shifts in regimes in which the stochastic processes driving the system are altered, that is to say, when the system moves from one rational expectations equilibrium to another. Ordinary time-series analysis is not useful for the task. Shiller shows considerable skill and tenacity in looking for appropriate episodes. For example, he looks for changes in the seasonality of interest rates following the founding of the Federal Reserve system and for changes in the stochastic behavior of "real" interest rates following the Accord of 1951, when the Fed abandoned its peg on government security prices.

Despite his many efforts, Shiller is unable to provide unambiguous evidence on the question of whether the Fed can control real interest rates because the very shifts in regimes that could allow identification of parameters might have affected other parameters in the system. But he does find some evidence to support the proposition that the Fed can affect real interest rates.

It is possible that more evidence could be brought to bear on the issues if additional structure were introduced. The real interest rates that Shiller considers are real in Fisher's sense, that is, the real interest rate is taken to be the nominal interest rate less the expected rate of inflation. The Fisher approach is then applied to financial assets. But there is also a real return on real assets. There is no guarantee that these two interest

rates are always equal, but one would expect agents to exploit arbitrage opportunities between them. These opportunities drive the kind of model developed by Wicksell.

There is substantial evidence that some combination of Fed policy and inflationary shocks can drive a wedge between the real return on financial assets and that on real assets. For example, the real return on short-term financial assets has been negative for much of the period from 1974 to the present, yet many real assets such as commodity inventories and houses have enjoyed a substantial real return. Apparently, asset markets are more specialized and segmented than many observers have thought. It is difficult to remove by arbitrage differences in real return between treasury bills and houses. When wide margins do exist between the return on financial assets and that on real assets, such episodes can provide additional identifying restrictions for tests of relevant hypotheses concerning the Fed's ability to influence real interest rates. It is conceivable that this ability is considerably greater for financial than for real assets.

## Comment      Martin Feldstein

The basic economic decisions to save and invest do not depend on the real interest rate as such but on the *net-of-tax* real interest rate. The relevant question about the neutrality of monetary policy should therefore be restated as, "Can the Fed Control the Real *Net* Interest Rate?" I think that there can be little doubt that this is so.

It is important to note first that if the real interest rate remains unchanged, the real *net* rate will be significantly altered. This occurs because the tax rate applies to the nominal interest rate, making the effective tax rate a function of the rate of inflation. Consider, for example, an individual with a 50% marginal tax rate. If the interest rate is 4% and there is no inflation, the real rate is obviously 4% and the real net rate is 2%. If a 6% inflation rate keeps the real rate unchanged, the nominal rate becomes 10%; the net-of-tax nominal rate is 5% and the net real rate is -1%. So even if monetary policy is neutral in the sense that the 4% real interest rate is unchanged, the 6% rate of inflation can turn a 2% real net yield into a real net yield of -1%. Of course, for a borrower with a 50% marginal tax rate, the 6% inflation also causes a corresponding reduction in the real net cost of borrowing.

The assumption of a fixed real pretax interest rate also represents an extreme and unlikely case. In several papers, I have examined the theoretical and empirical aspects of the effect of inflation on the interest rate that business investors would be willing to pay if the real marginal

product of capital remained constant (Feldstein 1976, Feldstein, Green, and Sheshinski 1978, Feldstein and Summers 1978a). This analysis suggests that, with current tax rates and depreciation rules, each 1% of inflation raises the interest rate that firms would be willing to pay by somewhat more than 1%. The net effect of inflation depends also on the way in which tax rules affect the supply of funds and the demand for funds in other markets. Because of differences in tax rules, it is clear that inflation will not affect investment in housing in the same way it affects investment in industrial plant and equipment.

These results have important implications about the interpretation of the existing evidence on the “neutrality” of monetary policy. Evidence that each 1% of expected inflation raises the interest rate by 1% has incorrectly been viewed as implying such neutrality. Just the opposite is true. A demonstration that the real interest rate remains unchanged should be interpreted as evidence of nonneutrality because it implies a change in the real *net* rate of interest.

A sustained increase in the rate of growth of money thus alters the real net interest rates that govern individual decisions. The complexity and distortions introduced in this way should be regarded as a major reason for opposing such inflation.

## General Discussion

Shiller was asked whether under the hypotheses he was testing, the nominal interest rate should not have fallen by 500 basis points in 1971 when Phase I of wage-price controls reduced the inflation rate by 5%. He replied that only the first hypothesis carries this implication; he did not doubt that hypothesis 1 could be rejected. In connection with Nelson’s proposed hypothesis that the real rate is constant, he noted that the Fama results could be rejected for periods other than 1951–73; he had to reject the hypothesis with a sample extended to 1977 for instance.

In response to a criticism that the paper was overly skeptical Shiller argued that he had clearly rejected hypothesis 1. While *prima facie* evidence against hypotheses 2 and 3 could not be found, it seemed unlikely that either was strictly true. He found it implausible that the aggregate price level should optimally incorporate information about future monetary policy, as these hypotheses imply. Shiller said that he had concentrated on short rather than long rates in this study, but that his work with Siegel on British consol yields over 250 years found that long-term real yields showed large movements. Movements in nominal long-term yields worked in the direction of *increasing* the amplitude of the movement in real long-term yields.

Robert Hall suggested that the paper was missing an analysis of the economic forces that might stabilize the real interest rate. Arbitrage is the potential link between the behavior of nominal interest rates and prices. The consumer price index is not representative of the goods subject to arbitrage over time, since it includes perishables.

It was suggested that arbitrage could not account for the behavior of interest rates during 1975 and 1976, since ex ante real treasury bill rates then were clearly negative. Paul Samuelson replied that arbitrage possibilities of the type discussed by Hall did not necessarily rule out non-negativity of real interest rates. If there were commodities storable at zero cost, then the real rate, at least as measured in terms of those goods, could not become negative. In the absence of such commodities, the real rate could indeed be negative.

Herschel Grossman argued that the fact that money supply data are revised several times tends to support the view that confusion about the level of the money stock contributes to the business cycle. He was not confident that existing theories based on incomplete information were enough to explain business cycles, but also doubted that existing theories based on nonclearing of markets could provide the full explanation.

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