NBER WORKING PAPER SERIES

UNDERSTANDING REAL INTEREST RATES

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Working Paper No. 2691

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
August 1988

Invited paper for the American Agricultural Economics Association Meetings, Knoxville, Tennessee, August 1-3, 1988. This research has been funded by a Faculty Research Fellowship, Graduate School of Business, Columbia University. It is part of NBER's research programs in Economic Fluctuations and Financial Markets and Monetary Economics. Any opinions expressed are those of the author not those of the National Bureau of Economic Research. The data in the figures in this paper as well as the other data used in the analysis will be made available free of charge to any researcher who will send me a standard formatted 360 KB diskette with a self-addressed mailer.

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ABSTRACT

This paper outlines an approach to measuring real interest rates and testing hypotheses on their behavior. It then describes what we know about real interest rates in the aggregate economy and provides estimates of real interest rates for the agricultural sector.

The evidence presented in this paper indicates that real interest rates for the agricultural economy have been extremely high in the 1980s and that their behavior seems to be linked to that found for real rates in the aggregate economy. What has been the source of these high real rates? The answer seems to be that it was a result of a concerted effort by the monetary authorities to disinflate the economy. However, the brunt of the Fed's disinflationary policy has fallen more heavily on the farm sector which has had to face far higher real rates than the rest of the economy. Although breaking the back of inflation was certainly a worthy goal for the Fed, farmers have had to pay a heavy price. They have had to suffer for the sins of an economy that was excessively inflationary, which then had to be brought back into line with disinflationary policy.

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I. Introduction

Real interest rates are among the most important economic variables and have been studied extensively. They figure prominently in discussions of the transmission mechanisms of monetary policy and also play a prominent role in explanations of business cycles and particular business cycle episodes. Real interest rates are a central element in savings-consumption decisions and in debates about how to encourage savings, a topic which has been prominent in recent years because of the rise of supply-side economics. Real interest rates are also a critical explanatory variable for investment decisions since they represent the real cost of borrowing. They are especially important in the agricultural sector since farmers must make extensive use of debt markets in order to finance their production.

This paper outlines an approach to measuring real interest rates and testing hypotheses on their behavior. It then describes what we know about real interest rates in the aggregate economy and provides estimates of real interest rates for the agricultural sector. By examining the behavior of real interest rates in the agriculture sector, we may develop a better understanding of some of the woes of the farming industry in recent years.

II. Methodology

The real interest rate of concern to economists is more precisely referred to as the ex ante real interest rate. The ex ante real interest rate for a one-period bond, that is, its expected real return, is:

$$(1) \qquad rr_t = i_t - \pi_t^e$$

where,

rr_t = the ex ante real interest rate on the one-period bond at time t: i.e., the ex ante real return from time to t+1.

i_t = the nominal interest rate on the one-period bond at time t: i.e., the nominal return from time t to t+1.

π_t^e = the inflation rate from time t to t+1 expected at time t.

The problem with measuring the ex ante real interest rates is that expected inflation, π_t^e, is not directly observable and so neither is the ex ante real interest rate. In the literature, several approaches have been used to measure ex ante real interest rates. In one approach, real interest rates have been calculated by subtracting survey data on inflation expectations, such as the Livingston data, from nominal interest rates. The problem with survey-based measures of real interest rates is that they are only as good as the survey measure of inflation expectations and there may be little incentive for the survey respondents to answer accurately. An even more telling criticism of survey-based measures, often ignored in the literature, is that the behavior of market expectations is driven by economic agents at the margin who are eliminating unexploited profit opportunities. Market expectations are unlikely, therefore, to be well measured by the average expectations of survey respondents.[1]

Another approach is to use futures market data to examine real interest rate behavior. Futures market data can be used to directly construct own-commodity real interest rates -- i.e., the ex-ante real return on a bond in terms of specific commodities -- and then the own-commodity real rates can be used to make inferences about the real interest rate for the aggregate economy. As pointed out by Mishkin (1987), however, this approach also runs into problems because own-commodity real rates constructed using futures market data contain information not only about the real interest rate for the aggregate economy or for a particular sector, but also about ex ante relative price movements for the particular commodity. Since, as demonstrated in Mishkin (1987), these ex ante relative price movements (which can be thought of as noise) are far greater in magnitude than movements in the aggregate real interest rate (the signal), then the noise-to-signal ratio in own-commodity real rates will be very high. Own-commodity real rates constructed using futures market data will thus contain little information about the aggregate real interest rate of primary concern to economists.[2]

Although the ex ante real interest rate is not directly observable, the ex post real interest rate, which is the actual real return from holding the one-period bond from t to t+1 is observable. It is defined as,

(2) $$eprr_t = i_t - \pi_t = rr_t - \varepsilon_t$$

where,

$eprr_t$ = the ex post real interest rate on the one-period bond at time t: i.e., the realized real return from time t to t+1.

π_t = the actual inflation rate from time t to t + 1.

ε_t = the inflation forecast error, $\pi_t - \pi_t^e$.

The approach for measuring ex ante real interest rates outlined here makes use of ex post real interest rate data with the assumption of rational expectations. Specifically, the assumption of rational expectations implies that inflation forecast errors are unforecastable given any information at time t: i.e., $E(\varepsilon_t | \phi_t) = 0$, where $E(\ldots | \phi_t)$ is the mathematical expectations operator conditional on all information available at time t, ϕ_t.

If the ex ante real rate is correlated with observable variables, X_t, we can describe the ex ante real interest rate as a linear projection onto X_t:

(3) $$rr_t = X_t \beta + u_t$$

where,

X_t = a set of variables in the available information set ϕ_t.

u_t = the error from projecting rr_t onto X_t, which by definition is uncorrelated with X_t.

Finally, combining equations (1) through (3) we obtain the following regression equation,

(4) $$eprr_t = X_t \beta + u_t - \varepsilon_t$$

Since data on $eprr_t$ and X_t are observable, equation (4) can be estimated by ordinary least squares (OLS) and hypothesis tests can be conducted on β. Measures of the ex ante real rate can be constructed from the fitted values obtained from the OLS estimate of this regression equation: i.e.,

(5) $$\hat{r}r_t = X_t \hat{\beta}_{OLS}$$

In a similar fashion, estimates of expected inflation are generated by

(6) $$\hat{\pi}_t^e = i_t - \hat{r}r_t = i_t - X_t \hat{\beta}_{OLS}$$

The question arises: what are the properties of the estimated β's and of the measures of the ex ante real interest rate and expected inflation described above. The answers to this question are outlined briefly in the following set of econometric points. More formal demonstrations of these points can be found in Mishkin (1981a, 1984a).

1. The $\hat{\beta}_{OLS}$ estimate is a consistent estimate of the projection equation β in (4). This follows directly from the fact that u_t is orthogonal to X_t by definition, while ε_t is also orthogonal to X_t because X_t is in the information set ϕ_t and rational expectations implies that ε_t is orthogonal to any information included in ϕ_t. Another way of thinking about the result is that a regression using ex post real rates will asymptotically yield the same estimates of β as a regression using ex ante real rates. Thus we can make inferences about the relationship of the ex ante real interest rate with variables known at time t via ex post real rate regressions, even though the ex ante real rate is unobservable.
2. However, we do lose information by using ex post real rates in a regression rather than ex ante real rates. The appearance of the error term ε_t in the ex post real rate regression equation (5) means that $\hat{\beta}_{OLS}$ will have higher standard errors and will be measured less precisely. Furthermore, as a result, the statistical power of tests on the β-coefficients may be quite low.
3. The β and its consistent estimate $\hat{\beta}_{OLS}$ do not imply causation from X_t to the ex ante real rate for two reasons: (i) the X_t variables are not necessarily exogenous and (ii) information relevant to real rates that is correlated with X_t may have been excluded from the explanatory variables of the regression equation. Without further

identifying information, the $\hat{\beta}_{OLS}$ can be interpreted only as reflecting the correlation of ex ante real rates with the X_t variables.

4. The $\hat{rr}_t$ and $\hat{\pi}^e_t$ estimates will be good estimates of real interest rates and expected inflation only if the variance of the u_t error term is small. This will be the case if no relevant information is excluded from the ex post real rate regression or if the relevant information left out is highly correlated with X_t.

5. An important diagnostic check for a good specification of X_t that produces a small u_t involves examining the residuals from the ex post real rate regression to see if they are white noise. Under rational expectations, ε_t is serially uncorrelated because with the holding period matching the observation interval (non-overlapping data), all past ε's are in the information set ϕ_t and are thus uncorrelated with ε_t.[3] On the other hand, u_t may be autocorrelated or correlated with past values of ε_t. If this is the case and the variance of u_t is large, then the regression residual, $u_t - \varepsilon_t$, will be serially correlated. However, if the variance of u_t is small, then the regression residual, $u_t - \varepsilon_t$, is dominated by ε_t and is necessarily serially uncorrelated. Thus the absence of serial correlation in the residuals of the ex post real rate regression is a necessary condition for a small variance of u_t, and hence for good $\hat{rr}_t$ and $\hat{\pi}^e_t$ estimates.[4]

6. In order for OLS to yield correct standard errors for the β-estimates, the regression residuals must satisfy the Gauss-Markov conditions that they not be heteroscedastic or serially correlated. Satisfying the diagnostic check described above is therefore also

important because it helps insure that the OLS standard errors of the coefficients are correct.[5]

III. Real Interest Rates for the Aggregate Economy: What Do We Know?

Using the methodology above, a number of basic facts about the behavior of the real interest rates have been uncovered. The interested reader is directed to papers by Fama, Nelson and Schwert, Mishkin (1981a, 1984a, 1984b) Fama and Gibbons, Summers (1983), Huizinga and Mishkin (1984, 1986), and Cumby and Mishkin (1986). Note that all of these results involve the measurement of an ex ante real interest rate for the aggregate economy in which inflation is measured with a broad-based price index such as the CPI.

1. The hypothesis that the real interest rate is constant (i.e., that ß-coefficients on all variables except the constant term equal zero in equation (4) is strongly rejected for most sample periods. Only in the unusual sample period from 1953 to 1971 studied by Fama, in which there was very little variation in the data, is the constancy of the real rate not rejected. Even in this sample period, the failure to reject constancy of the real rate should not be taken as strong evidence that the real interest rate was constant in that period; rather it appears to be a reflection of the lack of statistical power of tests on the ß-coefficients.
2. The real interest rate is negatively correlated with expected inflation. This finding is an extremely robust one, having been found for sample periods going back over a hundred years and for other countries besides the United States. Another way of

characterizing this result is that bonds have been a poor inflation hedge even in an ex ante sense.

3. Increased money supply growth is associated with a decline in real interest rates. However, little evidence has been found that money growth affects real interest rates other than through its effect on inflation, although this result could be due to the low power of the statistical tests.

4. In the postwar period in the United States, fluctuations in nominal interest rates have typically reflected changes in expected inflation rather than in real interest rates. This so-called Fisher effect in which there is a high correlation between nominal interest rates and expected inflation is not a general phenomenon. There is little evidence of a Fisher effect in the U.S. in the period between the two world wars and during the change in Federal Reserve operating procedures from October 1979 to November 1982.

5. Movements in nominal interest rates are often not a reliable indicator of movements in real rates. The correlation of nominal interest rates with real rates in the U.S. has been found to be negative in most of the postwar period, with the exception of the October 1979 to October 1982 period. However, in that period, nominal interest rates became highly positively correlated with real interest rates, moving one-for-one with them.

6. Other countries often display a different relationship between nominal interest rates with either expected inflation or real interest rates than is found in the U.S. Even before 1979, several other countries had only a very weak Fisher effect with low correla-

tion between nominal interest rates and expected inflation, yet have had a strong positive correlation between nominal and real rates.

7. Real interest rates were extremely high during the contraction phase of the Great Depression. From the perspective of real interest rates, money was extremely tight in this period.
8. Real interest rate were positive in the 1950s and 60s, turned negative in the mid to late 1970s, jumped up dramatically in the early 1980s to levels comparable to those during the contraction phase of the Great Depression, and although having declined somewhat have continued to remain at levels above those in the 50s and 60s.
9. Real interest rates in other developed countries do tend to move in tandem with those in the United States. Just as in the U.S., real interest rates in these countries declined from the 1960s to the 70s, and then rose to levels unprecedented in the postwar period. Although there is a statistically significant link between real interest rates in these countries and those in the U.S., real rates in these countries do not move one-for-one with those in the U.S. As a result, the equality of real interest rates across countries can be strongly rejected.

An important puzzle in the list of facts above is why real interest rates became so high in the 1980s. Politicians and many economists blame the high real rates on the dramatic jump in the U.S. budget deficit after 1981, but closer scrutiny of the data does not give strong support to this view.[6] Instead, recent research by Huizinga and Mishkin (1986) points to monetary policy as the source of high real interest rates. Because the issue of why real interest rates have been so high in recent years is such an important one, particularly to the agricultural sector, it is worthwhile describing the evidence for the conclusion that the high real interest rates in the 1980s are a monetary phenomenon.

Modern monetary theory [Lucas] suggests that regime changes have an important impact on the stochastic process of many economic variables. With the change in monetary regime in October 1979, the Fed changed the method of conducting monetary policy; in order to reverse the inflationary monetary policy of the 1970s. The basic question is whether this disinflationary, monetary regime change is associated with a shift in the stochastic process of real interest rates which resulted in the high real rates in the 1980s.

The answer appears to be yes. When the Fed altered its behavior in October 1979, there was a statistically significant shift in the stochastic process of real interest rates. In addition, if one asks when the shift in the stochastic process of real rates actually occurred, statistical evidence indicates that it corresponded exactly to the October 1979 change in the monetary policy regime. These results point the finger at Volcker's change to a disinflationary monetary policy regime as a major factor causing the high level of real rates.

The research strategy described above is one in which we look for a clearly definable historical event such as the October 1979 change in Federal Reserve operating procedures, and then see if there is a significant change in the behavior of a particular economic variable immediately afterwards. Suppose that for historical reasons we know the first event is <u>exogenous</u>, so that it occurs as a result of an independent action that could not possibly be caused by the other economic variable. Then when a significant change in the economic variable follows the exogenous event, we have strong evidence that the first event is <u>causing</u> the change in the behavior of the economic variable. In a sense then, we are treating the October 1979 change in the Fed operating procedures as an exogenous event -- in other words, a controlled experiment -- and when we see the shift in the behavior of the real interest rate, we are ascribing causation from the monetary regime shift to the change in real rate behavior.

The approach described above actually provides identification using historical knowledge to rule out such problems as reverse causation. It is one method for getting around the identification problem posed by the rational expectations revolution [see Sims]. However, one danger of such a historical-econometric approach is that it runs the danger of fitting one historical episode with one tailor-made theory. Truly convincing evidence that the Fed''s monetary policy regime change led to high real interest rates must involve examination of similar "controlled experiments" in other time periods. Examination of another episode of a monetary regime shift in 1920 that has many similarities to the October 1979 shift provides exactly this kind of evidence.

At the beginning of 1920, the pursuit of the real bills doctrine by the Fed led to rapid money supply growth, a sustained high level of inflation with double digit levels similar to that of the late 1970s, and a weak dollar. In January and June of 1920, the Fed decided to reverse its inflationary monetary policy by raising the discount rate sharply -- by 1 1/4% in January and 1% in June. In the early years of the Fed, changing the discount rate was the main tool of monetary policy, and it was particularly potent at this time because the total amount of member bank borrowing from the Fed exceeded the amount of nonborrowed reserves. The result of this policy was a rapid disinflation (in fact, a deflation). This disinflation was similar to the one we saw in the early 1980s and thus we might expect to find parallels between the two periods.

The empirical analysis of the period surrounding 1920 reveals a significant shift in the stochastic process of real interest rates which has many similarities to the experience of the 1980s. Not only is the shift significant, but the dating of the shift is coincident with the Fed's taking action to raise the discount rate in June 1920. Furthermore, the 1920 monetary regime change and the subsequent disinflation is associated with a strengthening of the correlation of nominal interest rates and real interest rates and a shift to a sustained higher level of real interest rates.[7] The striking correspondence between the impact of the monetary regime shifts on real interest rates in 1920 and 1979 provides strong support for the view that the recent shift in real rate behavior is a monetary phenomenon. Particularly important in this regard is that high budget deficits were not a feature of the 1920s,[8] thus suggesting that monetary factors are more important than budget deficits to the recent behavior of real interest rates.[9]

Now that we have discussed what we know about real interest rate behavior for the aggregate economy, we might ask whether the real interest rate that is more applicable to the agricultural sector has behaved in a similar way. This is what we turn to now.

IV. Real Interest Rate Behavior for the Agricultural Sector

Clearly, there is no unique real interest rate. The real rate depends not only on the risk characteristics of the particular security being studied, but, more importantly, also on the price index used to calculate real returns. The real interest rate relevant to production decisions in the agricultural sector is not the real interest rate calculated with a broad-based price index such as the CPI, the one discussed above. Instead, a real interest rate relevant to the agricultural sector should be measured with a price index that reflects the prices of agricultural output.

Using the farm products component of the producer price index and one-month Treasury bills, ex post real interest rates for the agricultural sector have been constructed for the January 1953 - December 1986 sample period. Ex post real rate regressions for the pre-October 1979 and post-October 1979 sample periods have been run using the same explanatory variables as in Huizinga and Mishkin (1986), but the only explanatory variable with a statistically significant coefficient in either period is the one-month bill rate (i_t).[10] Even with just this one explanatory variable in the regressions, the diagnostic check for serial correlation of the residuals does not reveal any evidence of serial correlation.[11] Not only are the Durbin-Watson statistics near two, but Q-statistics cannot reject that the first twelve autocorrelations of the residuals are zero. Thus there is no evidence that the specification of the X_t information set is inadequate. The regression results with standard errors of coefficients in parenthesis are as follows:[12]

Sample Period: January 1953 - October 1979

$$eprr_t = \underset{(3.69)}{3.27} - \underset{(.81)}{.53}\, i_t + \varepsilon_t$$

$R^2 = .001$ Standard Error = 30.49 Durbin-Watson = 2.05

Sample Period: November 1979 - December 1986

$$eprr_t = \underset{(9.74)}{-15.22} + \underset{(1.01)}{2.73}\, i_t + \varepsilon_t$$

R^2 = .080   Standard Error = 26.48   Durbin-Watson = 1.73

The first striking feature of these results is the very large standard error of the regression, which is on the order of 30 percentage points. Since the absence of serial correlation in the residuals suggests that most of the variation of the regression residuals can be attributed to the forecast error of inflation, these regressions indicate that one-month forecast errors for farm products inflation have a standard deviation of thirty percentage points at an annual rate. On the other hand, for the same time periods, standard errors of the regression for ex post real rate regressions using the CPI price index are on the order of 2 to 2.5 percentage points,[13] which is less than one-tenth as large. The exceedingly large forecast errors for farm products inflation is not surprising considering how volatile far prices are, but it does mean, as the earlier discussion of methodology suggests, that ex post real rate regressions for the agricultural sector will have low statistical power. This helps explain why only the T-bill rate is found to be a significant explanatory variable in the regressions.

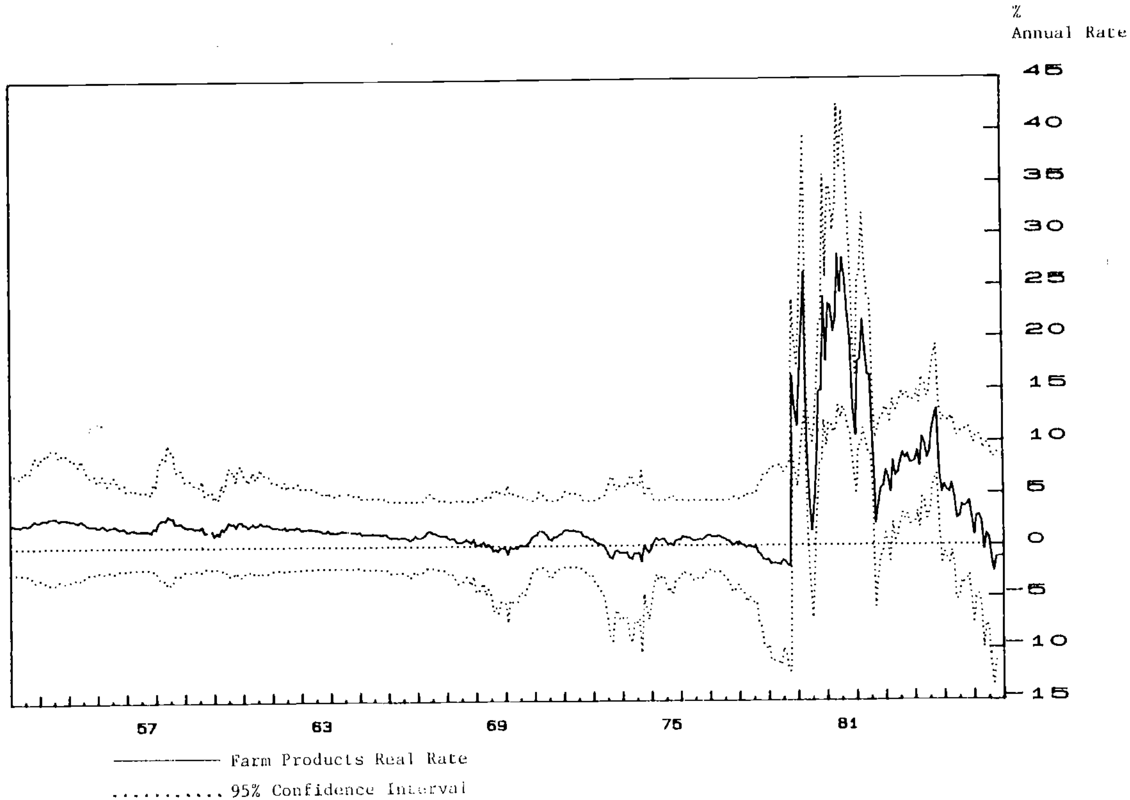
Despite the low statistical power, the ex post real rate regressions above for farm products yield similar conclusions to ones estimated using the CPI price index. They suggest that in the pre-October 1979 period ex ante real rates for the agricultural sector are negatively correlated with nominal interest rates, while after the monetary regime shift in 1979 they become positively correlated. In addition, an F-test for the stability of the coefficients in the two sample periods indicates that the stochastic process of real rates for the farm sector also undergoes a significant shift in October 1979: $F(2,404) = 3.57$ while the critical value at the 5% level is 3.00.

Using the fitted values of the above regressions to construct measures of expected farm products inflation, we can run regressions of ex post real rates on expected inflation. The results are that the coefficient on expected inflation is -.35 in the pre-October 1979 period with a standard error of .34, and the coefficient is -1.58 in the post-October 1979 period, also with a standard error of .34.[14] Thus, just as with results using broader-based price indices such as the CPI, real rates for farm products are found to be negatively correlated with expected inflation.

Figure 1 displays the estimates of the real interest rate for farm products derived from the above regressions, along with 95% confidence intervals for these estimates.[15] We see that over the January 1953 to October 1979 period the estimated real rate is relatively constant but has a slight downward trend. The real rate has an average of 1% over the period, but has small negative values in the late 1970s. After October 1979, the behavior of the real rate changes dramatically. It jumps to near the 30% level in the 1980-81 period, with even the lower bound of the 95% confidence interval above ten percent, and it remains high afterwards. The real rate estimates for the agricultural sector in Figure 1 suggest one factor that has led to the difficulties of the agricultural sector in the 1980s is that farmers faced a real cost of borrowing in terms of their production of almost 30% in 1980-81 and an average of 10% for the entire November 1979 to December 1986 period.

Figure 1

Estimated Real Interest Rate for Farm Products



Real rates of this magnitude certainly have made life for the American farmer a difficult one in recent years.

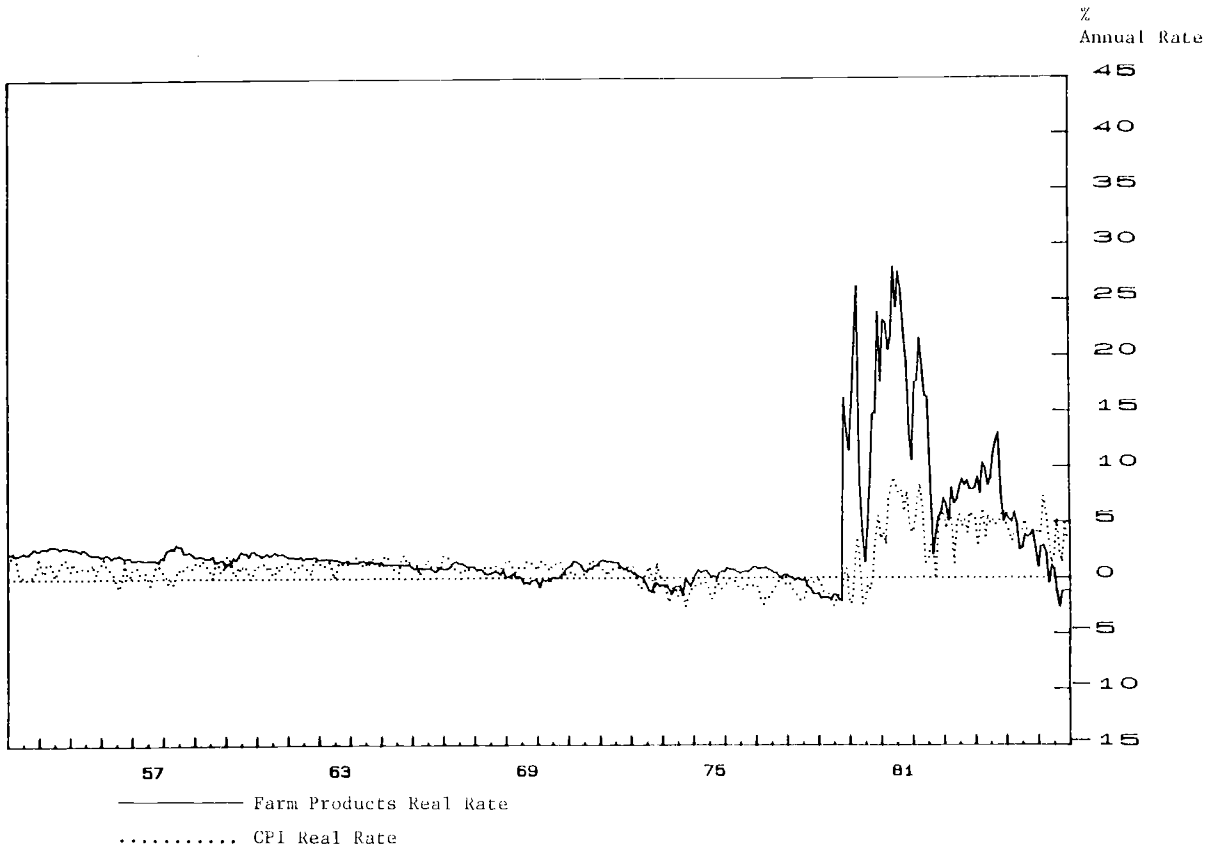
A natural question to ask is: has the striking behavior of real interest rates for the agricultural sector been similar to that of real interest rates for the aggregate economy. This question is answered in Figure 2 which compares estimated ex ante real rates for farm products with estimated ex ante real rates using the CPI price index.[16] As we can see in Figure 2, the general pattern of real rate movements is the same for the aggregate economy and for the agricultural sector. The aggregate real rate also has small positive values in the 1950s and 60s, has small negative values in the late 1970s, then also jumps dramatically to levels above 8% in the 1980-81 period and remains high thereafter. Indeed the real rate for the agricultural sector looks like an amplified movement of the real rate for the aggregate economy. This is confirmed by regressing the estimated real rate for farm products on the CPI estimated real rate. The estimated coefficient on the CPI real rate is 1.52 with a standard error of.70,[17] so that there is a statistically significant comovement of these two series ($t = 2.16$) in which the farm products real rate moves more than one-for-one with the CPI real rate.

V. Conclusion

The evidence presented in this paper indicates that real interest rates for the agricultural economy have been extremely high in the 1980s and that their behavior seems to be linked to that found for real rates in the aggregate economy. What has been the source of these high real

Figure 2

Comparison of Farm Products
Real Rate and CPI Real Rate



rates? The answer seems to be that it was the result of a concerted effort by the monetary authorities to disinflate the economy. However, the brunt of the Fed's disinflationary policy has fallen more heavily on the farm sector which has had to face far higher real rates than the rest of the economy. Although breaking the back of inflation was certainly a worthy goal for the Fed, farmers have had to pay a heavy price. They have had to suffer for the sins of an economy that was excessively inflationary, which then had to be brought back into line with disinflationary policy.

Footnotes

* Graduate School of Business, Columbia University and National Bureau of Economic Research. This research is part of the NBER's research program in Economic Fluctuations and Financial Markets and Monetary Economics. The usual disclaimer applies. The data in the figures in this paper as well as the other data used in the analysis will be made available free of charge to any researcher who will send me a standard formatted 360 KB diskette with a self-addressed mailer.

1. See Mishkin (1981b).

2. On the other hand, an own-commodity real interest rate measured with futures market data may provide valuable information on the real cost of borrowing to a producer of that commodity. For a hog farmer, a high own-commodity real rate in terms of hogs indicates a high cost of financing hog storage or production.

3. If the data are overlapping, say the observation interval is one period and the holding period and time to maturity of the bond is j periods, then ε_t will be serially correlated and will have a MA(j-1) time series process. This occurs because ε_{t-1} to ε_{t-j+1} can be correlated with ε_t since they will not be realized at time t and thus will not be in the information set ϕ_t. In the overlapping data case the diagnostic check examines whether ε_t is uncorrelated with ε's lagged j periods or more.

4. Although the diagnostic check described here is valuable, it is not powerful against certain alternatives. If u_t is not serially correlated or correlated with past ε_t, then the regression residual,

$u_t - \varepsilon_t$, will not be serially correlated even if the variance of u_t is large.

5. Although OLS produces consistent estimates of β in the overlapping data case of footnote 3 in which ε_t is serially correlated, the OLS standard errors of the coefficients will be incorrect. The standard errors can be corrected, however, using the techniques outlined by Hansen and Hodrick and Cumby, Huizinga and Obstfeld [see references in Huizinga and Mishkin (1986)].
6. For example, see Blanchard and Summers and Evans.
7. The 1920 regime shift is also associated with a weakening of the Fisher effect, just as occurred after October 1979.
8. Although the federal government ran substantial budget deficits in the years 1917-1919 as a result of World War I, there were budget surpluses in every year from 1920 to 1929.
9. Note that financial deregulation, investment tax credits and oil price shocks were also not present in the 1920s. Thus the correspondence between the 1920s and the 1980s of real interest rate behavior also weakens the case that these were important factors affecting recent real rate behavior.
10. The list of explanatory variables examined included the one-month bill rate, two lags of the inflation rate (calculated using the farm products price index) and one lag of a supply shock variable measured as the relative price of energy in the PPI.
11. Goldfeld-Quandt tests also reveal no evidence of heteroscedasticity in the post-October 1979 sample period, but do reject homoscedasticity in the pre-October 1979 period. However, when the pre-October 1979 regression is rerun with a weighted least squares

correction for heteroscedasticity along the lines of Glesjer, the results are very similar to those reported in the text; the coefficient of the bill rate is still negative and insignificantly different from zero.

12. The one-month bill rate data was obtained from the Center for Security Prices (CRSP) at the University of Chicago. The bill rate and ex post real rate are continuously compounded percentages at an annual rate. The timing of the data is as follows: A January bill rate observation uses the end of December bill rate, while the January observation for the one-month inflation rate is calculated as the logarithmic change from the December to January values of the farm products ppi index (multiplied by 1200 to put it as percent at an annual rate). The January ex post real rate observation equals the January bill rate observation minus the January farm products inflation observation.

13. Huizinga and Mishkin (1986) reports the standard errors of these regressions on page 247. Note, however, that the Huizinga-Mishkin standard errors have to be multiplied by 1200 to be in percent at an annual rate.

14. The standard errors of the expected inflation coefficient are estimated with an instrumental variables procedure described by McCallum and Pagan [see references in Huizinga and Mishkin (1986)]. This is necessary because OLS estimates of the standard errors will be incorrect since OLS estimation involves a two-step procedure in which expected inflation is estimated first and then ex post real rates are regressed on this measure.

15. The formula for the confidence interval is derived under the reasonable assumption that the variance of inflation forecast errors are large relative to the variance of u_t. The formula is given in Mishkin (1981a).

16. The estimated rates using the CPI price index are estimated using the regression specification of Huizinga and Mishkin (1986).

17. For reasons similar to those described in footnote 14, correct standard errors of this coefficient are obtained with an instrumental variables technique. This procedure is described in Cumby and Mishkin.

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