

An Empirical Test of the Real Interest Rate in Germany, 1970-2000

by

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(Abstract)

This thesis is an empirical test of the constancy of the real rate of interest in Germany over the period of 1970 to 2000. The methodology, based on Mishkin (1981), employs Ordinary Least Squares regressions to search for correlation in movements of real rates with lagged inflation, time trends, and ten other variables that commonly appear in the literature. Overall results reject the hypothesis of the constancy of the real rate. The Fisher Effect (Fisher, 1930), that movements in nominal interest rates reflect changes in expected inflation, is found to be only moderate for Germany. The monetary policy implication is that nominal interest rates contain little information about real interest rates and therefore on the tightness of monetary policy. Overall lack of significance in the test results may (as Mishkin found) be because there is so little variation in real rate movements.

Dedication

To my brother, Patrick.

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I. Introduction

An understanding of real interest rates, and their relationship to inflation, is central to the conduct of monetary policy. Central banks employ policy instruments such as reserve requirements, open-market operations, and discount rates to affect intermediate targets such as monetary aggregates and short-term interest rates in order to achieve ultimate goals such as price stability and economic growth. To effectively utilize the policy instruments available to them, central banks must understand the monetary transmission mechanism. This means understanding the movement of real interest rates.

The German economy is the largest in Europe. (References to Germany prior to November 1990 refer to West Germany only; references to Germany after that date refer to the reunited West Germany and East Germany.) The German currency, the Deutschemark, entered a floating exchange rate regime in 1971, with the unraveling of the post-World War II Bretton Woods agreement and the end of the gold reserve standard. The Deutschemark was the anchor currency of the European Monetary System, which operated from 1979 to 1993. In January 1999, as a result of the Maastricht Treaty of 1992, Germany and ten other European Union members entered into monetary union and began using a single currency, the euro.

From 1975 through 1998, the German central bank, the Bundesbank, set annual targets for both inflation and money supply growth for the Deutschemark. The Bundesbank officially emphasized a monetary aggregate as its primary monetary target, but has acknowledged using inflation targets as well as other information in the conduct of monetary policy. (Abel and Bernanke, p 632; Bernanke and Mihov, pp 1026-1027) In order to successfully target inflation, the central bank must be able to measure and respond to movements in the real interest rate.

This paper is an empirical test of the constancy of the real interest rate in Germany over the period 1970 to 2000. The methodology employed is based on “The Real Interest Rate: An Empirical Investigation,” by Frederic S. Mishkin, in *Carnegie-Rochester Conference on Public Policy* (Autumn 1981), Volume 15, pages 151-200, which applied to the U.S. experience. The paper addresses several important questions raised by Mishkin (Mishkin, 1981, pp 151-152):

- (1) Are German real interest rate movements correlated with expected inflation?
- (2) Are German real interest rates correlated with cyclical movements in real variables?

(3) How valid is the Fischer Effect (Fisher, 1930), which posits that movements in nominal interest rates reflect changes in expected inflation, in the case of Germany? These questions are important since, if nominal interest rates contain little or no information on real interest rates, and therefore on the tightness of monetary policy, they will not be useful as central bank monetary policy targets. (Mishkin, 1981, p 193)

II. Background

A. Targeting

In the conduct of monetary policy, the ultimate monetary policy targets are variables such as inflation, unemployment, or real output. The interest rate, or the rate of growth of money, debt, or credit, are intermediate targets. The discount rate, open market operations, and reserve requirements are policy instruments. (Dornbusch and Fischer, p 419)

Intermediate targets give the central bank something specific to aim for, and help the private sector know what to expect and to better predict future output and prices. (Dornbusch and Fischer, pp 420-421) Targets allow the central bank to be held accountable for its actions by encouraging dialogue as to suitability of the targets, and judgment as to the success in achieving them. (Dornbusch and Fischer, p 421) The ideal intermediate target is a variable that the central bank can control precisely and that has a precise relationship to the ultimate policy target. (Dornbusch and Fischer, pp 421-422) In practice, the central bank has to make a trade-off between those intermediate targets it can control exactly and those that are most closely related to the ultimate targets. (Dornbusch and Fischer, p 422)

Thus, good intermediate targets are those that are (1) quickly measurable, (2) controllable, and (3) predictably linked to one or more monetary policy goals. Central banks have used either interest rates or monetary aggregates as intermediate targets. (Hubbard, p 530) Both interest rates and monetary aggregates are quickly observable and measurable; interest rates can be tracked continuously, monetary aggregates with a lag of up to two weeks. (Hubbard, p 533) The central bank can choose money supply growth or interest rates as intermediate targets, but not both. (Hubbard, p 531)

Instantaneous measurement of interest rates does not necessarily make them better intermediate targets than monetary aggregates. This is because what is being measured is the nominal interest rate. Assessing the real interest is more problematic, given the difficulty of

measuring the other component of the nominal interest rate, inflation expectations. (Hubbard, pp 532-534) The argument in favor of interest rates as intermediate targets is based on the fact that they influence savings, investment, and portfolio allocation decisions. The problems with this approach are two-fold:

(1) The central bank's influence over real interest rates is weaker than its influence over nominal rates; and

(2) A central bank's policy to stabilize interest rates may be inconsistent with the goal of maintaining economic growth. (Hubbard, 1994, p 534)

In general, if the real economy (i.e., saving and investment decisions by consumers and firms) is stable, interest rate targets offer the central bank a more predictable means of stabilizing economic fluctuations, notwithstanding that the central bank cannot completely control interest rates. (Hubbard, p 535)

After selecting an intermediate target, the central bank must select a policy instrument that will best influence it. As for the intermediate target, the criteria for selecting a policy instrument are measurability, controllability, and predictability. Additionally, the policy instrument must be consistent with the intermediate target. If the central bank selects a market interest rate as the intermediate target, for example, it will select an interest rate (such as the Bundesbank's "call rate") as its policy instrument. (Hubbard, pp 535-536)

B. Bundesbank Monetary Policy

Germany is characterized as a "hybrid" inflation targeter, despite its claim to be a monetary targeter. (Bernanke and Mishkin, p 103; Bernanke, Laubach, Mishkin, and Posen, pp 41-42) Some economists believe that German central bank behavior in fact has more in common with inflation targeting than with monetary targeting. (Mishkin and Posen, p 21)

Others have concluded that, despite public focus on monetary targeting, German monetary policy in practice involves the management of short-term interest rates, as in the U.S. They find that the Bundesbank has aggressively adjusted interest rates to achieve and maintain low inflation, a goal that is paramount. However, the performance of the real economy also influences Bundesbank decisions. (Clarida and Gertler, pp 403-405)

Still others have found that there is evidence that the Bundesbank pays attention to ultimate objectives other than inflation. (Bernanke and Mihov, pp 1048-1049) But they

conclude that the Bundesbank is better characterized as an inflation targeter than a monetary targeter. (Bernanke and Mihov, p 1051).

III. Literature Review

There is a substantial literature concerning German real interest rates. The following are relevant for this paper:

(1) Mishkin (1984a) explores real interest rate movements in seven developed countries, including Germany, from 1964 to 1979. He finds that the constancy of real interest rates is strongly rejected and that real rates and expected inflation are negatively correlated for all seven countries. (Mishkin, 1984a, p 307) Moreover, in Germany, the Fisher Effect is found to be weak and movements in nominal interest rates appear to reflect one-for-one movements in real rates. (Mishkin, 1984a, pp 307-308)

(2) Mishkin (1984b) finds that the hypothesis of real interest rate equality across countries, including Germany, is strongly rejected. (Mishkin, 1984b, p 1345)

(3) Mishkin and Cumby (1986) find that ex ante real rates climbed sharply from the 1970s to the 1980s in both Europe (including Germany) and the United States, and that real rate movements in Europe and the United States are positively correlated (although not one-for-one). (Mishkin and Cumby, p 5)

(4) Mishkin (1991) finds, in the case of Germany, that the shorter-maturity nominal interest rate term structure contains some information about future inflation and even more information about the term structure of real interest rates. (Mishkin, 1991, p 2)

(5) Mishkin and Jorion (1991) find, in the case of Germany, that the long-term nominal interest rate term structure has significant ability to forecast changes in inflation, especially at longer maturities. (Mishkin and Jorion, p 59)

IV. Methodology

The methodology employed in this thesis is derived from Mishkin (1981). As Mishkin notes, the relationship of nominal interest rates, real interest rates, and inflation is stated by the Fisher (1930) equation:

$$i_t = rr_t + \pi_t^e \quad (1),$$

where \dot{i}_t = the nominal rate of interest earned on a one-year bond maturing at time t (i.e., the nominal return from holding the one-period bond from t-1 to t);

π_t^e = the rate of inflation expected by the bond market at t-1 for the period from t-1 to t;

rr_t = the real rate of interest expected by the bond market at t-1 on a one-period bond maturing at t. (Mishkin, 1981, pp 152-153)

The real interest rate rr_t is thus the difference between the nominal interest rate \dot{i}_t and the expected inflation rate π_t^e . The real rate is also referred to as the ex ante rate, since it is the return expected at the beginning of the period (i.e., at t-1). The ex post real rate is the actual return from holding the bond from t-1 to t. It equals the nominal interest rate minus the actual inflation rate from t-1 to t, and may be written as follows:

$$eprr_t = \dot{i}_t - \pi_t = rr_t - (\pi_t - \pi_t^e) \quad (2),$$

where $eprr_t$ = ex post real rate for a one-period bond maturing at time t; and

π_t = the actual inflation rate for the period from t-1 to t. (The term “real rate” hereafter refers to the ex ante real rate.) (Mishkin, 1981, pp 152-153)

The underlying assumption of Mishkin’s analysis is rational expectations of inflation in the bond market. This implies the following condition:

$$E(\pi_t - \pi_t^e | \theta_{t-1}) = 0 \quad (3),$$

where θ_{t-1} = information available at time t-1.

This says that the forecast error of inflation must be uncorrelated with past available information. (Mishkin, 1981, p 154)

If the real rate rr determined at $t-1$ is correlated with a row-vector of variables X_{t-1} that are included in the available information set Θ_{t-1} , then

$$rr_t = X_{t-1}(\beta) + u_t \quad (4),$$

where β is a column-vector of coefficients. The error term u_t , with $E(u_t) = 0$

and $\text{COV}(u_t, u_{t-1}) = 0$, is also determined at $t-1$. Substituting (4) into (2) and rewriting the

inflation forecast term $\pi_t - \pi_t^e$ as ε_t , we can write

$$eprr_t = X_{t-1}(\beta) + u_t - \varepsilon_t \quad (5).$$

Since data on $eprr_t$ are, in contrast to data on rr_t , observable, equation (5) can be estimated.

(Mishkin, 1981, p 154)

V. Procedure

A. Introduction

The following procedure was employed in the empirical analysis of the null hypothesis of the constancy of the real rate of interest in Germany over the period 1970-2000. The approach follows that in Mishkin (1981). All data is monthly data provided by the Office of the Comptroller of the Currency, United States Department of the Treasury. Analysis was performed on EViews 3.1 Student Version econometrics software.

Testing began with the running of an autocorrelation correlogram to see the serial correlation structure of the ex post real rate (EPRR). For purposes of this paper, the EPRR is the actual annual return from a German interbank currency deposit, maturing at time t , from $t-1$ to t . The deposit rate used is the Frankfurt Interbank Offered Rate (FIBOR). Testing was then performed using Ordinary Least Squares (OLS) regression estimation on a series of 23 equations. Equation numbering (equations are listed below) is based roughly on the numbering

in Mishkin (1981). The dependent variable in all cases is EPRR.

Equations 2.1 through 2.3 test the constancy of the EPRR. Equation 2.1 uses inflation lagged one period as a regressor. Equation 2.2 uses a time trend raised to powers of one, two, three, six, nine, and twelve as regressors. Finally, Equation 2.3 uses both lagged inflation and the time trend variables as regressors. Equations 2.1 and 2.3 are then used in performing Chow Breakpoint Tests (Chow, 1960) for the stability of the established relationship over different historical periods.

Equations 3.1 through 3.20 test the correlation of EPRR with ten other explanatory economic variables, first using only lagged values of the variable itself (odd-numbered equations), then using both inflation lagged one period as well as lagged values of the variable (even-numbered equations). The lag structure for all exogenous regressors in Equations 3.1 through 3.20 (except inflation) was also one, two, three, six, nine, and twelve months.

Briefly, testing proceeded by first estimating an original equation, then checking for autocorrelation and heteroskedasticity, re-estimating the equations with corrections, and finally checking again for autocorrelation and heteroskedasticity. A discussion of the variables and equations follows.

B. Variables

Variables used in the analysis (and, in some cases, generated for purposes of this analysis) are as follows:

(1) INFLATION = rate of inflation = German Consumer Price Index (CPI), seasonally adjusted, base year 1995=100, for January 1970 through January 2000 (i.e., 1970:01-2000:01), divided by German CPI for the previous period (i.e., $CPI(-1) = CPI/CPI(-1)$), then logged;

(2) EPRR = ex post real rate of interest = log of the Frankfurt Interbank Offered Rate (FIBOR), in percentage terms, for January 1970 through January 2000, minus INFLATION.

The FIBOR is the rate at which major banks offer to make currency deposits for a given maturity with other major banks in Frankfurt. (Ferris and Jones, 1994, p 161);

(3) TIME = time trend running from 0.00 in January 1960 through 4.83 in April 2000;

(4) TIME2 = time trend raised to the second power;

(5) TIME3 = time trend raised to the third power;

(6) TIME6 = time trend raised to the sixth power;

- (7) TIME9 = time trend raised to the ninth power;
- (8) TIME12 = time trend raised to the twelfth power;
- (9) M3 = log of the German broad monetary aggregate M3, seasonally adjusted, in billions of Deutschemark (DM), for January 1970 through December 1998. M3 is the sum of currency in circulation, sight deposits, time deposits with maturities less than four years, and savings deposits with less than three months' withdrawal notice (Mishkin and Posen, p 23);
- (10) INDUSTRIAL PRODUCTION = log of German industrial production, seasonally adjusted, base year 1995=100, for January 1970 through December 1999;
- (11) GOVERNMENT REVENUES = log of German federal government revenues, seasonally adjusted, in billions of DM, for January 1970 through December 1999;
- (12) GOVERNMENT EXPENDITURES = log of German federal government expenditures, seasonally adjusted, in billions of DM, for January 1970 through December 1999;
- (13) SURPLUS/DEFICIT = German federal government surplus or deficit, seasonally adjusted, in billions of DM, for January 1970 through December 1999;
- (14) UNEMPLOYMENT = German unemployment rate, in percent of labor force, seasonally adjusted, for January 1970 through November 1999;
- (15) STOCK MARKET = Frankfurt Stock Exchange (DAX) Share Performance Index, seasonally adjusted, base 31 December 1987=100, for January 1971 through January 2000;
- (16) LEADING INDICATORS = FERI index of leading German economic indicators, seasonally adjusted, in percentage terms, for January 1971 through December 1999;
- (17) EXCHANGE RATE = real dollar/DM exchange rate, seasonally adjusted, base December 1995=100, average, for January 1970 through December 1999;
- (18) TRADE BALANCE = German trade balance, seasonally adjusted, in billions of DM, for January 1970 through December 1999.

All variables that represent growth rates are expressed as the change in the monthly log (i.e., logged first differences). The data in variables UNEMPLOYMENT, EXCHANGE RATE, and STOCK MARKET were converted to seasonally adjusted from non-seasonally adjusted data to conform to the seven other explanatory variables.

Stationarity

Since standard statistical inference procedures do not apply to regressions that contain

nonstationary variables, unit root testing was performed on all final data series before using them for regression estimation. (EViews User's Guide, p 298) The Augmented Dickey-Fuller (ADF) Test (Dickey and Fuller, 1979) was used for this purpose since, in addition to testing for a unit root, it also controls for higher-order serial correlation in a series. (EViews, User's Guide, p 299) Among the final data series for which the ADF Test was performed were several final variables that were first-differenced for stationarity at the time they were formed: INFLATION, EPRR, M3, INDUSTRIAL PRODUCTION, GOVERNMENT REVENUES, and GOVERNMENT EXPENDITURES.

For all data series, twelve lagged first-differenced terms were included in the ADF Test specification. A constant and a linear time trend were also included in all test specifications, on the presumption that all data series contained an underlying trend. (EViews User's Guide, p 300) Where the ADF Test null hypothesis of the existence of a unit root (i.e., nonstationarity of the data series) could not be rejected, first-differencing of the data was applied to address the drift in mean and autocovariances (EViews User's Guide, p 297), and the ADF Test was again performed. If the null hypothesis still could not be rejected, second-differencing was applied, and so on, until stationarity was implied. (EViews User's Guide, p 301) ADF Test results for the following final variables implied first-differencing was necessary to reach stationarity: INFLATION, STOCK MARKET, LEADING INDICATORS, EXCHANGE RATE, and TRADE BALANCE. Accordingly, they were first-differenced before using them for regression estimation. First-differencing of INFLATION also affected EPRR, the dependent variable, since INFLATION was used in its formation. (For comparison purposes, all equations were run without first-differencing the above five variables, with modest differences in results for equations having the variables in question: the third and twelfth lags of both LEADING INDICATOR formulations, the sixth lag of both EXCHANGE RATE formulations, and the third lag of both TRADE BALANCE formulations all went from significant (without first differencing) to not significant (with first differencing).)

C. Equations

All 23 equations tested were of the same estimable form:

$$eprrr_t = X_{t-1}(\beta) + u_t - \varepsilon_t \quad (5).$$

Estimation for all equations was by OLS. The dependent variable for all equations was EPRR, and all equations included a constant term C. Equations were as follows (equation numbering is based roughly on the numbering in Mishkin (1981)):

Equation 2.1: $EPRR = C + INFLATION(-1)$;

Equation 2.2: $EPRR = C + TIME + TIME^2 + TIME^3 + TIME^6 + TIME^9 + TIME^{12}$;

Equation 2.3: $EPRR = C + INFLATION(-1) + TIME + TIME^2 + TIME^3 + TIME^6 + TIME^9 + TIME^{12}$;

Equation 3.1: $EPRR = C + M3(-1) + M3(-2) + M3(-3) + M3(-6) + M3(-9) + M3(-12)$;

Equation 3.2: $EPRR = C + INFLATION(-1) + M3(-1) + M3(-2) + M3(-3) + M3(-6) + M3(-9) + M3(-12)$;

Equation 3.3: $EPRR = C + INDUSTRIAL PRODUCTION(-1) + INDUSTRIAL PRODUCTION(-2) + INDUSTRIAL PRODUCTION(-3) + INDUSTRIAL PRODUCTION(-6) + INDUSTRIAL PRODUCTION(-9) + INDUSTRIAL PRODUCTION(-12)$;

Equation 3.4: $EPRR = C + INFLATION(-1) + INDUSTRIAL PRODUCTION(-1) + INDUSTRIAL PRODUCTION(-2) + INDUSTRIAL PRODUCTION(-3) + INDUSTRIAL PRODUCTION(-6) + INDUSTRIAL PRODUCTION(-9) + INDUSTRIAL PRODUCTION(-12)$;

Equation 3.5: $EPRR = C + GOVERNMENT REVENUES(-1) + GOVERNMENT REVENUES(-2) + GOVERNMENT REVENUES(-3) + GOVERNMENT REVENUES(-6) + GOVERNMENT REVENUES(-9) + GOVERNMENT REVENUES(-12)$;

Equation 3.6: $EPRR = C + INFLATION(-1) + GOVERNMENT REVENUES(-1) + GOVERNMENT REVENUES(-2) + GOVERNMENT REVENUES(-3) + GOVERNMENT REVENUES(-6) + GOVERNMENT REVENUES(-9) + GOVERNMENT REVENUES(-12)$;

Equation 3.7: $EPRR = C + GOVERNMENT EXPENDITURES(-1) + GOVERNMENT$

EXPENDITURES(-2) + GOVERNMENT EXPENDITURES(-3) + GOVERNMENT EXPENDITURES(-6) + GOVERNMENT EXPENDITURES(-9) + GOVERNMENT EXPENDITURES(-12);

Equation 3.8: $EPRR = C + INFLATION(-1) + GOVERNMENT EXPENDITURES(-1) + GOVERNMENT EXPENDITURES(-2) + GOVERNMENT EXPENDITURES(-3) + GOVERNMENT EXPENDITURES(-6) + GOVERNMENT EXPENDITURES(-9) + GOVERNMENT EXPENDITURES(-12);$

Equation 3.9: $EPRR = C + SURPLUS/DEFICIT(-1) + SURPLUS/DEFICIT(-2) + SURPLUS/DEFICIT(-3) + SURPLUS/DEFICIT(-6) + SURPLUS/DEFICIT(-9) + SURPLUS/DEFICIT(-12);$

Equation 3.10: $EPRR = C + INFLATION(-1) + SURPLUS/DEFICIT(-1) + SURPLUS/DEFICIT(-2) + SURPLUS/DEFICIT(-3) + SURPLUS/DEFICIT(-6) + SURPLUS/DEFICIT(-9) + SURPLUS/DEFICIT(-12);$

Equation 3.11: $EPRR = C + UNEMPLOYMENT(-1) + UNEMPLOYMENT(-2) + UNEMPLOYMENT(-3) + UNEMPLOYMENT(-6) + UNEMPLOYMENT(-9) + UNEMPLOYMENT(-12);$

Equation 3.12: $EPRR = C + INFLATION(-1) + UNEMPLOYMENT(-1) + UNEMPLOYMENT(-2) + UNEMPLOYMENT(-3) + UNEMPLOYMENT(-6) + UNEMPLOYMENT(-9) + UNEMPLOYMENT(-12);$

Equation 3.13: $EPRR = C + STOCK MARKET(-1) + STOCK MARKET(-2) + STOCK MARKET(-3) + STOCK MARKET(-6) + STOCK MARKET(-9) + STOCK MARKET(-12);$

Equation 3.14: $EPRR = C + INFLATION(-1) + STOCK MARKET(-1) + STOCK MARKET(-2) + STOCK MARKET(-3) + STOCK MARKET(-6) + STOCK MARKET(-9) + STOCK MARKET(-12);$

Equation 3.15: $EPRR = C + LEADING INDICATORS(-1) + LEADING INDICATORS(-2) + LEADING INDICATORS(-3) + LEADING INDICATORS(-6) + LEADING INDICATORS(-9) + LEADING INDICATORS(-12);$

Equation 3.16: $EPRR = C + INFLATION(-1) + LEADING INDICATORS(-1) + LEADING INDICATORS(-2) + LEADING INDICATORS(-3) + LEADING INDICATORS(-6) +$

LEADING INDICATORS(-9) + LEADING INDICATORS(-12);

Equation 3.17: $EPRR = C + EXCHANGE\ RATE(-1) + EXCHANGE\ RATE(-2) + EXCHANGE\ RATE(-3) + EXCHANGE\ RATE(-6) + EXCHANGE\ RATE(-9) + EXCHANGE\ RATE(-12)$;

Equation 3.18: $EPRR = C + INFLATION(-1) + EXCHANGE\ RATE(-1) + EXCHANGE\ RATE(-2) + EXCHANGE\ RATE(-3) + EXCHANGE\ RATE(-6) + EXCHANGE\ RATE(-9) + EXCHANGE\ RATE(-12)$;

Equation 3.19: $EPRR = C + TRADE\ BALANCE(-1) + TRADE\ BALANCE(-2) + TRADE\ BALANCE(-3) + TRADE\ BALANCE(-6) + TRADE\ BALANCE(-9) + TRADE\ BALANCE(-12)$;

Equation 3.20: $EPRR = C + INFLATION(-1) + TRADE\ BALANCE(-1) + TRADE\ BALANCE(-2) + TRADE\ BALANCE(-3) + TRADE\ BALANCE(-6) + TRADE\ BALANCE(-9) + TRADE\ BALANCE(-12)$.

1. Original Equation Estimation

Procedural steps were as follows:

(a) For each equation, testing began with an OLS estimation. A Wald Test (Wald, 1943) was then run to see whether the independent variables, taken together, explained movement in the dependent variable (i.e., $H_0: B_1 = B_2 = \dots = 0$). (Although Wald Tests were run for all equations, the Wald Test results for final Equations 2.1 through 2.3 (coupled with the autocorrelation results for the data series EPRR in Table 1) were the basis for determining the constancy of the real interest rate for purposes of this paper.)

(b) A 36-lag autocorrelation of the fitted dependent variable EPRR from each equation was then run. The resulting correlogram showed the pattern of temporal dependence in the fitted equation. (EViews User's Guide, p 159) The correlogram was visually examined for lags exceeding two standard errors.

(c) In all cases, correlograms showed autocorrelation exceeding two standard errors for 20 or more lags. To reject the null hypothesis of no autocorrelation, the autocorrelations and partial autocorrelations at all lags should be nearly zero, and all Q-Statistics (Ljung and Box, 1979) should be insignificant with large probabilities. (EViews User's Guide, p 275)

The Q-Statistic with its corresponding probability is the test statistic for the null hypothesis of no autocorrelation for a specified order of lags. (EViews User's Guide, p 159) The fitted values of EPRR in all equations exhibited a pattern similar to that for the unfitted data series EPRR in Figure 1, except that most fitted-value autocorrelations turned negative after lag 27. Although the patterns and Q-Statistics with probabilities were used to determine the presence of autocorrelation, they were not used in making decisions on the specific treatment for the autocorrelation found.

(d) The Breusch-Godfrey Serial Correlation (Lagrangian Multiplier (LM)) Test (Godfrey, 1988) was run, with a lag specification of twelve, as an additional check for serial correlation.

(e) Finally, a White Heteroskedasticity Test (White, 1980) was run, without cross-terms, to check for heteroskedasticity.

2. Final Equation Estimation

Procedural steps were as follows:

(a) Based on visual examination of the correlograms, the original specification for each equation was modified to address autocorrelation. This was done by adding autoregression (AR) lags as regressors for twelve lags, although autocorrelation exceeded two standard errors for 20 lags or more in all equations.

(b) Based on the White Heteroskedasticity Test, performed without cross-terms, the original specification was also modified to address heteroskedasticity by applying the Newey-West Heteroskedasticity and Autocorrelation (HAC) Consistent Covariance Estimator (Newey and West, 1987). This corrects the standard error, and is valid in the presence of autocorrelation. (EViews User's Guide, p 252)

(c) Each equation was then re-estimated. A Wald Test was run on each final equation result. Again, the results of the Wald Test for final Equations 2.1 through 2.3 (coupled with the autocorrelation results for the data series EPRR) were the basis for determining the constancy of the real interest rate and the basis for the conclusions reached in this paper.

(d) Each final equation correlogram, showing autocorrelations and Q-Statistics with probability for 36 lags, was compared with each original equation correlogram to assess removal of autocorrelation.

(e) Breusch-Godfrey Serial Correlation LM Tests (with a lag structure of twelve), and

(f) White Heteroskedasticity Tests (without cross-terms) were run on each final equation, to allow comparison with original equation results to assess the degree to which serial correlation and heteroskedasticity were addressed by the application of AR and Newey-West HAC Estimator treatment, respectively.

Appendix 1 contains an explanation of specification and diagnostic tests referred to above. Appendix 2 contains the step-by-step modifications made to the original equations and results achieved in the final equations.

VI. Results

A. Introduction

The null hypothesis of the constancy of the real interest rate in Germany over the period 1970-2000 was tested following Mishkin (1981), using two types of tests:

- (1) the first looked at the serial correlation structure of the EPRR data series, and
- (2) the second performed a series of regression estimations on variables that appear in the literature as having a possible relationship to the EPRR. These are the “weak form” and “strong form” tests, respectively, discussed in the efficient markets literature. (Mishkin, 1981, p 160) Additionally, for the regression estimations, the null hypothesis was tested (a) before any treatment for serial correlation or heteroskedasticity (i.e., on original equations), and (b) after treatment (i.e., on final equations), for comparison purposes, although the final equation results are used as the basis for the conclusions in this paper.

Results from both test types, including those for both the original and final equations from the second test type, are summarized in Tables 1-5 (which follow the format of Tables 1-3 in Mishkin (1981)), and Figures 1-6 (which follow the format of Figures 1-3 in Mishkin (1981)). Concerning the diagnostic tests and treatment for serial correlation and heteroskedasticity, the following are notable:

- (1) All final equations showed autocorrelations of two standard errors or less for almost all lags (for all equations, lags 12, 24, and 36 remained in excess of two standard errors), but Ljung-Box Q-Statistics indicated the continuing presence of autocorrelation; and
- (2) For final equations, the Breusch-Godfrey Test and the White Test frequently indicated the continued presence of serial correlation and heteroskedasticity, or both, despite AR and Newey-West HAC Estimator treatment applied after the original equations were run.

Chow Breakpoint Tests (Chow, 1960) were also performed on Equations 2.1 and 2.3, both original and final, at three dates having historical significance for German monetary policy, as a check on robustness of estimation results:

(1) 1973:03: The breakdown of the Bretton Woods gold/fixed exchange rate regime (Krugman and Obstfeld, p 550);

(2) 1990:07: The monetary union of East Germany and West Germany (Krugman and Obstfeld, p 585); and

(3) 1999:01: The monetary union of eleven European Union participants (i.e., fixing of the euro against national currencies in preparation for introduction of euro currency in January 2002).

B. Tables

Table 1 shows the autocorrelation pattern of the data series EPRR, the dependent variable for all regression equations in this paper. Tables 2 and 4 show the regression results before and autocorrelation and heteroskedasticity treatment, respectively, for Equations 2.1 through 2.3. Tables 3 and 5 show the regression results before and after treatment, respectively, for Equations 3.1 through 3.20.

Discussion of the results, table by table, is as follows:

Table 1: Correlogram showing serial correlation structure of the Ex Post Real Rate (EPRR), Germany, 1970-2000 (after Mishkin (1981))

Table 1 shows the first 36 autocorrelations of the dependent variable EPRR. Autocorrelations at all lags should be nearly zero if there is no serial correlation, and all Q-Statistics (Ljung-Box, 1979) should be insignificant with large probabilities. Here, all are positive, and most exceed two standard errors. The null hypothesis that all autocorrelations equal zero, and by implication that the EPRR is constant, is strongly rejected.

Table 2: Tests of the Constancy of the Ex Post Real Rate (EPRR), Original Equations, Germany, 1970-2000 (after Mishkin (1981))

Table 2 summarizes the results from Equations 2.1, 2.2, and 2.3 in their original form (i.e., before AR treatment for autocorrelation or Newey-West HAC Estimator treatment for heteroskedasticity, or both). INFLATION is negative but not significant in either equation in which it appears (Equations 2.1 and 2.3). The time trend variable TIME alternates sign, based

on the power to which it is raised, in both equations in which it appears (Equations 2.2 and 2.3), and has highly significant t-statistics at every power. Equation 2.1 has Adjusted R^2 of 0.96 and standard error of 0.079, while Equation 2.2 and 2.3 have Adjusted R^2 of 0.33 and standard error of 0.33.

The Wald Test null hypothesis that all coefficients jointly equal zero cannot be rejected for Equations 2.1, but is decisively rejected for Equations 2.2 and 2.3, both by the F-Statistic and the χ^2 Statistic (applicable for nonlinear equations such as Equations 2.2 and 2.3). The Breusch-Godfrey Test run after each equation shows zero probability of rejecting the null hypothesis of no serial correlation for any of the three equations. The White Test run after each equation shows only Equation 2.1 as having any probability (0.46) of rejecting the hypothesis of no heteroskedasticity.

Table 3: Tests for Correlation of the Ex Post Real Rate (EPRR) with Other Variables, Original Equations, Germany, 1970-2000 (after Mishkin (1981))

Table 3 summarizes results from Equations 3.1 through 3.20, in their original form. INFLATION is negative in seven of the the ten equations in which it is included (the even-numbered equations), but is not significant in any of the ten. INDUSTRIAL PRODUCTION is negative and significant for the first two lags, both in the specification that does not include INFLATION (Equation 3.3) and the one that does (Equation 3.4). Additionally, SURPLUS/DEFICIT is positive and significant in the first and ninth lags, for both specifications; UNEMPLOYMENT is negative and significant in the twelfth lag of both specifications; STOCK MARKET is negative and significant in the first, third, sixth, and ninth lags of both specifications; and LEADING INDICATORS is negative and significant in the first and second lags of both specifications.

The Wald Test null hypothesis that all coefficients jointly equal zero is rejected for only eight of the 20 equations. The equations are both formulations (i.e., without and with INFLATION) of SURPLUS/DEFICIT, UNEMPLOYMENT, STOCK MARKET, and LEADING INDICATORS. The Breusch-Godfrey Test run after each equation shows zero probability of rejecting the null hypothesis of no serial correlation, for any equation. The White Test run after each equation shows probabilities of rejecting the null hypothesis of no heteroskedasticity ranging from 0.17 to 0.99 for twelve of the 20 equations; the rest showed zero

probability.

Table 4: Tests of the Constancy of the Ex Post Real Rate (EPRR), Final Equations, Germany, 1970-2000 (after Mishkin (1981))

Table 4 is the “after” counterpart to Table 2's “before.” As such, it summarizes the results from Equations 2.1- 2.3 in their final form (i.e., after AR treatment for autocorrelation or Newey-West HAC Estimator treatment for heteroskedasticity, or both). INFLATION is positive but not significant in both equations in which it appears (Equations 2.1 and 2.3). The time trend variable TIME alternates sign in both equations in which it appears (Equations 2.2 and 2.3), but is nowhere significant. Adjusted R^2 is 0.96 and standard error is 0.079 for all equations.

The Wald Test null hypothesis that all coefficients are jointly equal to zero cannot be rejected for Equation 2.1, but is strongly rejected for Equations 2.2 and 2.3. The Breusch-Godfrey Test run after each equation shows zero probability of rejecting the null hypothesis of no serial correlation for any of the equations. The White Test run after each equation shows only Equation 2.1 as having any probability (0.36) of rejecting the hypothesis of no heteroskedasticity, and application of the Newey-West HAC Estimator has reduced the probability of no heteroskedasticity only slightly for this equation.

Table 5: Tests for Correlation of the Ex Post Real Rate (EPRR) with Other Variables, Final Equations, Germany, 1970-2000 (after Mishkin (1981))

Table 5 is the “after” counterpart to Table 3's “before.” As such, it summarizes the results from Equations 3.1-3.20 in their final form. INFLATION is positive in all ten equations in which it appears, but is not significant in any of them. INDUSTRIAL PRODUCTION is negative and significant in the third lag in both the specification that does not include INFLATION (Equation 3.3) and the one that does (Equation 3.4). No other variables are significant in any formulation, at any lag.

The Wald Test null hypothesis that all coefficients jointly equal zero can only be rejected (at the 4% and 5% significance levels, respectively) for the two formulations (without INFLATION and with INFLATION) of EXCHANGE RATE. The Breusch-Godfrey Test run after each equation shows probabilities of rejecting the null hypothesis of no serial correlation ranging from zero for four equations to less than 0.00015 for the remaining sixteen. The White Test run after each equation shows probabilities of rejecting the null hypothesis of no

heteroskedasticity ranging from zero (for two equations) to 0.91.

C. Chow Breakpoint Tests

Breakpoint testing was performed on Equations 2.1 and 2.3, both the original and the final versions, as a measure of the robustness of the OLS results obtained in Tables 2 and 4.

Breakpoints were selected that corresponded to historical events that might reasonably be expected to affect the stability of the EPRR in Germany over the period 1970-2000:

- (1) 1973:03: Breakdown of the Bretton Woods gold/fixed exchange rate regime put in place by the major world economic powers immediately after World War II;
- (2) 1990:07: Monetary union of East Germany and West Germany, in preparation for political reunification in November 1990; and
- (3) 1999:01: Monetary union of eleven of the fifteen European Union member countries. This represents the date that national currencies' exchange rate was fixed against the new single currency unit, the euro, in preparation for the substitution of the euro for national currencies in January 2002.

The 1999:01 test attempt for the original Equation 2.3 and the 1973:03 test attempt for the final Equation 2.3 both resulted in a near-singular matrix and were not computed. The 1999:01 test attempts for the final Equations 2.1 and 2.3 both had an insufficient number of observations and were not computed.

Results for seven of the eight Chow Breakpoint tests completed allowed the null hypothesis of no structural change in the equation parameters before and after the breakpoint to be rejected at the 10% significance level or higher. Only the test results for 1990:07 in the final version of Equation 2.3 could not be rejected.

D. Figures

As noted by Mishkin (1981), Figures 1-6 offer an alternative approach to understanding the results presented in Tables 1-5. Again, "original" equations are those run before any serial correlation or heteroskedasticity treatment; "final" equations are those run after serial correlation and heteroskedasticity treatment, or both. Discussion of the results, figure by figure, is as follows:

Figure 1: Estimated Real Interest Rate with 95% Confidence Interval, Original Equations, Germany, 1970-2000 (after Mishkin (1981))

Figure 1 plots the forecast of the fitted values of the EPRR from Equation 2.3 (i.e., the real rate estimated with INFLATION and the TIME powers as regressors) over the period 1970-2000, along with upper and lower bounds consisting of plots two standard errors above and below the fitted EPRR. Unlike Mishkin (1981), where Equation 2.3 was chosen because it had the best fit among Equations 2.1-2.3, Equation 2.3 was chosen here because it has the most robust set of regressors among Equations 2.1-2.3, which have virtually the same fit. Figure 1 shows that the real interest rate declined sharply over 1970-74, remained relatively stable until around 1987, rose slowly until around 1992, declined steeply until 1999, and rose sharply at the end of the period. The real rate remains in positive territory throughout the period.

Figure 2: Comparison of Estimated Real Interest Rates Calculated from Equation Including Only Inflation (Equation 2.1 Fitted) and from Equation Including Both Inflation and Time (Equation 2.3 Fitted), Original Equations, Germany, 1970-2000 (after Mishkin (1981))

Figure 2 plots the forecast of the fitted values of the EPRR from the original Equation 2.1 (i.e., the real rate estimated with INFLATION only as a regressor) for 1970-2000, along with the forecast of fitted values from the original Equation 2.3 in Figure 1. Due to optimized linear scaling, Equation 2.1 appears to be virtually a straight line. Normalized data scaling better demonstrates actual data movements but, because it is centered on zero, also makes the real rate appear to be negative over a certain range.

The EPRR regression results for Equations 2.2 and 2.3 in Table 2 show that all of the time trend variables contain significant explanatory power, suggesting that there are economic variables left out that explain real rate movements and are correlated with the time trend variables. (Mishkin, 1981, p 170) Comparing real rates from the model with INFLATION only (although INFLATION is not significant) to the model with both INFLATION and a time trend shows that the time trend (or left out) variables make the estimated real rate lower than it otherwise would have been over the periods 1970-74 and 1975-84, slightly higher than it would have been over the periods 1985-87, lower again during 1987-95, and higher again during 1995-2000. Economic variables missing from this analysis should affect the real rate in a similar direction. (Mishkin, 1981, p 172)

Figure 3: Nominal Interest Rate, Estimated Real Interest Rate, and Estimated Expected Inflation, Germany, 1970-2000 (after Mishkin (1981))

The EPRR estimates obtained in original Equations 2.1 and 2.3 can be used to derive an estimate of expected inflation. This is done by subtracting the estimated real rate from the nominal rate:

$$\hat{\pi}_t^e = i_t - \hat{r}_t = i_t - X_{t-1} \hat{\beta}_{EPRR} \quad (6)$$

where $\hat{\pi}_t^e$ = the estimated expected inflation at time t;

i_t = the nominal rate of interest at time t (in this paper, the FIBOR);

\hat{r}_t = the estimated real rate of interest at time t;

X_{t-1} = a row-vector of variables that are included in the available information set at t-1; and

$\hat{\beta}_{EPRR}$ = a column-vector of estimated coefficients from EPRR.

Figure 3 plots the forecast of the fitted values of EPRR from the original Equation 2.3 in Figure 1 (i.e., the estimated real interest rate), the FIBOR (i.e., the nominal interest rate), and the forecast of the estimated real rate minus the nominal rate (i.e., estimated expected inflation). Figure 3 shows a strong Fisher Effect (Fisher, 1930); namely, movements in nominal interest rates reflect changes in expected inflation. The correlation of estimated expected inflation and the nominal interest rate is 0.786631. By comparison, the correlation of estimated expected

inflation with the real rate is only $9.27E-05$, and the correlation of the real rate and the nominal rate is 0.617496.

Figure 4: Estimated Real Interest Rate with 95% Confidence Interval, Final Equations, Germany, 1970-2000 (after Mishkin (1981))

Figure 4 is the final equation counterpart to the original equation plotted in Figure 1. Figure 4 plots the forecast of the fitted values of the EPRR from the final Equation 2.3 over the period 1970-2000, along with upper and lower bounds consisting of plots two standard errors above and below the fitted EPRR. Again, Equation 2.3 was selected because it has the most robust set of regressors among Equations 2.1-2.3, and not because it has the best fit (all have virtually the same fit). Figure 4 shows that the real interest rate declined sharply over 1970-74, remained relatively stable until around 1987, rose slowly until around 1992, declined steeply until 1999, and rose sharply at the end of the period. The real rate remained in positive territory throughout the period.

Figure 5: Comparison of Estimated Real Interest Rates Calculated from Equation Including Only Inflation (Equation 2.1 Fitted) and from Equation Including Both Inflation and Time (Equation 2.3 Fitted), Final Equations, Germany, 1970-2000 (after Mishkin (1981))

Figure 5 is the final equation counterpart to the original equations plotted in Figure 2. Figure 5 plots the forecast of the fitted values of the EPRR from the final Equation 2.1 for 1970-2000, along with the forecast of the fitted values from the final Equation 2.3 in Figure 4. Again, optimized linear scaling makes Equation 2.1 appear to be virtually a straight line; normalized data scaling shows data movements better but makes the real rate appear to be negative over certain ranges. Unlike the original equations in Table 2, the EPRR regression results for Equations 2.1 and 2.3 in Table 4 show that none of the time trend variables contain significant explanatory power.

Figure 6: Nominal Interest Rate, Estimated Real Interest Rate, and Estimated Expected Inflation, Final Equations, Germany, 1970-2000 (after Mishkin (1981))

Figure 6 is the final equation counterpart to the original equations plotted in Figure 3. As in Figure 3, the EPRR estimates obtained in final Equations 2.1 and 2.3 are used, following equation (6), to derive an estimate of expected inflation. Figure 6 plots the forecast of the fitted

values of EPRR from the final Equation 2.3 in Figure 4, along with the nominal rate and estimated expected inflation. Figure 6 shows a moderate Fisher Effect (i.e., movements in nominal interest rates reflect changes in expected inflation). The correlation of estimated expected inflation and the nominal interest rate is 0.662510. By comparison, the correlation of estimated expected inflation and the real rate is -0.222087, and the correlation of the real rate and the nominal rate is 0.583212.

VII. Conclusions

This paper has conducted an empirical test of the constancy of the real interest rate in Germany over the period 1970-2000. The conclusions below are based on Table 1 and on results from the final equations summarized in Tables 4 and 5, and in Figures 4-6.

In response to the three questions framed in **I. Introduction**, the following findings are offered:

(a) The hypothesis that the real interest rate is constant is strongly rejected, based on Tables 1, 4, and 5;

(b) Movements in economic variables are, with one exception (INDUSTRIAL PRODUCTION), not significantly correlated with the real interest rate, according to Table 5. Interestingly, money supply (i.e., M3) is among the low significance variables;

(c) The Fisher Effect, that movements in nominal interest rates reflect changes in expected inflation is only a moderate one, according to Figure 6.

Other important findings are as follows:

(d) The real rate is positively correlated with inflation, but never significantly so, according to Tables 4 and 5;

(e) The real interest rate may be characterized as having undergone a steep decline near the beginning and end of the period, but was relatively stable for most of it, and has never dipped below zero, according to Figures 4-6;

(f) Movements in nominal interest rates are not a reliable reflection of movements in real rates either, according to Figure 6.

The results from the final equations have overall low significance. This may be attributable, as in Mishkin (1981), to lack of variation in real rate movement. The original equations displayed more significance, but their validity is suspect. Reduced differencing of key

variables did not appreciably alter the results.

An important policy implication of this paper, as for Mishkin (1981), is that nominal interest rates contain little information on real interest rates, and therefore on the tightness of monetary policy. To the degree that this is true, nominal rates will not be useful as central bank monetary policy targets.