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THE REAL INTEREST RATE:
A MULTI-COUNTRY EMPIRICAL STUDY

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ABSTRACT

How real interest rates behave over time is critical to our understanding of many macroeconomic issues, and much recent research has pursued this question. Very little of the research, however, has focused on real interest rates outside the United States. This paper is an empirical exploration of real interest rate movements in seven OECD countries from 1967-II to 1979-II. Further research is needed on real rates in other countries for several reasons. Not only are measures of foreign real rates of interest in their own right, but extending an analysis of real rates to other countries also has the following additional benefits: it can generate more powerful statistical tests of propositions previously tested on U.S. data and yield information on whether results found for the U.S. hold up in other countries.

This study pursues several questionsthat have arisen naturally from this earlier work. Is the hypothesis that the real rate is constant rejected when the analysis is extended to other countries? Does the real rate decline with increased inflation and money growth in other countries besides the United States? How reliable is the Fisher effect, in which nominal interest rates reflect changes in expected inflation? Are movements in nominal interest rates a reliable indicator of movements in real rates? What kind of variations in real interest rates are there in different countries? Have real rates declined from the '60s to the '70s for other countries besides the U.S.?

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I. INTRODUCTION

How real interest rates behave over time is critical to our understanding of many macroeconomic issues, and much recent research has pursued this question.[1]. Very little of the research, however, has focused on real interest rates outside the United States.[2] In contrast, this paper is an empirical exploration of real interest rate movements in seven OECD countries from 1967-II to 1979-II.

Further research is needed on real rates in other countries for several reasons. Not only are measures of foreign real rates of interest in their own right, but extending an analysis of real rates to other countries also has the following additional benefits: it can generate more powerful statistical tests of propositions previously tested on U. S. data and yield information on whether results found for the U. S. hold up in other countries.

A previous paper, Mishkin (1981a), analyzed real interest rates in the United States. This study pursues several questions that have arisen naturally from this earlier work. Is the hypothesis that the real rate is constant rejected when the analysis is extended to other countries? Does the real rate decline with increased inflation and money growth in other countries besides the United States? How reliable is the Fisher effect, in which nominal interest rates reflect changes in expected inflation? Are movements

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1 For example, Aliber (1980), Cargill (1976), Carlson (1977), Fama (1975, 1976), Fama and Gibbons (1981), Fama and Schwert (1979), Garbade and Wachtel (1978), Gibson (1972), Hess and Bicksler (1975), Hodrick (1980), Joines (1977), Lahiri (1976), Mishkin (1981a), Nelson and Schwert (1977), Pearce (1979), Roll (1979), and Schiller (1980).

2 Aliber (1980), Cumby and Obstfeld (1982), Hodrick (1980), and Roll (1979) are exceptions, but they pursue a more limited set of issues than are analyzed here and in a companion piece Mishkin (1982).

in nominal interest rates a reliable indicator of movements in real rates? What kind of variations in real interest rates are there in different countries? Have real rates declined from the '60s to the '70s for other countries besides the U. S.?

II. METHODOLOGY

Each country's real rate of interest for a one-period bond is defined from the Fisher (1930) equation[3]

$$(1) \qquad i_t \equiv rr_t + \pi_t^e$$

where i_t = the nominal interest rate earned on a one-period bond maturing at time t--i.e., it is the nominal return from holding the one-period bond from t-1 to t.

π_t^e = the rate of inflation from t-1 to t, expected at time t-1.

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3 All returns, inflation and interest rates in the empirical work are assumed to be continuously compounded so that the usual additional second order term is not necessary in the Fisher equation (1). Note that if holding period real returns are used in the empirical work here rather than continuously compounded returns, there is almost no change in the results. Note also that the definition ignores the taxation of nominal interest rates. As pointed out in Mishkin (1981a) it is extremely difficult to know what the appropriate marginal tax rate is for holders of these one period bonds. However, to the extent that the effective marginal tax rate is above zero, it will just strengthen some of the results found here, such as the negative correlation of real rates and inflation.

rr_t = the one-period real rate of interest expected for the bond maturing at time t.

Hence, the real interest rate, rr_t, is just the difference between the nominal rate of interest and the expected rate of inflation: it is the real return from holding the one-period bond from t-1 to t which is expected at time t-1. Because the real rate is a return expected at the beginning of the period, it is also frequently referred to as the ex ante real rate. The more precise terminology is used to differentiate it from the ex post real rate, namely, the actual real return from holding the one-period bond from t-1 to t. It equals the nominal interest rate minus the actual inflation rate from t-1 to t and can be written as

$$eprr_t \equiv i_t - \pi_t \equiv rr_t - (\pi_t - \pi_t^e) \tag{2}$$

where $eprr_t$ = the one-period ex post real rate for the bond maturing at time t,

π_t = the actual inflation rate from t-1 to t.

Note that for expositional convenience, the ex ante real rate is always referred to as the real rate throughout this paper, while the ex post real rate always refers to the variable defined in (2).

The underlying assumption behind the methodology used here is rationality of inflation expectations in the bond market, which yields the condition[4]

(3) $$\pi_t^e = E(\pi_t | \phi_{t-1})$$

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

Note that the rationality of inflation expectations is necessary and sufficient for the rationality of the ex ante real rate, implying that the ex ante real rate equals the expected real return on the one-period bond, conditional on available information: i.e.

(4) $$rr_t = E(eprr_t | \phi_{t-1})$$

There is a large body of evidence that supports this rationality, or equivalently the efficiency of financial markets, and tests directed more specifically at the rationality of inflation forecasts in the bond market also support the use of this assumption over long sample periods such as are used here.[5]

If the real rate determined at t-1, rr_t, is correlated with observable variables, X_{t-1}, which are elements of the available information set ϕ_{t-1}, then we can write the linear projection of rr_t into X_{t-1} as:

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4 An alternative methodology would involve using survey data to measure inflationary expectations in order to construct real rates. Mishkin (1981a) discusses why the methodology used here should be more reliable.

5 See Mishkin (1983).

(5) $$P(rr_t | X_{t-1}) = X_{t-1}\beta$$

and then

(6) $$rr_t = X_{t-1}\beta + u_t$$

where

$$u_t = rr_t - P(rr_t | X_{t-1})$$

Note that $P(u_t | X_{t-1}) = 0$ by using the law of iterated projections,[6] and so u_t is orthogonal to X_{t-1}. Furthermore, u_t is also in the information set ϕ_{t-1} because economic agents observe the ex-ante real rate even if the econometrician cannot. Equation (5) cannot be estimated because rr_t is not observable. However, substituting (6) into (2) and writing the inflation forecast error as ε_t we get:

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

where

$$\varepsilon_t = \pi_t - \pi_t^e.$$

Since data on the ex post real rate are observable, the above equation can be estimated for each country with ordinary least squares (OLS). How do

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6 See Sargent (1981) for an excellent exposition of linear projection and the law of interated projections.

the resulting estimates relate to what would have been obtained from OLS estimates of (6) if it were estimable? The rationality of inflation expectations implies that the error term ε_t has the attractive property that

(8) $$E(\varepsilon_t | \phi_{t-1}) = 0$$

so that it is uncorrelated with all past available information which includes X_{t-1} and u_t. It is then easy to demonstrate, as in Mishkin (1981b), that the resulting $\hat{\beta}$ estimates will have the desirable property that they will be consistent estimates of β. This result indicates that, although we cannot observe the ex ante real rate, rr_t, we can infer information about its relationship with variables known at time t-1 via ex post real rate regressions.

Although the procedure followed here will yield consistent estimates of the real rate projection in (5), we must be careful in interpreting the results. Nothing in the empirical work here demonstrates that the variables in X_{t-1} are exogenous and thus there is no guarantee that the estimated $\hat{\beta}$ are consistent estimates of the effects on real rates from exogenous changes in the X-variables.

An even more interesting issue for the methodology here is the situation where relevant information has been excluded from X_{t-1}. Assume that the true real rate has the following linear relationship to X_{t-1} and another relevant set of information Z_{t-1} which has been ignored by the econometrician.

(9) $$rr_t = X_{t-1}\,\beta^* + Z_{t-1}\delta$$

then

$$(10) \qquad P(rr_t | X_{t-1}) = X_{t-1}(X'X)^{-1}X'(X\beta^* + Z\delta)$$
$$= X_{t-1}[\beta^* + (X'X)^{-1}Z\delta]$$

Equation (10) above tells us that the $\hat{\beta}$ estimate from the ex-post real rate regression where Z_{t-1} is excluded will not be a consistent estimate of β^*. Indeed the larger is δ and the more correlated Z_{t-1} is with X_{t-1} the more serious this bias becomes. Hence, even if X_{t-1} were exogenous, leaving out relevant information would lead to inconsistent estimates of the effects from changes in X_{t-1}.

The remarks above indicate that, without further identifying information, it is not appropriate to make inferences on causation from the results produced here. Nonetheless they are useful. This paper is a study in the measurement of real rates. Knowing how real rates have moved with other variables and how they have moved over time is important to constructing theories of what determines real rate movements. The estimates of the projection equation yield exactly this information.

For purposes of inference on the movement of real rates and the relationship of real rates with the X-variables, we need to calculate appropriate standard errors for the $\hat{\beta}$ and the estimated real rates. An important element of the methodology in this paper is the use of non-overlapping data--i.e. where the forecast horizon is never longer than the observation interval--because rational expectations then implies that ε is serially uncorrelated. As has been emphasized in Nelson and Schwert (1977) and Mishkin (1981a,b), forecast errors of inflation are probably extremely large and much greater in magnitude than the u's. Hence, even if u were serially correlated or correlated with past ε, the amount of serial correlation in the composite error term $u - \varepsilon$, should necessarily be slight.

Evidence in Mishkin (1981b) supports this view and the results below also find that serial correlation is not a serious problem.[7]

One advantage from using data on several countries is that we can conduct joint tests for several countries at once. This can result in more powerful statistical tests of propositions such as the constancy of real rates because more data are exploited in conducting these tests. One pitfall to beware is that these joint tests cannot be conducted by estimating each country's OLS constrained and unconstrained regressions separately, adding up their sum of squares, and then carrying out the usual comparison to construct the F-

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7 For example, in the regressions used to generate the estimated real rates in Figures 2-8 the residual autocorrelations do not display any evidence of serial correlation. The Durbin-Watson statistics range from 1.74 to 2.36, none of which indicate the presence of first order serial correlations and none of the Ljung-Box (1978) Q(12) statistics reject the null hypothesis that the first twelve residual autocorrelations all equal zero: the Q(12) statistics range from 5.23 to 17.88 while the critical value at the 5% level is 21.0 In regressions with fewer explanatory variables there are a few cases where Durbin-Watson statistics sometimes fall below 1.6 but never below 1.0. However, this is an unusual occurence. Goldfeld-Quandt (1965) tests also did not indicate that the homoscedasticity assumption is strongly violated. For example in the regressions used to generate Figures 2-8 there was only one rejection of homoscedasticity in the seven CPI regressions and one in the seven WPI regressions. However, these rejection were not for the same country and there was no consistent pattern of the variance of the residuals having a similar upward or downward trend in all the countries.

test.[8] This yields incorrect test statistics because the covariance of the OLS parameter estimates in different equations is being ignored.[9]

The correct variance-covariance of the stacked OLS parameter estimates is

$$V(\hat{\beta}-\beta) = \begin{bmatrix} \sigma_1^2(X_1' X_1)^{-1} & \cdots & \sigma_{1m}(X_1'X_1)^{-1}X_1' X_m(X_m' X_m)^{-1} \\ \vdots & \ddots & \vdots \\ \sigma_{1m}(X_1' X_1)^{-1}X_1'X_m(X_m' X_m)^{-1} & \cdots & \sigma_m^2(X_m' X_m)^{-1} \end{bmatrix} \quad (11)$$

where

X_i = the $n x k_i$ (n=# of observations) matrix of explanatory variables for country i.

σ_{ij} = $\text{cov}\,(u_{it} - \varepsilon_{it}, u_{jt} - \varepsilon_{jt})$

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8 This is equivalent to generating the test statistics using a standard seemingly unrelated regression package where the variance-covariance matrix of the residuals is specified to be diagonal.

9 Since we must allow for covariance of the residuals and the parameter estimates in order to generate correct F-statistics, why are the models estimated here with OLS rather than a GLS seemingly unrelated regressions technique. Furthermore, using OLS was actually far more costly in time and effort than GLS because standard econometric packages (such as SAS or TSP) are not set up to calculate the F-statistics in (12) easily. There are two primary reasons why OLS is preferred. First, one sensible view of results from ex post real rate regressions is that they are nothing more than useful summary statistics when OLS is used. The OLS results have an easy interpretation in terms of the comprehensible concept of correlation. If the regressions are not viewed as reduced forms, however, then GLS results have no easy interpretation. Second, when GLS is used in estimation, the parameter estimates from ex post regressions no longer have the desirable property that they are equal in the expectation (or in the probability limit) to those obtained from ex ante real rate regressions. It is easy to demonstrate that they will only be equal if the variance-covariance matrix of ε is proportional to the variance-covariance matrix of u. The use of OLS rather than GLS does not appreciably affect the results in this paper. The GLS standard errors are slightly smaller and test statistics slightly higher as we might expect, while the parameter estimates are quite close to those reported in the text. The basic conclusions of the paper thus do not change. The GLS results are available from the author on request.

σ_i^2 = $\text{cov}(u_{it} - \varepsilon_{it}, u_{it} - \varepsilon_{it})$

m = the number of countries

The $F(q, mn - \sum_{i=1}^{m} k_i)$ statistic is then

$$(12) \qquad \frac{(mn - \sum_{i=1}^{m} k_i)}{q} \; \frac{(R\hat{\beta}-b)' \, [R\hat{V}(\hat{\beta} - \beta)R']^{-1}(R\hat{\beta}-b)}{(u-\hat{\varepsilon})' \; [\hat{\Sigma}^{-1} \otimes I) \; (u-\hat{\varepsilon})}$$

where there are q constraints, $R\hat{\beta} = b$, and $\hat{\Sigma}$ = the variance-covariance matrix of the stacked $u-\hat{\varepsilon}$.

Estimates of the real rate, $\hat{rr}_t$, can be obtained from the fitted values of the estimated ex post real rate regression: that is,

$$(13) \qquad \hat{rr}_t = \hat{X}_{t-1} \hat{\beta}$$

and the error is

$$(14) \qquad rr_t - \hat{rr}_t = X_{t-1}(\beta-\hat{\beta}) + u_t = X_{t-1}(X'X)^{-1}X'(\varepsilon-u) + u_t$$

whose probability limit is

$$(15) \qquad \text{plim } (rr_t - \hat{rr}_t) = u_t$$

since rational expectations implies plim $\frac{X'\varepsilon}{T} = 0$ and the defintion of u indicates plim $\frac{X'u}{T} = 0$. In the example above where the relevant information Z_{t-1} has been left out of the regression equation,

$$(16) \qquad u_t = rr_t - P(rr_t|X_{t-1}) = Z_{t-1}\delta - X_{t-1}(X'X)^{-1}Z\delta$$
$$= [Z_{t-1} - P(Z_{t-1}|X_{t-1})]\delta$$

The following points about the $\hat{rr}_t$ estimate of the real rate are now easily seen. It will be a consistent estimate of rr_t only if u_t equals zero. This will occur if no relevant information is left out of the explanatory variables in the ex post real rate regression or if the information left out is perfectly correlated with the X_{t-1} information. Therefore, the consistency of the real rate estimate does not depend on the consistency of the $\hat{\beta}$ estimate. Indeed, paradoxically, the more highly correlated is the left out information with X_{t-1}, the more inconsistent is the $\hat{\beta}$ estimate, but the more consistent is the $\hat{rr}_t$ estimate.

Even if $\hat{rr}_t$ is not a consistent estimate of the real rate because u_t is non zero, we can still use it to conduct inference about the actual real rate because we can calculate the variance of its within sample error. Mishkin (1981a) derives this to be[10]

$$(17) \qquad \text{Var}(rr_t - \hat{rr}_t) = (\sigma_\varepsilon^2 - \sigma_u^2)X_{t-1}(X'X)^{-1}X'_{t-1} + \sigma_u^2$$

Since we do not know the relative size of the variance of u and ε, the formula in (17) cannot be used directly to yield the standard errors of the estimated real rates. However, we can calculate bounds on the standard errors

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[10] This derivation requires that u as well as ε is serially uncorrelated. This can be achieved by including lags of the ex post real rate in X_{t-1}. This is not necessary in the models used to derive $\hat{rr}_t$ in Figure 2-8 because they do not display any serial correlation in the residuals (see footnote 7) and four lagged values of the ex post real rate do not add significant explanatory power to these models.

for two extreme cases. With the estimated standard error of the regression denoted by $\hat{\sigma}$, if all variation in the error term is attributed to the forecast error of inflation, then $\hat{\sigma}_u = 0$ and $\hat{\sigma} = \hat{\sigma}_\varepsilon$. The standard error of the estimated real rate is then:

$$(18) \qquad \hat{SE}_\varepsilon(rr_t - \hat{rr}_t) = \hat{\sigma}\sqrt{X_{t-1}\ (X'X)^{-1}X_{t-1}}.$$

If none of the variation in the error term is attributed to the forecast error of inflation, then $\hat{\sigma}_\varepsilon = 0$, $\hat{\sigma} = \hat{\sigma}_u$, and the standard error of the estimated real rate is

$$(19) \qquad \hat{SE}_u(rr_t - \hat{rr}_t) = \hat{\sigma}\sqrt{1 - X_{t-1}(X'X)^{-1}X_{t-1}}.$$

Because the variance of the forecast error of inflation, is likely to exceed greatly that of u, $\hat{SE}_\varepsilon$ should be a far more accurate measure of the true standard error than $\hat{SE}_u$. Thus in the discussion of the estimated real rates attention will focus on $\hat{SE}_\varepsilon$. $\hat{SE}_u$ will also be reported so that someone with a different prior can see how this might affect inference.[11]

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[11] Note that the more that one's prior is that important information has been excluded from the ex post real rate regression, the potentially larger is u and the true standard error will be assumed to be further from SE_ε. However, if σ_ε^2 is sufficiently large then even if important information is known to have been excluded, the true standard error wil still be closer to SE_ε than to SE_u.

III. EMPIRICAL RESULTS

THE DATA

Obviously, there is no unique real interest rate. The magnitude of a real rate depends not only on the risk charcteristics of the security being studied, but also on the price index used to calculate real returns. What is the appropriate price index depends on what economic decision is being analyzed. For example, if we are interested in the savings--consumption decision, a price index based on a commodity bundle of consumption goods, such as the CPI, is appropriate. If, on the other hand, we are interested in decisions to trade among countries, then a price index with tradeable goods a larger proportion of its commodity bundle, such as the WPI, is more appropriate.

This study analyzes real interest rates in the Euro deposit market in the 1967-II to 1979-II period for the following OECD countries: the United States, Canada, the United Kingdom, France, West Germany, the Netherlands, and Switzerland. Quarterly data on three-month euro rates obtained from the Harris Bank tape are used in this study for several reasons.[12] High quality data for domestic, short-term interest rates are not readily available for other countries besides the United States and Canada. Unlike the U. S. and Canada, other countries' treasury bill rates are not market clearing, so that

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12 Only seven of the ten countries' data available in the tape are used here because three of the countries--Italy, Belgium and Japan--either had a high proportion of the data missing or did not satisfy interest partity because of two-tiered exchange rates. In the few cases where euro rate data were missing for the seven countries, the euro rate was calculated from the interest parity condition. The rest of the data were checked by verifying that there were no large deviations from interest parity. Several obvious errors in the tape were found in this manner and were corrected.

these data, although available, do not reflect the true cost of credit. Euro rates, however, are market clearing. In addition, euro deposits denominated in different countries' currencies are issued by the same bank and therefore have similar default risk and are not subject to capital controls because they are offshore securities. Hence a comparison of real euro rates across countries will not have to be adjusted for differing default risks or non-comparability because of capital market controls. Quarterly data on three-month rates have the advantage that the data are non-overlapping and timing problems that would arise with monthly data are avoided.[13] The dating convention is as follows. The ex post real rate for a quarter is the actual real return on a three-month euro deposit held from the beginning to the end of that quarter, continuously compounded. For each country the ex post real rate is constructed by subtracting the continously compounded inflation rate for that country from the continuously compounded nominal return on the euro

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13 See Mishkin (1981a).

deposit denominated in that country's currency.[14] Both the CPI and WPI are used in the empirical analysis to calculate inflation rates for the reasons discussed above. The money growth and inflation variables are calculated as the change in the log of the money stock or price level, from the last month of the previous quarter to the current quarter, and are also quarterly rates. The euro rate and U. S. treasury bill data were obtained from the Harris Bank tape maintained at the University of Chicago and the CPI, WPI and money stock data were obtained from the International Financial Ststistics (IFS) tape maintained by the International Monetary Fund.

RESULTS

The null hypothesis of the constancy of the euro real rates is studied here with two types of tests which are similar to those carried out in Fama (1975) and Mishkin (1981a). These tests correspond to the weak form and semi-strong form distinction discussed in the efficient markets literature by Fama (1970).

Table 1 contains the weak form tests which look at the first twelve

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[14] These real rates seem to be the most natural to study, but matching up the country's price index with the euro deposit rate denominated in its currency is somewhat arbitrary. Clearly a Frenchman might also be interested in his real return from holding a U. S. dollar denominated euro deposit even though the price index relevant to him is, say, the French CPI. If uncovered interest parity holds, which will be the case when the forward exchange rate is an unbiased forecast of the spot exchange rate since interest parity in euro rates is a pure arbitrage condition, then the real euro rate for a Frenchman will be the same regardless of the denomination of the euro deposit. Thus in this case only the real euro rates analyzed in this paper need to be studied. However, recent evidence does not support the unbiasedness of the forward rate prediction or uncovered interest parity (for example see Cumby and Obstfeld (1981, 1982), Hansen and Hodrick (1980) and Mishkin (1982). Thus it is potentially worth studying real rates where the currency denomination of the euro rate is not matched up to the price index for that country. This is not done here because it would make this already long paper unwieldly.

TABLE 1

Autocorrelations of Ex Post Real Rates

Country	Lag 1	2	3	4	5	6	7	8	9	10	11	12	Q(12)	Marginal Significance Level
PANEL A: Ex Post Real Rates Using CPI														
US	.34	.16	.21	.47	.23	.08	.21	.16	.11	-.03	.19	.08	33.67	.0008
CA	.39	.30	.23	.26	.13	.01	.14	.14	.10	-.19	-.02	-.14	26.92	.0079
UK	.23	.33	-.02	.46	.05	.11	-.07	.29	-.06	.01	-.15	.23	31.85	.0015
FR	.37	.29	.37	.07	.13	-.01	-.01	.02	-.09	-.14	-.18	-.13	25.35	.0132
FD	.22	-.12	.07	.41	-.03	-.41	-.12	.22	-.03	-.38	-.03	.25	39.70	.0001
ND	.28	.15	-.01	.23	-.06	-.09	-.18	.09	.09	-.11	-.13	.02	13.78	.3150
SW	.27	.29	.24	.32	-.05	.15	-.08	.05	-.24	-.14	-.25	-.11	28.73	.0043
PANEL B: Ex Post Real Rates Using WPI														
US	.30	.10	.23	.31	.21	.12	-.02	-.04	-.01	-.07	-.14	-.13	19.65	.0741
CA	.57	.49	.38	.46	.21	.12	-.05	.06	-.15	-.18	-.26	-.17	62.68	7.40×10^{-9}
UK	.55	.43	.38	.41	.34	.19	.17	.29	.20	.10	.12	.16	64.49	3.46×10^{-9}
FR	.53	.20	-.10	-.16	-.22	-.23	-.21	-.02	.06	.08	.02	.04	27.67	.0062
FD	.37	.04	.10	.25	-.01	-.19	-.19	.10	-.03	-.19	-.10	.28	24.29	.0186
ND	.25	.18	.23	.23	.15	.10	-.03	.09	.09	-.04	-.19	-.12	17.11	.1458
SW	.58	.25	.12	-.00	-.21	-.29	-.18	-.12	-.11	-.08	-.00	.05	33.33	.0009

Notes For All Tables: Countries: US = United States; CA = Canada; UK = United Kingdom; FR = France; FD = West Germany; ND = Netherlands; SW = Switzerland.

Marginal significance level = probability of getting that value of the test statistic or higher under the null hypothesis.

Notes to Table 1: Q(12) = adjusted Box-Pierce statistic [Ljung and Box (1978)]

$$= n(n+2) \sum_{k=1}^{12} (n-k)^{-1} \rho_k^2,$$ where n = number of observations and ρ_k is the autocorrelation at lag k: Q(12) is distributed approximately as $\chi^2(12)$ under the null hypothesis that $\rho_1=\rho_2=,\ldots,\rho_{12}=0$

approximate standard error of the autocorrelations = $1/\sqrt{n}$ where n = number of observations = 49 autocorrelations of the ex post real rates. The constancy of the real rate implies that all the autocorrelations should equal zero. It is formally tested with the adjusted Q-statistic suggested by Ljung and Box (1978). The Q(12) statistic is distributed approximately as $\chi^2(12)$, and its marginal significance level is the probability of getting that value of the test statistic or higher under the null hypothesis of all autocorrelations equaling zero: i.e., a marginal significance level less than .05 indicates a rejection of the null hypothesis at the five percent level. The serial correlation pattern for the ex post real rate in Table 1 is similar to that found for U.S. treasury bill data in Mishkin (1981a). The first four or five autocorrelations are usually positive with a high percentage significantly different from zero. The Q(12) statistic rejects the null hypothesis implied by the constancy of the real rate (at the 5% level) in 11 out of 14 cases, and only the ex post real rate for the dutch guilder displays no evidence of serial correlation.

Table 2 contains the semi-strong form tests for whether the ex post real rates in the seven OECD countries, and hence the real rates, are correlated with other variables whose values are known when the real rate was determined, i.e., at time t-1. The F-statistics in Table 2 test the null hypothesis that all coefficients of the explanatory variables in the real rate model for each country, except the constant terms, are zero. Line 2.1 follows Mishkin (1981a) in conducting a mechanical test of the constancy of the real rate by postulating that the real rate for each country moves with a fourth order

TABLE 2

Joint Tests of the Constancy of the Real Euro Rate in the Seven Countries

	Explanatory Variables in Real Rate Model for Each Country	PANEL A: Using CPI		PANEL B: Using WPI	
		F-statistic	Marginal Significance Level	F-statistic	Marginal Significance Level
2.1	TIME, $TIME^2$, $TIME^3$, $TIME^4$	$F(28,308) = 3.63$	1.12×10^{-8}	$F(28,308) = 3.92$	1.20×10^{-9}
2.2	MG(-1), i, 4 lags of π	$F(42,294) = 9.56$	7.17×10^{-35}	$F(42,294) = 3.27$	1.93×10^{-9}
2.3	MG(-1), i, 4 lags of π, TIME, $TIME^2$, $TIME^3$, $TIME^4$	$F(70,266) = 8.79$	1.19×10^{-39}	$F(70,266) = 2.76$	2.43×10^{-9}

Notes for All Tables:

Variables:

TIME = time trend = .01 in 1967-II, ..., .49 in 1979-II: superscript indicates TIME raised to that power

π = inflation rate for each country

MG(-1) = money growth for each country, lagged one period

i = nominal euro rate for each country, maturing at time t, but which is known at time t-1 and is thus in the information set ϕ_{t-1}

Marginal Significance Level = The probability of getting that value of the F-statistic or higher under the null hypothesis that all the coefficients except the constant terms equal zero.

polynomial in time.[15] The rejection of the constancy of the Euro real rates is very strong, with the marginal significance level indicating that the probability of getting such a high value of the test statistic under the null

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15 The time trend variables should be seen as a proxy for the smoothly moving component of economic variables that are related to real rates. For example, if the real rate projection against all available information, ϕ_{t-1}, is

$$P(rr_t \mid \phi_{t-1}) = X^E_{t-1}\beta$$

and

$$P(X^E_{t-1} \mid T_{t-1}) = T_{t-1}\Theta$$

where T_{t-1} = vector of the four time variables at t-1,

X^E_{t-1} = vector of the economic variables at t-1.

then

$$eprr_t = T_{t-1}\theta\beta + u'_t - \varepsilon_t$$

where

$$u'_t = rr_t - p(rr_t \mid T_{t-1})$$

footnote 15 continued)

The null hypothesis of the constancy of the real rate implies that $\beta=0$ and thus the coefficients on T_{t-1} in the ex-post real rate regression, $\theta\beta$ must also equal zero. The main advantage of this mechancial test is that it does not require knowledge of what the X^E_{t-1} variables are and may thus capture some effects from variables which belong in the relevant information set but have been ignored by the econometrician.

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hypothesis is less than one in 10 million. Line 2.2 uses economic variables to explain real rate movements while line 2.3 uses both the economic and noneconomic time variables to explain real rates. Note that the ex post real rate regressions for each country use only its own economic variables for explanatory variables and not those of other countries. Clearly other countries economic variables might affect domestic real rates, but if each country's regressions included all other countries' economic variables, almost all degrees of freedom would have been used up. Again, the rejection of the null hypothesis is strong, and in one case the marginal significance level drops below 10^{-38}. The rejection in Table 2 of the constancy of the real rates jointly in all seven countries is stonger than is the case for any country alone.[16] This demonstrates the increased power of joint statistical tests for several countries.

Table 3 through 5 explore in more detail the association of euro real - rate movements in the seven countries their own economic variables. Mishkin

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16 For example, in the CPI model 2.1 the smallest marginal significance level for the test in one country alone of the null hypothesis that the time variable do not have

TABLE 3

Relationship of Real Rates and Inflation

PANEL A: Using CPI

Country	Constant	$\pi(-1)$	Constant	4 lags[a] of π
	Dependent Variables: Ex Post Real Euro Rates			
	Coefficients of			
	System 3.1		System 3.3	
US	.0060 (2.97)	-.1950 (-1.61)	.0065 (2.75)	-.2331 (-1.56)
CA	.0074 (2.94)	-.2761 (-2.01)	.0091 (3.02)	-.3909 (-2.23)
UK	.0068 (1.81)	-.2554 (-2.10)	.0156 (4.43)	-.6124 (-4.92)
FR	.0073 (1.51)	-.0873 (-.37)	.0070 (1.32)	-.0821 (-.31)
FD	.0032 (1.42)	-.0925 (-.55)	.0061 (2.20)	-.3754 (-1.51)
ND	.0022 (.65)	-.1587 (-.88)	.0076 (1.60)	-.5000 (-1.79)
SW	-.0001 (-.06)	-.0084 (-.05)	.0025 (.86)	-.2488 (-1.10)
F-test[b]	F(7,329)=1.28		F(28,308)=3.19	
Marginal Significance Level	.2577		3.87×10^{-7}	
	Dependent Variables: Ex Post Real Euro Rates Adjusted for Default Risk			
	System 3.2		System 3.4	
US	.0034 (2.02)	-.3292 (-3.26)	.0046 (2.28)	-.4120 (-3.27)
CA	.0035 (1.49)	-.3257 (-2.53)	.0050 (1.81)	-.4265 (-2.61)
UK	.0017 (.45)	-.2365 (-1.97)	.0101 (2.79)	-.5785 (-4.53)
FR	.0036 (.77)	-.1373 (-.61)	.0038 (.74)	-.1575 (-.61)
FD	-.0016 (-.74)	-.0784 (-.48)	.0028 (1.10)	-.5127 (-2.24)
ND	-.0023 (-.68)	-.1706 (-.96)	.0047 (1.00)	-.6066 (-2.23)
SW	-.0036 (-1.52)	-.1171 (-.73)	.0000 (.01)	-.4446 (-1.99)
F-test[b]	F(7,329)=2.50		F(28,308)=3.50	
Marginal Significance Level	.0161		3.33×10^{-8}	

PANEL B: Using WPI

Dependent Variables: Ex Post Real Euro Rates

Coefficients of

Country	Constant	$\pi(-1)$	Constant	4 lags[a] of π
	System 3.5		System 3.7	
US	.0056 (1.86)	-.2337 (-1.81)	.0074 (2.07)	-.3557 (-1.96)
CA	.0102 (3.88)	-.4902 (-4.27)	.0112 (4.10)	-.5978 (-4.25)
UK	.0119 (4.17)	-.4898 (-5.54)	.0138 (4.50)	-.5714 (-5.68)
FR	.0160 (3.47)	-.4826 (-3.54)	.0117 (2.43)	-.1722 (-.90)
FD	.0051 (2.54)	-.2196 (-1.68)	.0047 (2.12)	-.1819 (-1.02)
ND	.0073 (3.03)	-.2093 (-1.40)	.0105 (3.45)	-.5143 (-2.19)
SW	.0066 (2.54)	-.4321 (-3.17)	.0050 (1.88)	-.1872 (-1.03)
F-test[b]	$F(7,329)=8.18$		$F(28,308)=3.65$	
Marginal Significance Level	3.43×10^{-9}		1.02×10^{-8}	
	System 3.6		System 3.8	
US	.0018 (.60)	-.2851 (-2.23)	.0044 (1.25)	-.4601 (-2.58)
CA	.0062 (2.40)	-.5332 (-4.68)	.0083 (3.01)	-.6782 (-4.96)
UK	.0074 (2.54)	-.4926 (-5.51)	.0091 (2.93)	-.5695 (-5.57)
FR	.0114 (2.53)	-.4863 (-3.64)	.0081 (1.66)	-.2457 (-1.27)
FD	.0009 (.43)	-.2683 (-2.02)	.0017 (.72)	-.3626 (-1.96)
ND	.0025 (1.04)	-.2008 (-1.32)	.0059 (1.93)	-.5276 (-2.23)
SW	.0422 (.86)	-.4700 (-3.54)	.0012 (.46)	-.3278 (-1.81)
F-test[b]	$F(7,329)=8.65$		$F(28,308)=3.69$	
Marginal Significance Level	1.00×10^{-9}		7.40×10^{-9}	

Notes to Tables 3-5: T-statistics in parentheses

[a] Sum of coefficients and t-statistics on sum of coefficients

[b] F-tests for whether the coefficient of this variable (or variables) equals zero for all countries.

(1981a) found a strong negative correlation of real U.S. Treasury bill rates with U. S. inflation lagged one period. Does this negative realationship of real rates and inflation hold up in the data here? The CPI results in System 3.1 to Table 3 provides only weak evidence that it does. The negative association of each country's real rate and lagged inflation appears in all seven countries. However, only two of these seven negative coefficients is signficantly different from zero, and the F-test for whether all of the inflation coefficients are zero is not rejected at the 5% level. Particularly surprising is the weak association of the U. S. euro dollar real rate and lagged U. S. inflation, considering the strong association found with Treasury bill data in Mishkin (1981b).

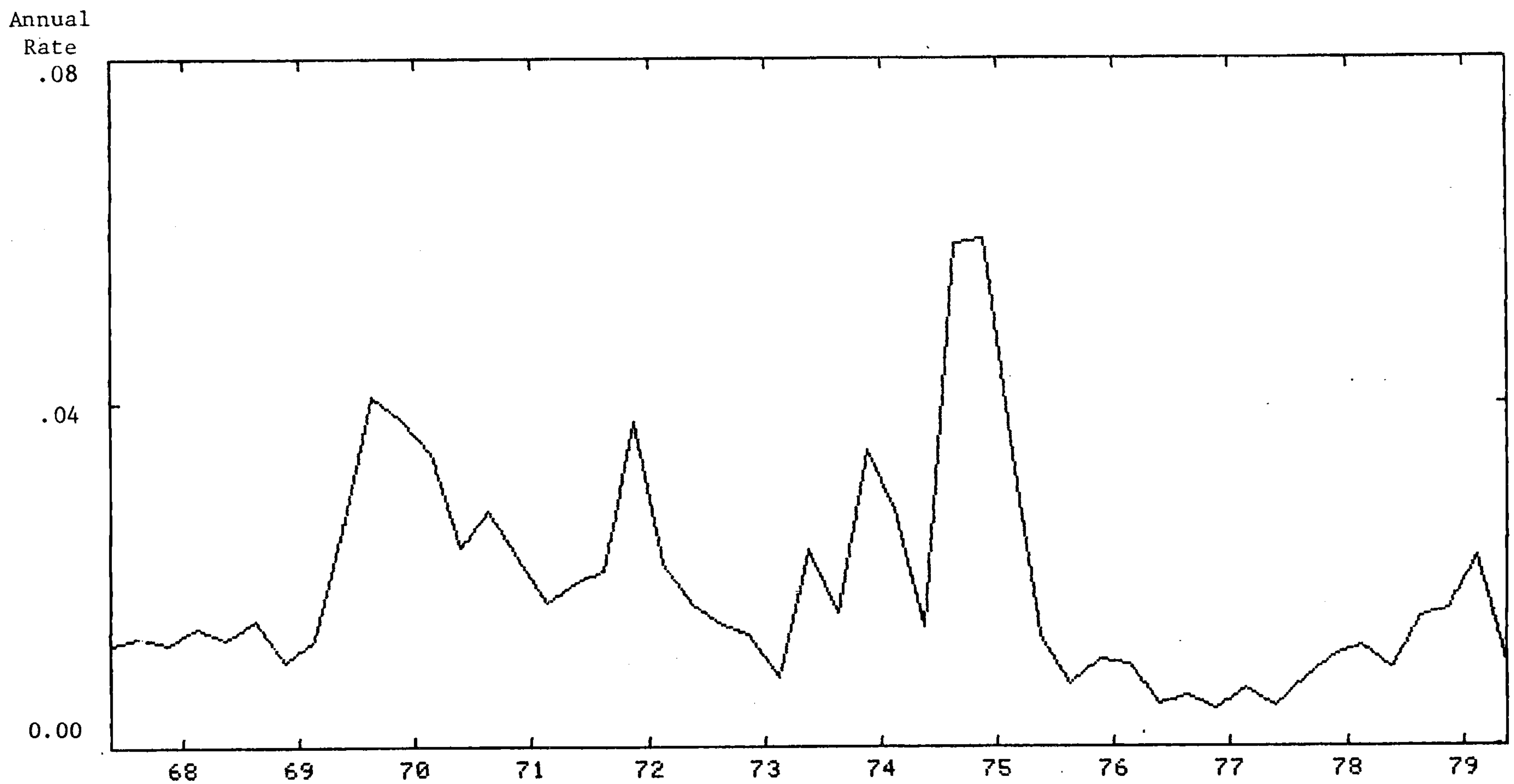
This result illustrates the important point that real rates for securities with different risk characteristics need not move together. The U.S. Treasury bill is a riskless interest rate in nominal terms while the euro dollar rate bears some default risk. The risk preminum for the three month euro dollar rate is plotted in Figure 1 and it does have substantial variation over time. Two periods are particularly important in this regard: 1969 and 1974. Both periods displayed a very large premium of the three month Euro dollar rate over the three month U.S. Treasury bill rate. Both periods were

explanatory power is .00003 versus 1.12×10^{-8} for the joint test.

17 One factor behind the positive correlation of the premium and inflation could be Regulation Q. When inflation rises, nominal interest rates would rise as well in the U. S. via a standard Fisher effect. With Regulation Q binding so that banks cannot compete for deposits in the U.S., they might go into the euro market and bid for funds, thus possibly raising euro rates relative to U. S domestic rates. Another factor might be the greater uncertainty in the international financial system as a result of financial crises: the Penn Central bankruptcy and major bank failures such as Franklin National and the Herstadt bank. The determination of the premium on euro dollar rates over U.S. T-bill rates is an interesting question that deserves further research.

Figure 1

Premium of Three Month Eurodollar Rate
Over Three Month U.S. Treasury Bill Rate



also a time of high inflation.[17] Hence, the positive correlation of the risk premium and inflation could be obscuring the negative relationship of real rates and inflation. This possibility is explored by adjusting the euro dollar rates for default risk by subtracting the premium of the three-month euro dollar rate over the three-month U.S. Treasury bill from each country's euro rate. In the case of the U.S., this leaves us with the three-month Treasury bill rate, while for other countries this leaves us with a nominal rate that is adjusted for bank default risk, but not for any political risk borne by domestic securities.[18] The resulting estimates can be found in system 3.2. All the inflation coefficients are negative, and now the inflation coefficient in the U.S. regression is statistically significant and has a very similar value to that found in Mishkin (1981a) which used a somewhat different sample period. The joint test of the null hypothesis that the inflation variables have no explanatory power is now rejected at the 5 percent level.

Systems 3.3 and 3.4 add three more lags of inflation to the models of Systems 3.1 and 3.2 because they have significant additional explanatory power,[19] and here the evidence is far stronger on the negative realationship of real rates and inflation. The sum of the inflation coefficients in each country is always negative, and the explanatory power of the inflation variables is highly significant: the null hypothesis that their coefficients equal zero is rejected at extremely small marginal significance levels.

Panel B of Table 3 contains the results using the WPI for each country as

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[18] See Aliber (1974).

[19] The null hypothesis that their coefficients are different from zero can be rejected at the one percent level. $F(21,308) = 3.61$ while the critical F at 1 percent is 1.9.

the price index. The inflation coefficients always have negative sums and, even in the System 3.5 results where the euro rates are not adjusted for default risk and only one lag of inflation is included, the hypothesis that these negative inflation coefficients equal zero is rejected very strongly. Overall then, the results in Table 3 do strongly support the existence of a negative correlation between inflation and real rates in other countries besides the United States.

Mishkin (1981a) found evidence that, as we might expect from standard monetary theory, money growth and real rates in the United States are negatively correlated. However, only weak evidence was found that money growth has explanatory power over and above that associated with inflation. Table 4 yields evidence on this issue for the seven countries studied here. Note that only one lag of each country's money growth is used as an explanatory variable because additional lags did not contain significant additional explanatory power.[20] The CPI results in Panel A show that real rates for other countries besides the U. S. are negatively associated with lagged money growth in that country. The money growth coefficients are negative in 13 out of 14 cases in Panel A, and the hypothesis that all the money growth coefficients equal zero is always rejected at the 1 percent

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[20] The null hypothesis that coefficients on three more lags on money growth are zero cannot be rejected at the five percent level. Using the CPI, $F(21,308) = 1.46$ and using the WPI, $F(21,308) = 1.34$, while the critical value of F at 5% is 1.6.

[21] For example when one lag of inflation for each country is added as a explanatory variable to the regressions in System 4.1, the null hypothesis that the coefficients on money growth are zero can be rejected at the one percent level, $F(7,322) = 3.70$ while the critical value of F at 1% is 2.04. Although we could interpret this result as indicating that monetary policy has an independent effect on real rates, it is also possible that money growth has significant explanatory power because it helps forecast inflation, and it is expected inflation which is negatively correlated with the real rate.

TABLE 4

Relationship of Real Rates and Money Growth

Panel A: Using CPI

Dependent Variables	Ex Post Real Euro Rates		Ex post Real Euro Rates Adjusted for Default Risk	
	Coefficients of		Coefficients of	
	Constant	MG(-1)	Constant	MG(-1)
	System 4.1		System 4.3	
Country				
US	.0039	-.0644	-.0015	-.0098
	(2.86)	(-.83)	(-1.18)	(-.14)
CA	.0035	-.0244	-.0014	-.0139
	(2.70)	(-1.22)	(-1.16)	(-.72)
UK	.0076	-.2778	.0020	-.2388
	(2.27)	(-2.79)	(.58)	(-2.40)
FR	.0064	-.0349	.0009	.0028
	(2.52)	(-.45)	(.36)	(.04)
FD	.0038	-.0668	-.0011	-.0577
	(1.57)	(-.79)	(-.46)	(-.70)
ND	.0058	-.2513	.0010	-.2460
	(2.83)	(-4.18)	(.49)	(-4.17)
SW	.0006	-.0404	-.0041	-.0391
	(.26)	(-.57)	(-1.91)	(-.54)
F-test[b]		F(7,329)=3.70		F(7,329)=3.28
Marginal Significance Level		.0007		.0022

PANEL B: Using WPI

	System 4.2		System 4.4	
Country				
US	.0037	-.1507	-.0017	-.0961
	(1.11)	(-.79)	(-.49)	(-.50)
CA	.0017	-.0058	-.0032	.0046
	(.82)	(-.18)	(-1.47)	(.14)
UK	.0025	-.1197	-.0032	-.0807
	(.71)	(-1.17)	(-.91)	(-.78)
FR	.0113	-.1490	.0058	-.1113
	(1.83)	(-.80)	(.95)	(-.60)
FD	.0023	.0286	-.0025	.0376
	(.84)	(.2956)	(-.90)	(.38)
ND	.0086	-.1390	.0038	-.1337
	(3.24)	(-1.80)	(1.40)	(-1.70)
SW	.0034	.0105	-.0013	.0118
	(.96)	(.09)	(-.38)	(.10)
F-test[b]		F(7,329)=.81		F(7,329)=.61
Marginal Significance Level		.5826		.7442

level.[21] In addition when lagged inflation for each country is also included in the regressions, the money growth coefficients continue to be negative and significantly different from zero. The finding here of an independent association of money growth and real rates over and above that coming from inflation is stonger than was found for U. S. data alone, as in Mishkin (1981a). Again this demonstrates the usefulness of analyzing data from many countries. The WPI results display only a weak tendency towards a negative association of real rates and money growth: the money growth coefficients for each country are negative in 9 out of 14 cases in Panel B, and the explanatory power of money growth is not strong: the null hypothesis of zero money growth coefficients cannot be rejected at the 5% level.

Results with U. S. data in Mishkin (1981a) indicated that movements in nominal interest rates were not positively correlated with real rates in the post war period. Hence, nominal interest rates may have been a misleading indicator of the tightness of monetary policy in this period. Has this been true for other countries besides the United States? Table 5 presents evidence on the relation of real and nominal rates for the seven OECD countries.[22]

The System 5.1 CPI results indicate that not only is the real euro rate not significantly correlated with the nominal euro rate for the U. S., but this is also true for the United Kingdom and Canada. The 5.1 results for the other countries are, however, quite different. France, Germany, the

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22 Additional lags of euro rates are not included as explanatory variables because this would have cut down on the sample period and because evidence on their explanatory power is mixed. The null hypothesis that coefficients on three lags of euro rates are zero cannot be rejected at the five percent level. Using the CPI: $F(21,287) = .90$ However using the WPI, $F(21,287) = 1.81$, while the critical value of F at 5% is 1.6. Note that the degrees of freedom in this test are smaller than in footnotes 19 and 20 because three observations for each country are lost when three lags of euro rates are included as explanatory variables.

TABLE 5

Relation of Real Rates and Nominal Rates

PANEL A: Using CPI

Dependent Variables	Ex Post Real Euro Rates		Ex Post Real Euro Rates Adjusted for Default Risk	
	Coefficients of		Coefficients of	
	Constant	i	Constant	i
	System 5.1		System 5.3	
Country				
US	-.0001 (-.03)	.1657 (1.01)	.0039 (1.38)	-.2893 (-2.02)
CA	-.0065 (-1.30)	.4854 (1.94)	-.0052 (-1.05)	.1778 (.72)
UK	.0011 (.14)	-.0256 (-.09)	-.0004 (-.05)	-.1463 (-.54)
FR	-.0149 (-6.02)	.8162 (9.26)	-.0173 (-6.52)	.7271 (7.69)
FD	-.0087 (-3.02)	.8562 (4.18)	-.0094 (-3.04)	.5424 (2.48)
ND	-.0162 (-4.70)	1.0022 (4.98)	-.0173 (-4.67)	.7750 (3.58)
SW	-.0075 (-2.81)	.6601 (3.25)	-.0088 (-2.99)	.3551 (1.58)
F-test[b]	$F(7,329)=17.26$		$F(7,329)=12.11$	
Marginal Significance Level	1.13×10^{-18}		1.31×10^{-12}	

PANEL B: Using WPI

	System 5.2		System 5.4	
Country				
US	.0044 (.55)	-.1445 (-.36)	.0084 (1.07)	-.5996 (-1.50)
CA	.0049 (.58)	-.1697 (-.40)	.0062 (.73)	-.4772 (-1.12)
UK	.0099 (1.36)	-.4004 (-1.52)	.0084 (1.17)	-.5211 (-2.00)
FR	-.0128 (-1.34)	.8269 (2.43)	-.0152 (-1.60)	.7378 (2.18)
FD	.0001 (.03)	.2231 (.83)	-.0005 (-.13)	-.0907 (-.32)
ND	-.0057 (-1.26)	.6863 (2.59)	-.0068 (-1.42)	.4591 (1.65)
SW	-.0034 (-.73)	.6356 (1.77)	-.0047 (-.98)	.3306 (.90)
F-test[b]	$F(7,329)=2.58$		$F(7,329)=2.50$	
Marginal Significance Level	.0133		.0162	

Netherlands and Switzerland display strong significant positive correlations of nominal and real euro rates. Indeed, the null hypothesis that the real euro rate moves one for one with the nominal euro rate cannot be rejected for these countries. Thus, contrary to the U. S. case, movements in nominal interest rates do provide information on the movements in real rates in France, Germany, the Netherlands and Switzerland.

We might suspect that positive associations of real and nominal euro rates using the CPI appear because of the substantial variation in the default risk premium pictured in Figure 1, which is reflected in both real and nominal euro rates. However, when the ex post real rates are adjusted for default risk in System 5.3, the positive correlation of the real rate with the nominal euro rate continues to be significant for France, Germany and the Netherlands. The WPI results in Table 5 do not display as strong a positive association between real and nominal rates as the CPI results. Only France and the Netherlands display a significant positive correlation of real and nominal rates, and when the real euro rate is adjusted for default risk, the correlation is no longer significant for the Netherlands. Nevertheless the pattern displayed in the CPI results is repeated in the WPI results: real rates in France, Germany, the Netherlands and Switzerland are more positively

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23 Even though all variables in the empirical work are calculated as quarterly rates the figures report the real rates as annual rates.

24 For the CPI system the F-statistic which tests the null hypothesis that the coefficients on the time variables are zero is $F(28,266) = 3.05$ with a marginal significance level of 1.57×10^{-6}. For the WPI system, $F(28,266) = 1.53$ with a marginal significance level of .0484. As should be clear from footnote 15, the time variables are proxying for additional economic information over and above the inflation and money growth variables that belong in the real rate projection equations. One possiblity is that the time variables proxy for world wide economic factors that are related to red rate movements in all countries.

associated with nominal rates than is true for the U.S., Canada, and the U.K. Thus, using movements in nominal rates as a guide to movements in real rates would me more misleading for the latter countries than the former, regardless of whether the CPI or WPI is used in calculating real rates.

We now turn to measures of the real euro rates for the 1967-II to 1979-II sample period. Figures 2 through 8 contain estimated real rates derived from model 2.3 in Table 2 which includes as explanatory variables for each country all the economic variables as well as a fourth-order polynominal in time.[23] The time variables are included because they do contain significant additional explanatory power in the CPI and WPI systems.[24] Figures 2 through 8 also contain 95% confidence intervals for the estimated real rates for the two extreme cases of equations (18) and (19) where: a) all the variance of the composite error term is attributed to forecast errors of inflation (the dotted lines) or b) none of the variance of the composite error term is attributed to the forecast errors of inflation (the dashed lines). Here, the discussion of inference will focus on the dotted-lines confidence interval because, as argued in Section II, this case is likely to be closer to reality.

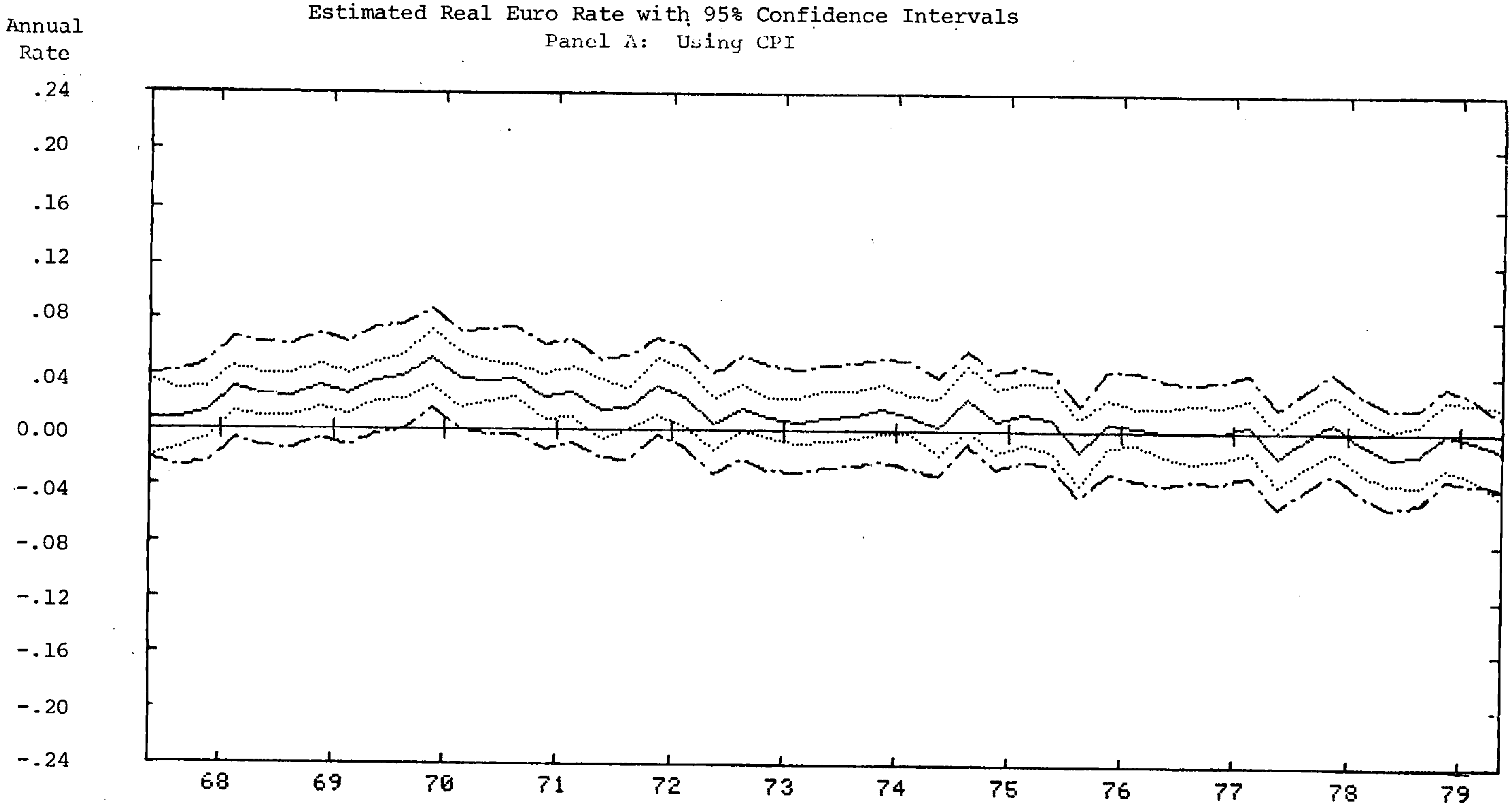
The U. S. results in Figure 2 are qualitatively similar to those found with Treasury bill data in Mishkin (1981a). In the period of the '60s the real euro dollar rate is positive and is frequently significantly so. In the '70s the real rate has fallen and fluctuates around zero. The significantly negative real rates for U. S. Treasury bills in the '70s rarely appear in the euro market because, as is seen in Figure 1, the default risk premium averages around 2 percent during this period. Canada's real rates are very close to those of the U. S., as might be expected, while the British real euro rates have greater fluctuations with significantly negative estimated real rates appearing in 1975 and 1976. The greater fluctuation in British real rates is

FIGURE 2

U.S. Dollar

Estimated Real Euro Rate with 95% Confidence Intervals

Panel A: Using CPI



——— estimated real rate, $\hat{rr}_t$

········ $\hat{rr}_t \pm 2\ \hat{SE}_{\varepsilon}(\hat{rr}_t - rr_t)$

-·-·-·- $\hat{rr}_t \pm 2\ \hat{SE}_{u}(\hat{rr}_t - rr_t)$

U.S. Dollar

Panel B: Using WPI

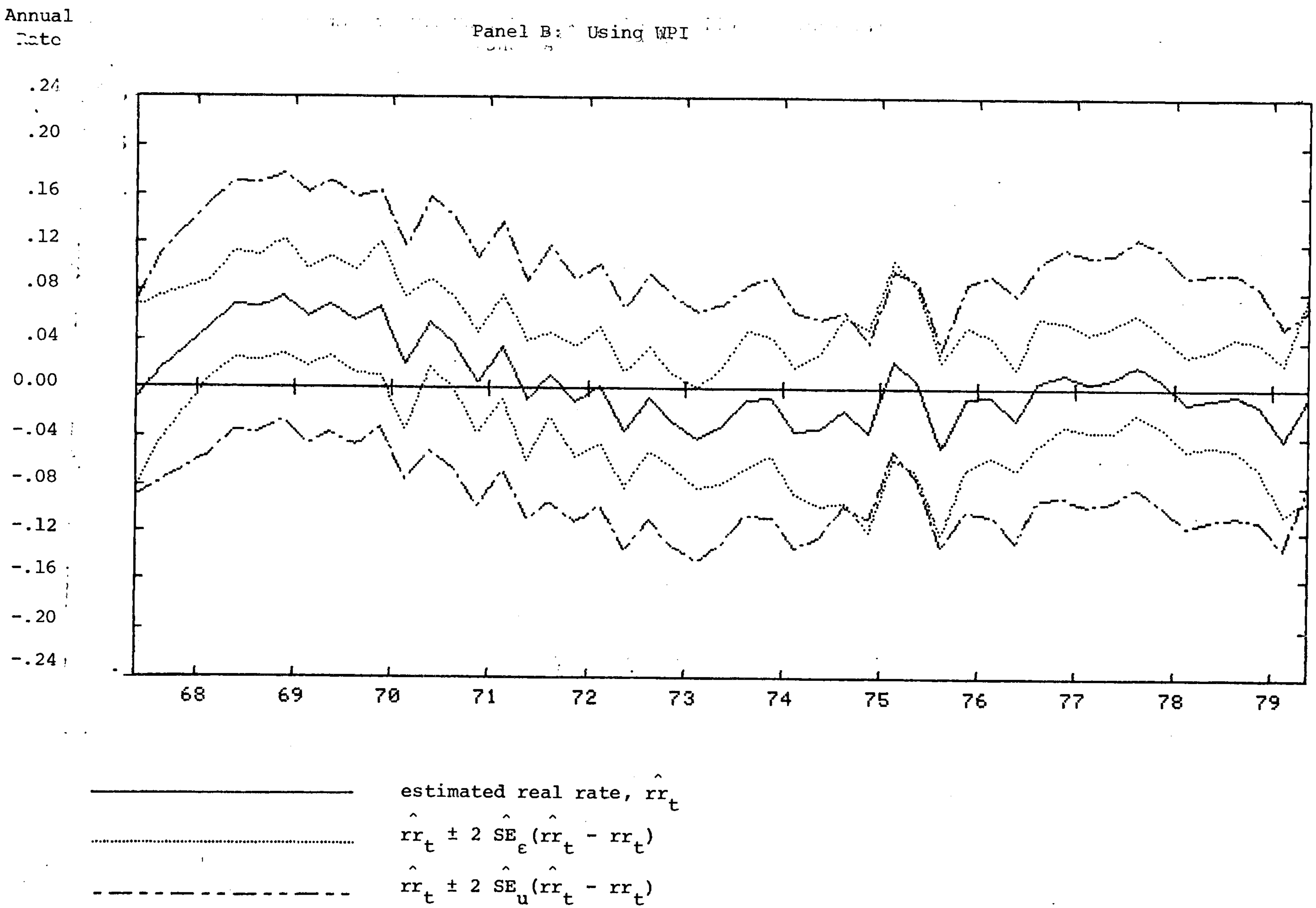
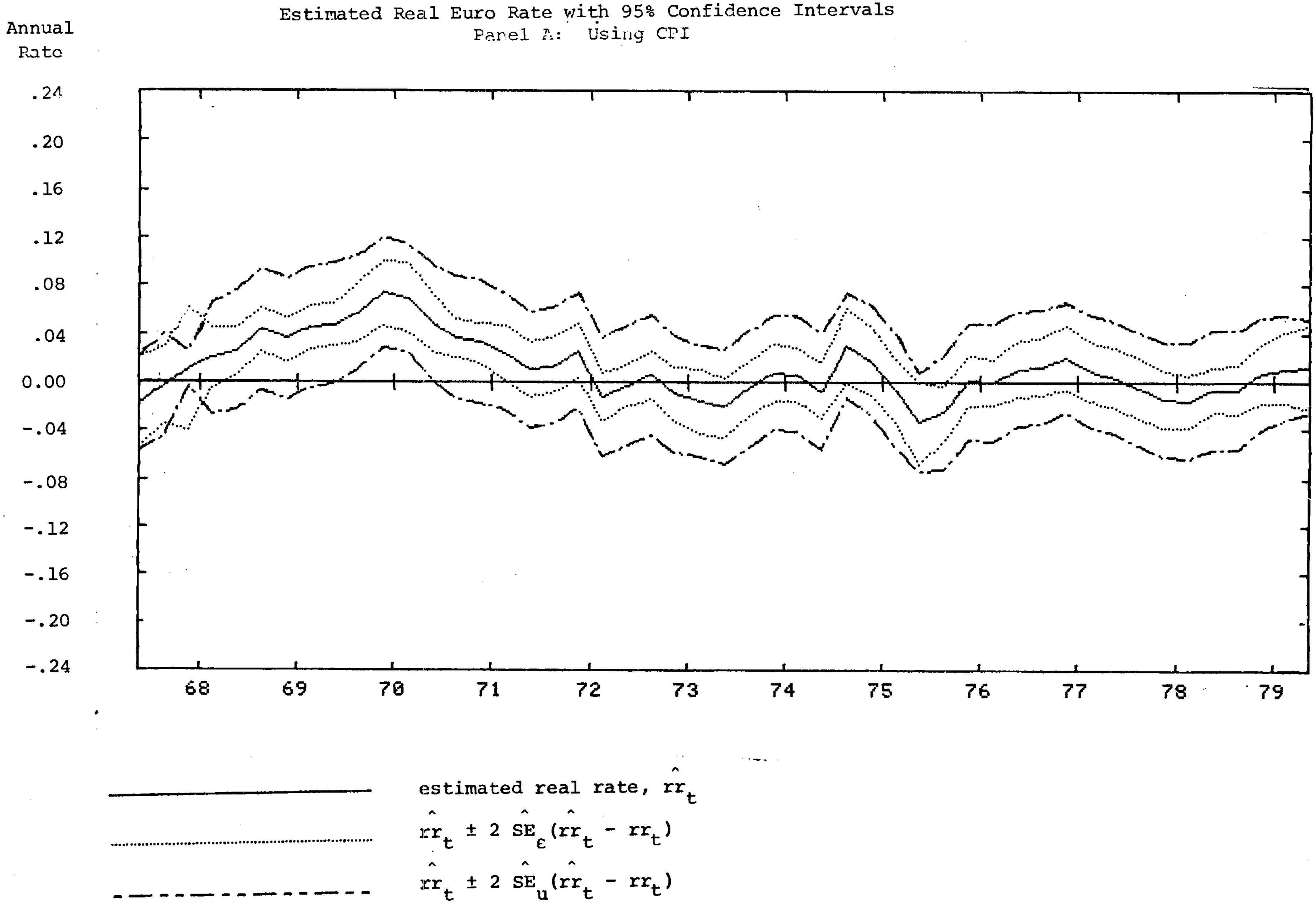


FIGURE 3

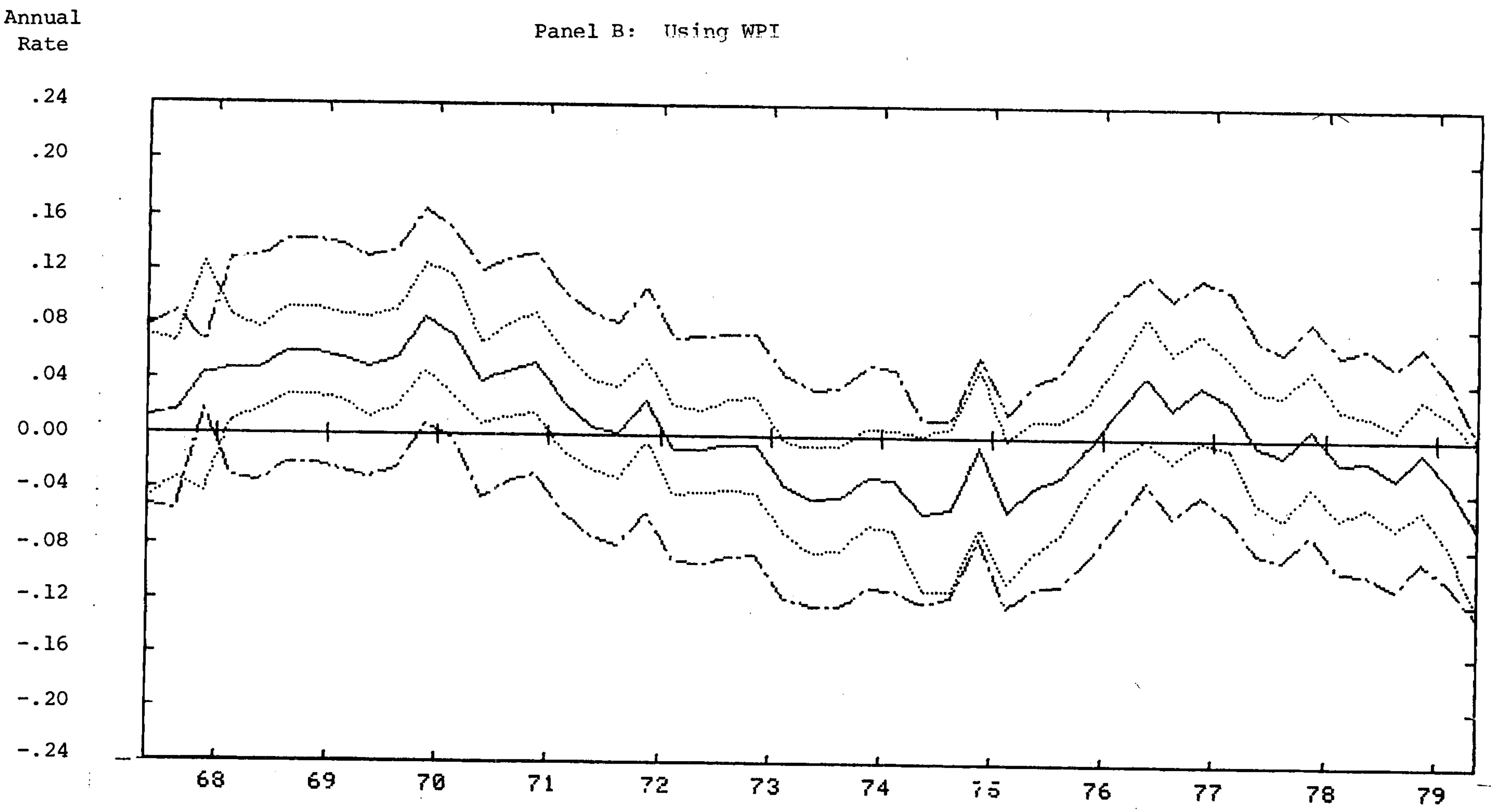
Canadian Dollar

Estimated Real Euro Rate with 95% Confidence Intervals
Panel A: Using CPI



Canadian Dollar

Panel B: Using WPI



estimated real rate, $\hat{rr}_t$

$\hat{rr}_t \pm 2\ \hat{SE}_\varepsilon(\hat{rr}_t - rr_t)$

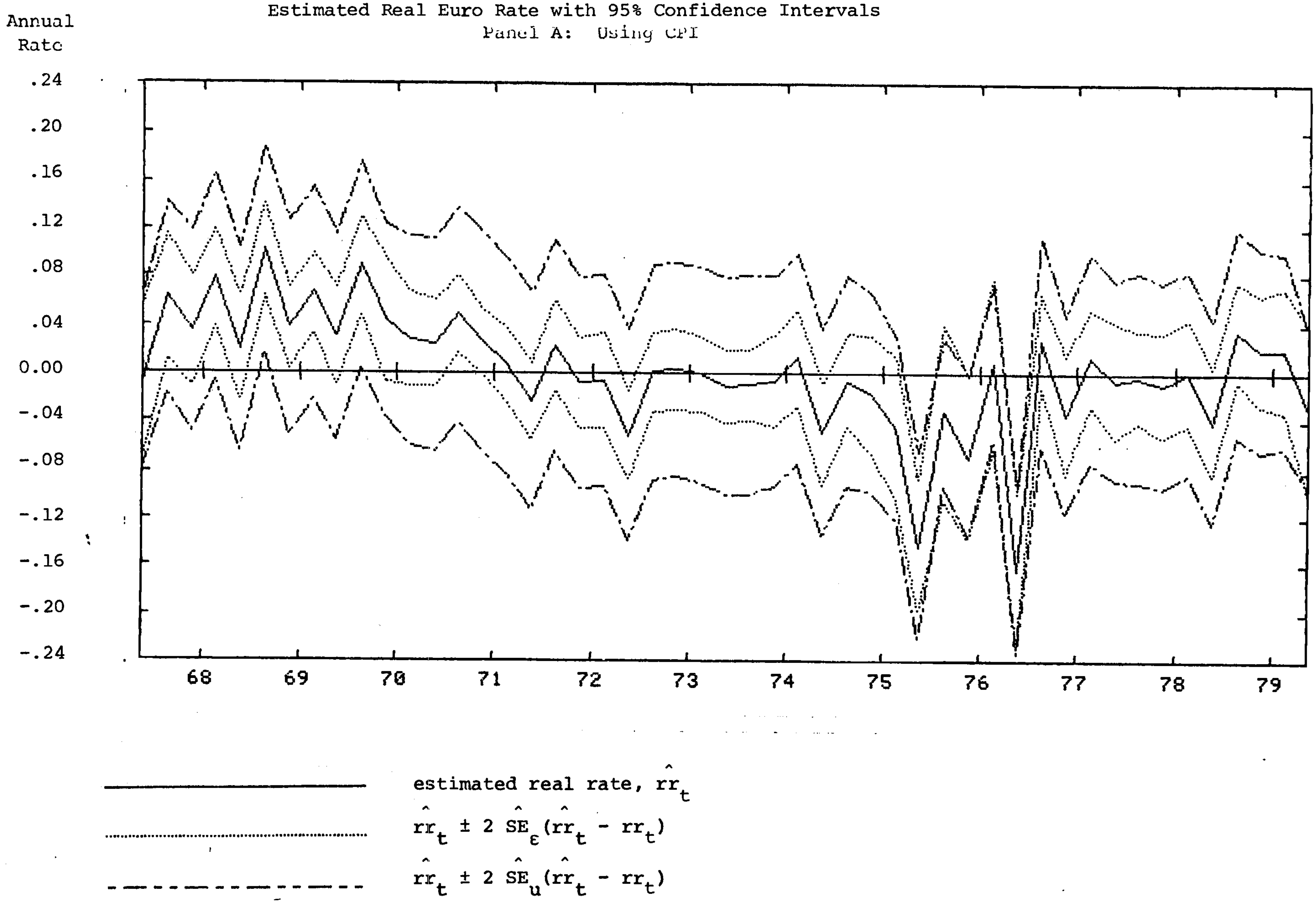
$\hat{rr}_t \pm 2\ \hat{SE}_u(\hat{rr}_t - rr_t)$

FIGURE 4

United Kingdom Pound Sterling

Estimated Real Euro Rate with 95% Confidence Intervals

Panel A: Using CPI



United Kingdom Pound Sterling

Panel B: Using WPI

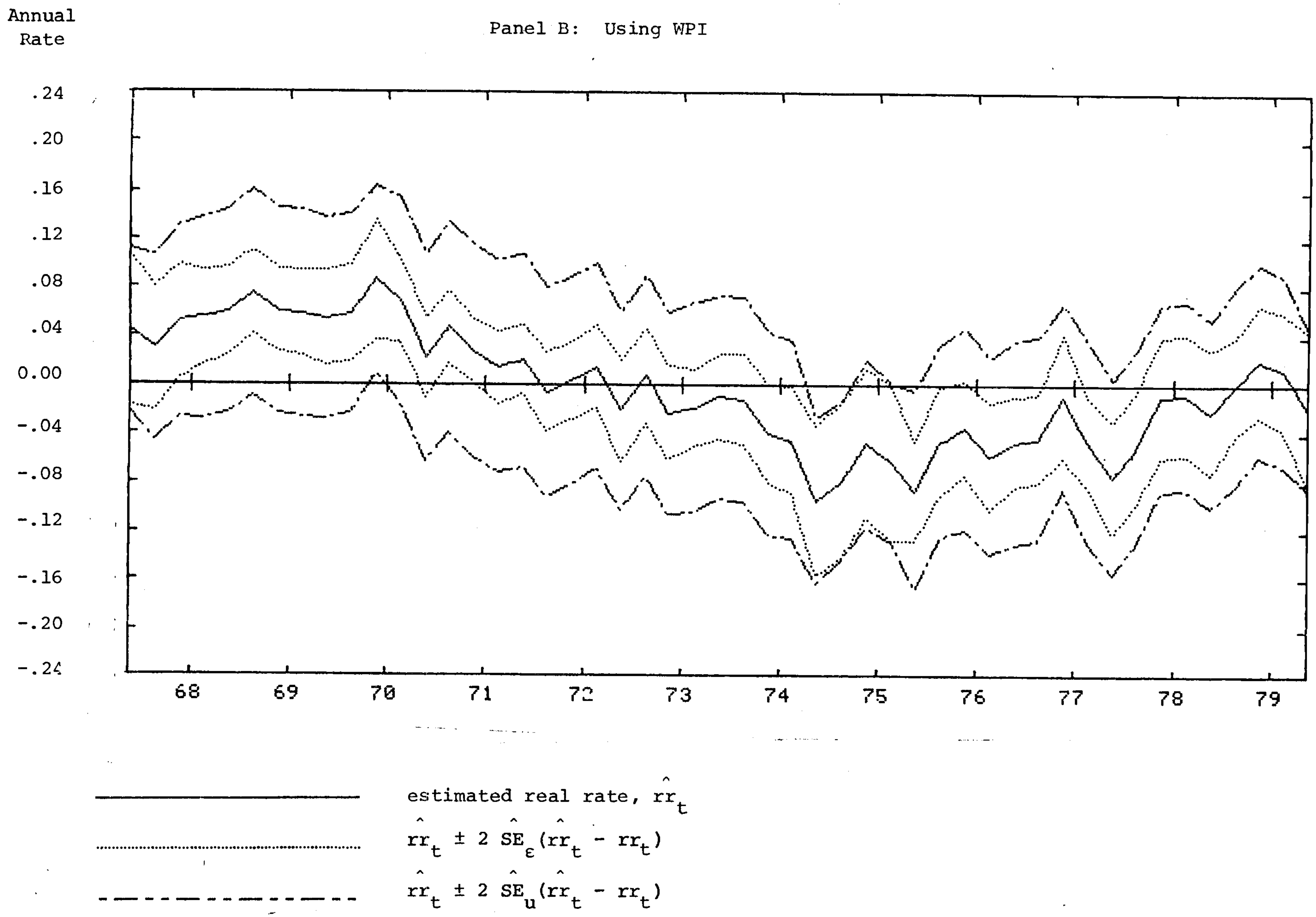
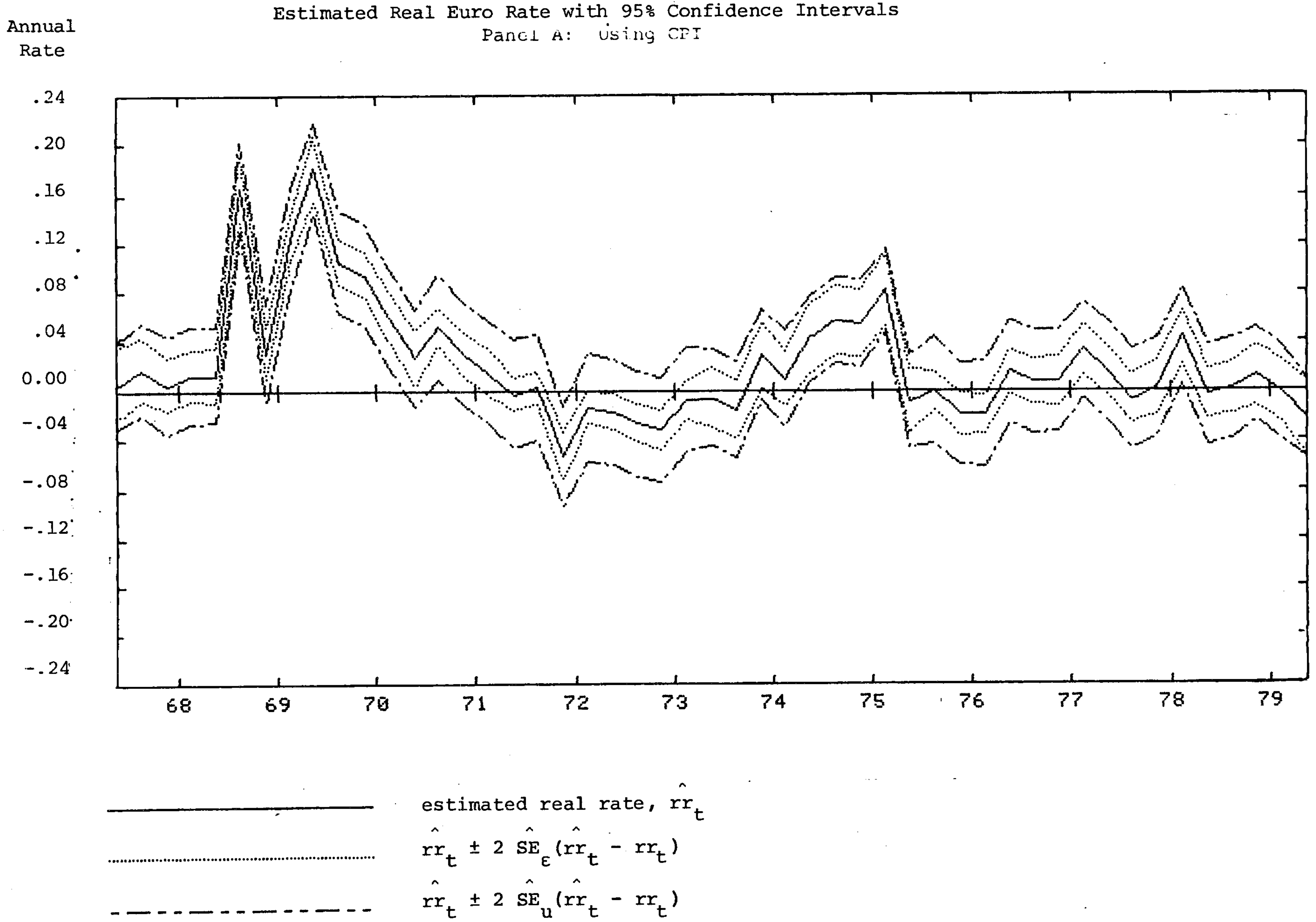


FIGURE 5

French Franc

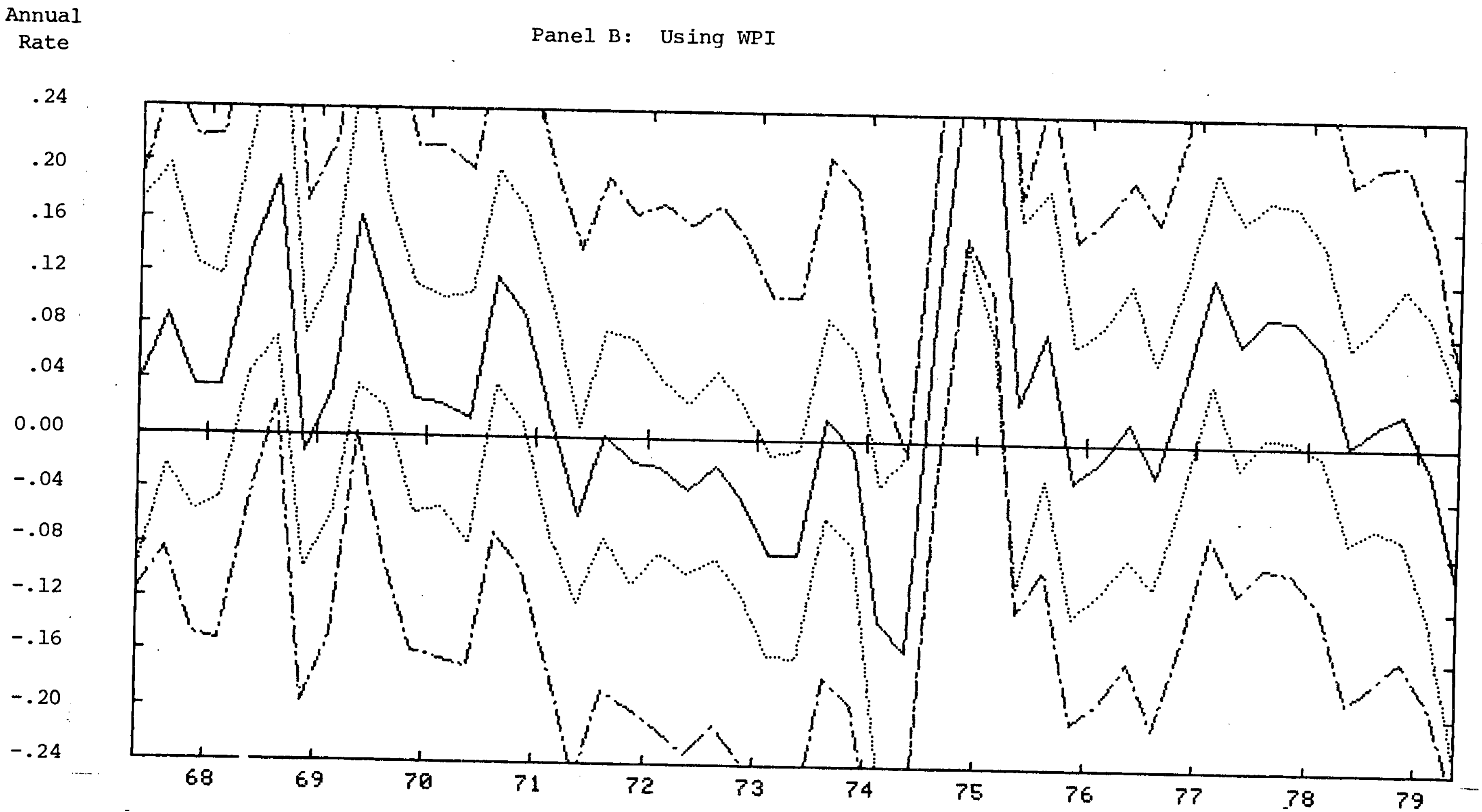
Estimated Real Euro Rate with 95% Confidence Intervals

Panel A: Using CPI



French Franc

Panel B: Using WPI



———— estimated real rate, $\hat{rr}_t$

········ $\hat{rr}_t \pm 2\ \hat{SE}_\varepsilon(\hat{rr}_t - rr_t)$

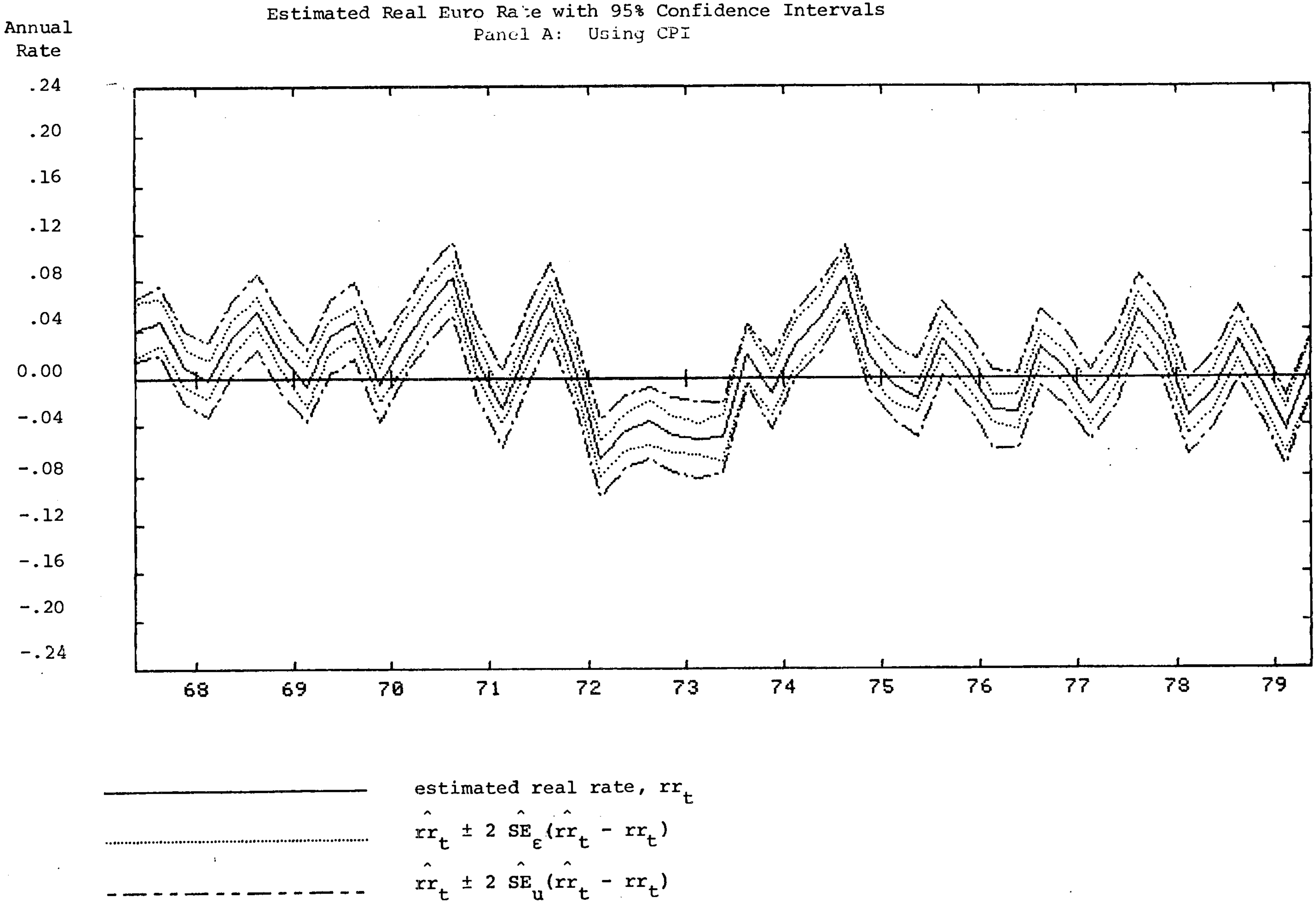
- - — - - $\hat{rr}_t \pm 2\ \hat{SE}_u(\hat{rr}_t - rr_t)$

FIGURE 6

West Germany Deutsche Mark

Estimated Real Euro Rate with 95% Confidence Intervals

Panel A: Using CPI



West Germany Deutsche Mark

Panel B: Using WPI

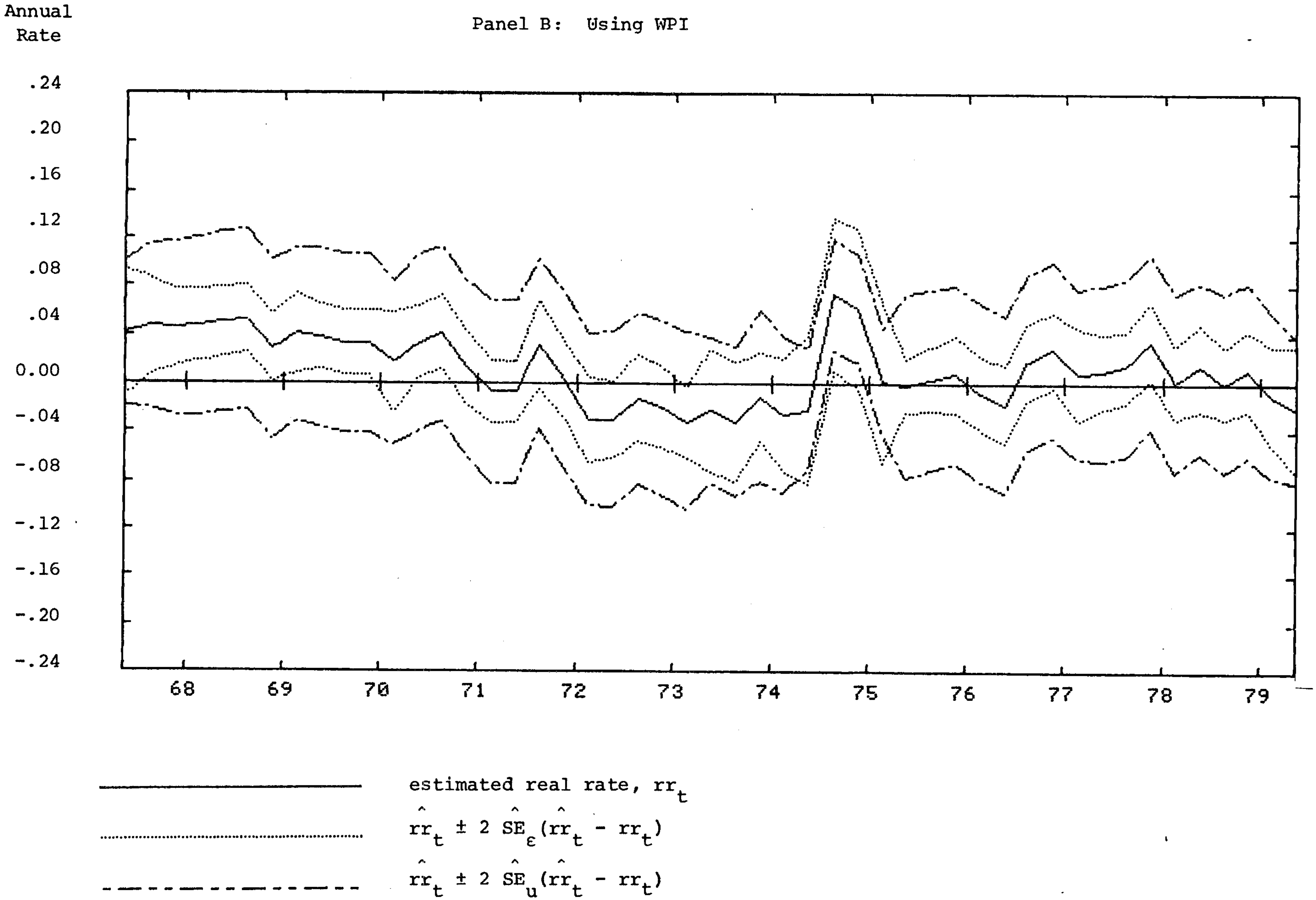
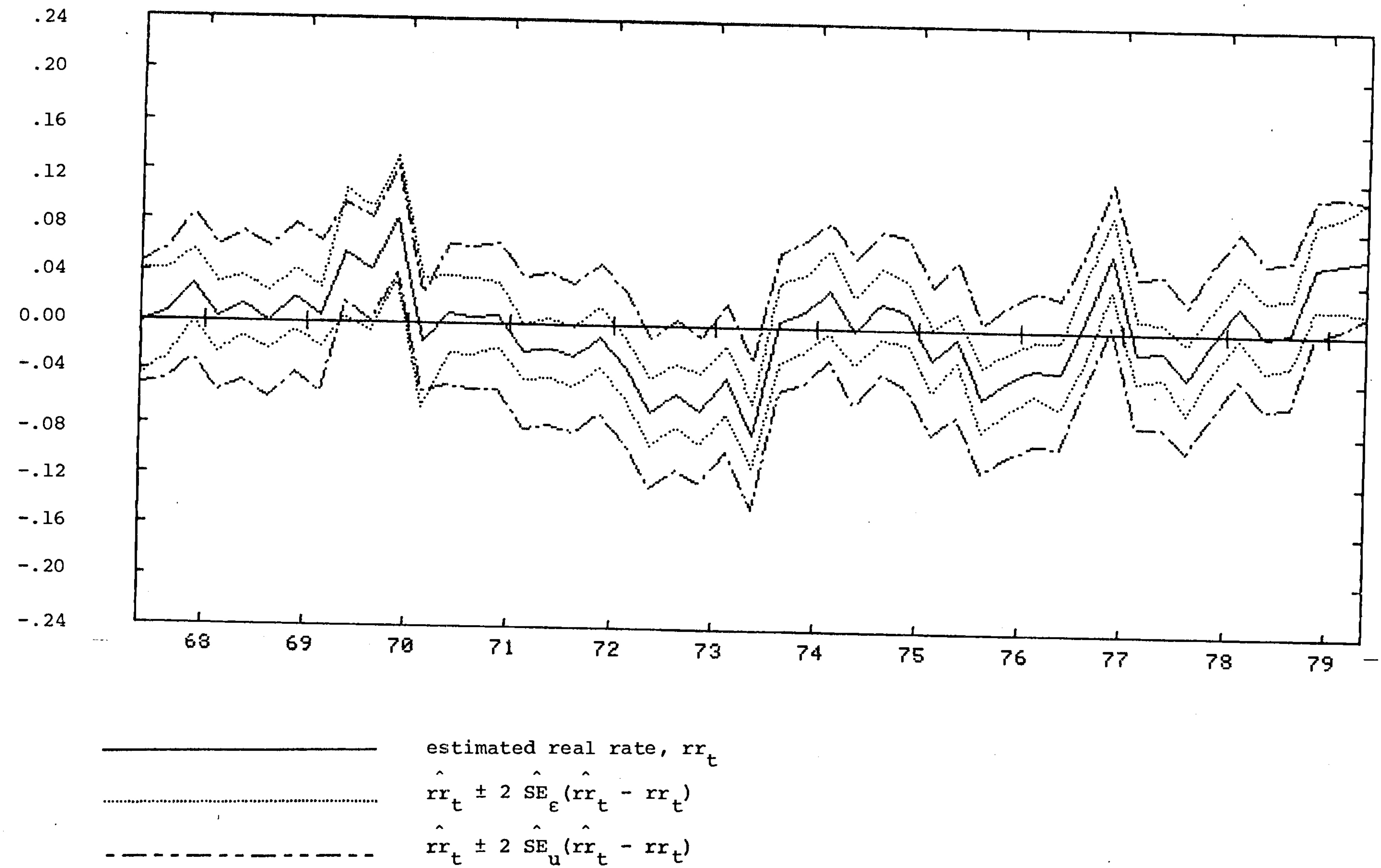


FIGURE 7

Dutch Guilder

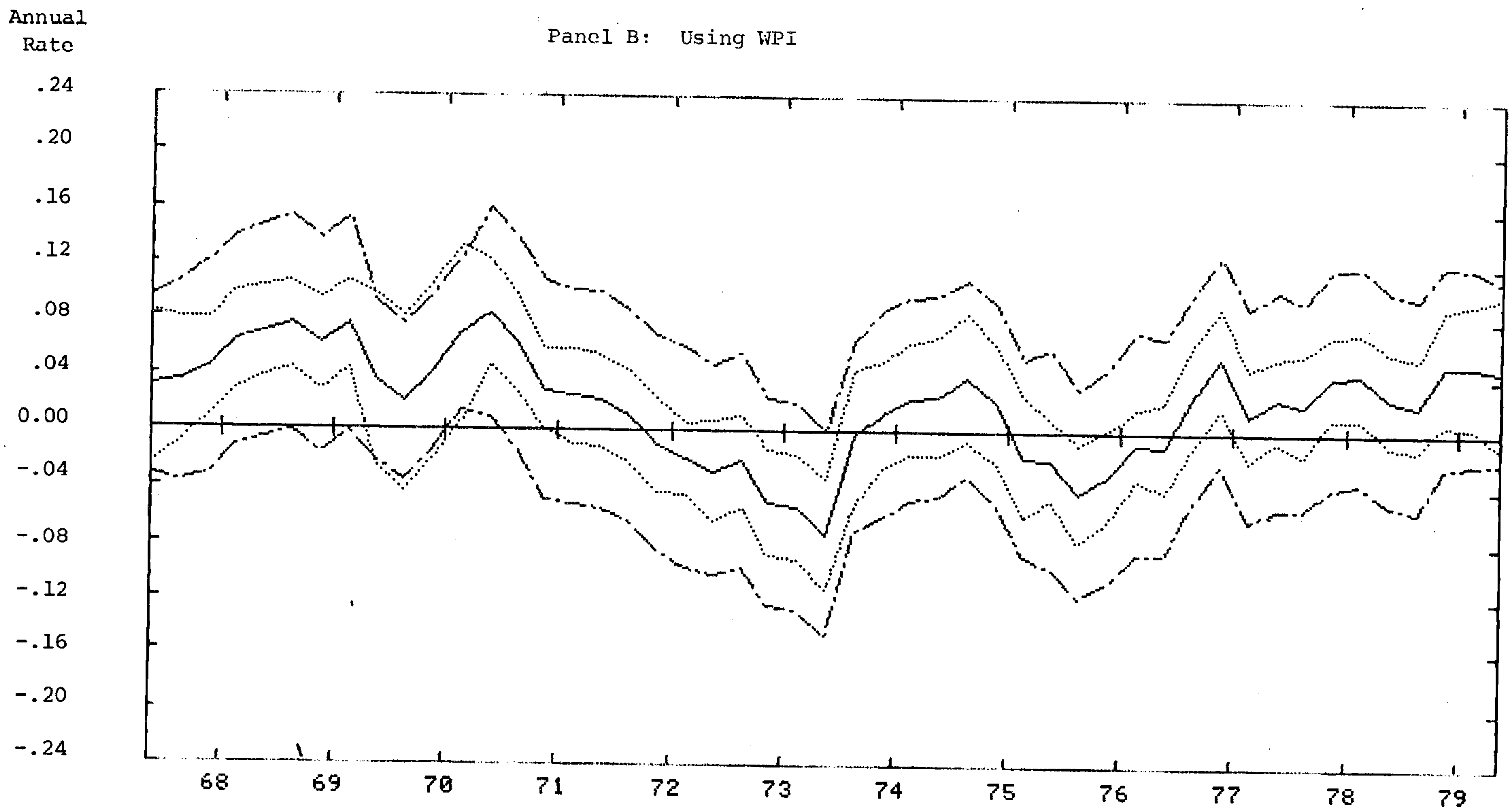
Estimated Real Euro Rate with 95% Confidence Intervals

Panel A: Using CPI



Dutch Guilder

Panel B: Using WPI



estimated real rate, rr_t

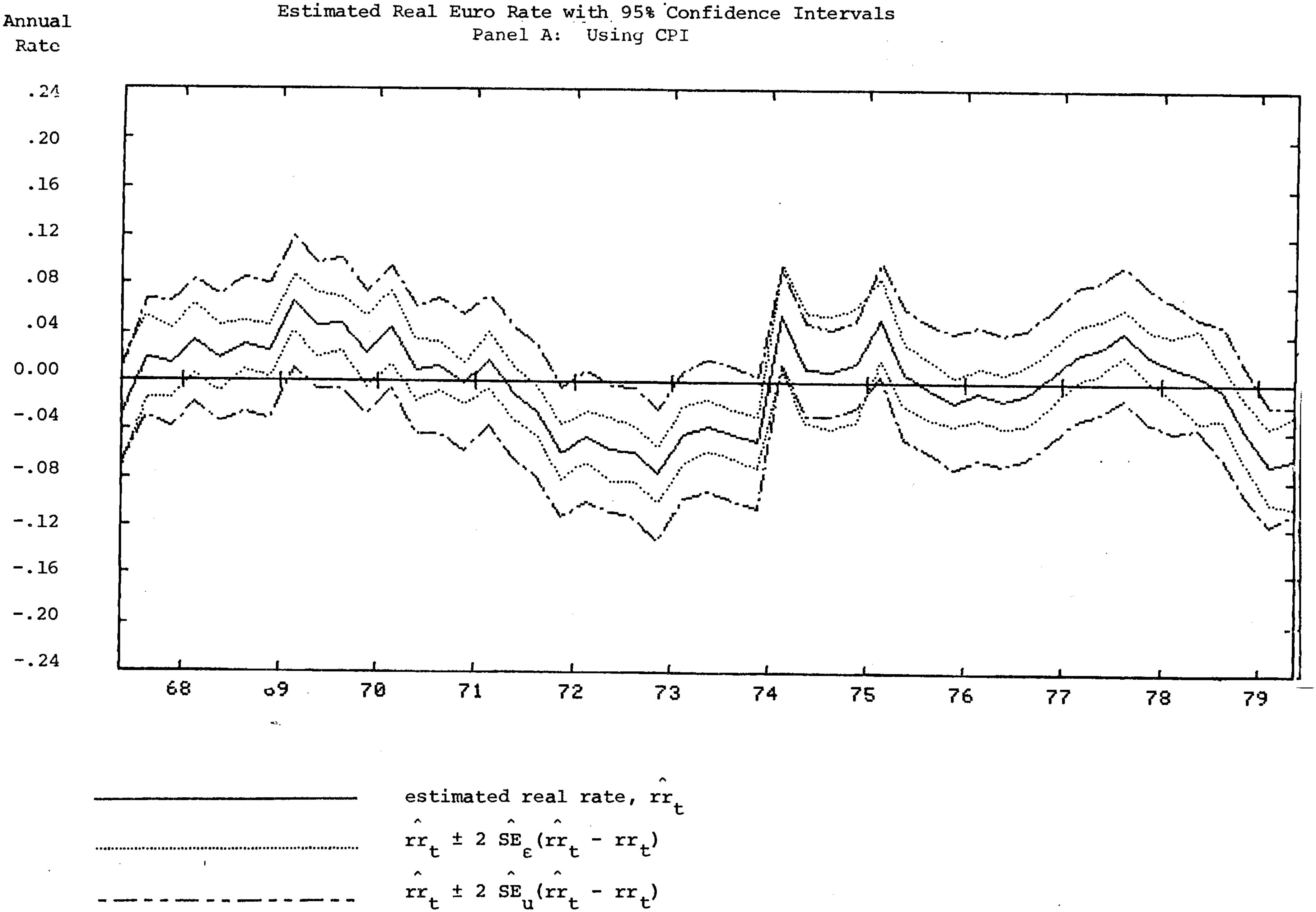
$\hat{rr}_t \pm 2\ \hat{SE}_{\varepsilon}(\hat{rr}_t - rr_t)$

$\hat{rr}_t \pm 2\ \hat{SE}_{u}(\hat{rr}_t - rr_t)$

FIGURE 8

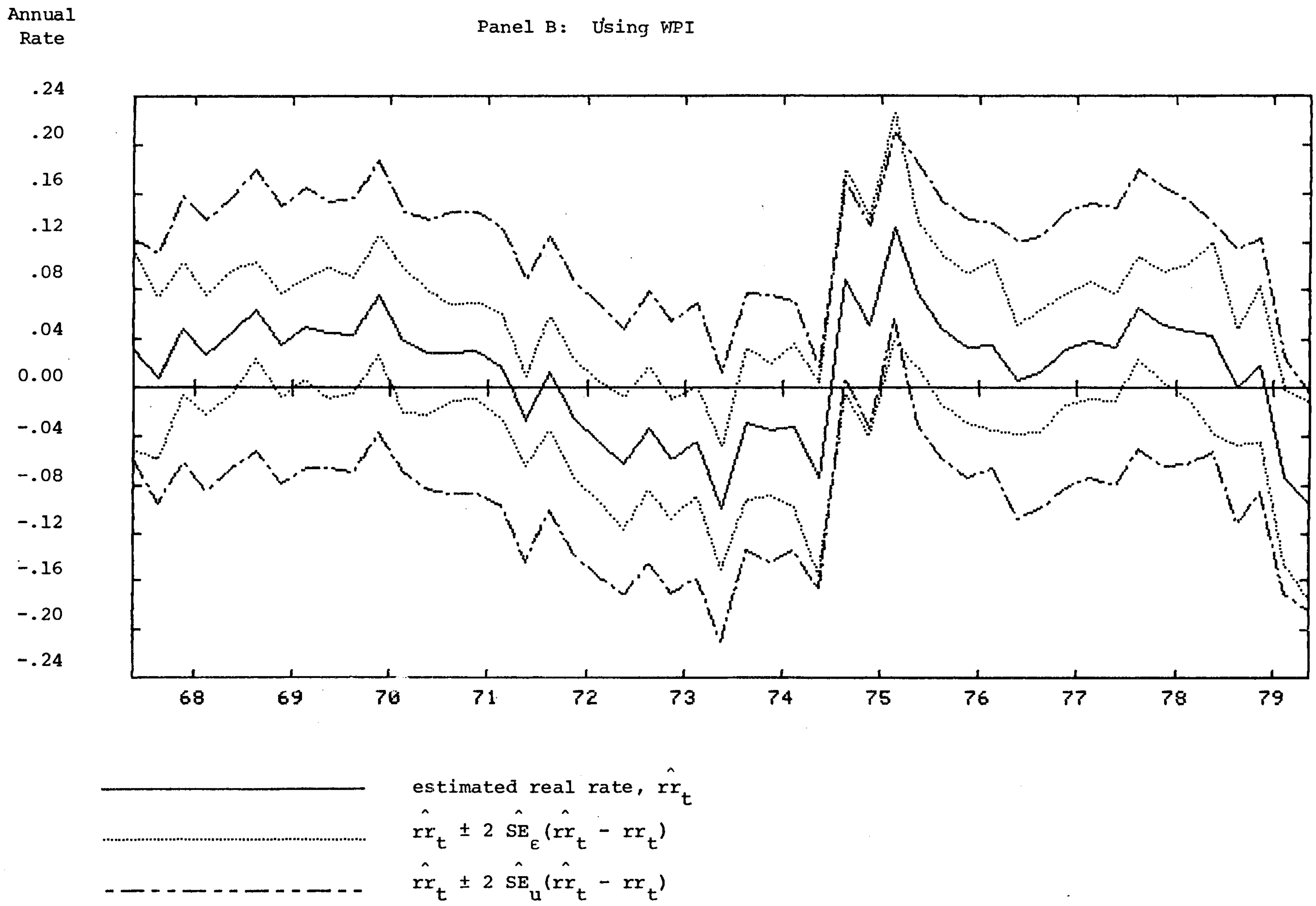
Swiss Franc

Estimated Real Euro Rate with 95% Confidence Intervals
Panel A: Using CPI



Swiss Franc

Panel B: Using WPI



not surprising considering the larger fluctuations in the British inflation rates. The French estimated real rates are particularly interesting because the results are so different depending on whether the CPI or WPI is used to calculate real returns. Both the CPI and WPI results indicate very high rates during the exchange rate crisis of 1968 and these are significantly positive. In 1974 both real rates rise substantially. However, the WPI real rate reaches an annual rate of 33 percent, while the CPI real rate only rises to 8 percent. The sharp differences in the French CPI and WPI real rates are the result of widely diverging patterns of CPI and WPI inflation for France.[25] Particularly striking is the fact that the French WPI actually declines in 1974 while the CPI inflation rate is substantial. This deflation of the WPI when the nominal French euro rate was high is the source of the unusually high WPI real rate in 1974. The German, Dutch and Swiss estimated real rates are also positive in the late 60's, sometimes significantly so; decline somewhat until 1974, rise and then fall in 1974; and then fluctuate around zero thereafter.

The estimated real rates in Figures 2 through 8 do have substantially different values in the seven OECD countries — real rate differentials of over 10 percent are not uncommon — but there are some similarities. The real euro rates are positive for most countries in the late '60s, decline thereafter, rise in 1974 and then fall back down again. More formal tests of the relations of these real rates across countries can be found in Mishkin (1982).

The estimates of the real rate in Figures 2-8 can be used to derive estimates of the expected inflation rate for each country, $\hat{\pi}^e_t$. It is easily

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25 See Frenkel (1981a).

calculated by substracting the estimated real rate, $\hat{rr}_t$, from the nominal interest rate, i_t: i.e.

(20) $$\hat{\pi}^e_t = i_t - \hat{rr}_t = i_t - X_{t-1}\hat{\beta}.$$

and its error is

(21) $$\pi_t - \pi^e_t = i_t - rr_t - (i_t - \hat{rr}_t) = -(rr_t - \hat{rr}_t).$$

Because this measure of expected inflation is likely to be more rational than alternative survery measures, Mishkin (1981a) argues that it is a potentially more accurate measure of the expected inflation rate. In addition, since the absolute value of its error equals that of the estimated real rate, standard error bounds are obtainable from equations (18) and (19).

Figures 9-15 show the relationship between each country's estimated expected inflation, real rates and nominal interest rates.[26] Table 6 provides the correlations of these variables for each country. Because there may be non-stationarity in these variables, we must be somewhat cautious in drawing inferences from these correlations. They are useful, however, as summary statistics that can help us pick out the co-movements in the figures.

As we would expect from the significant correlation of ex post real rates and lagged inflation, the negative correlation of expected inflation and real euro rates is sizeable. However, despite this, there is evidence of the Fisher effect: i.e., the positive correlation of expected inflation and

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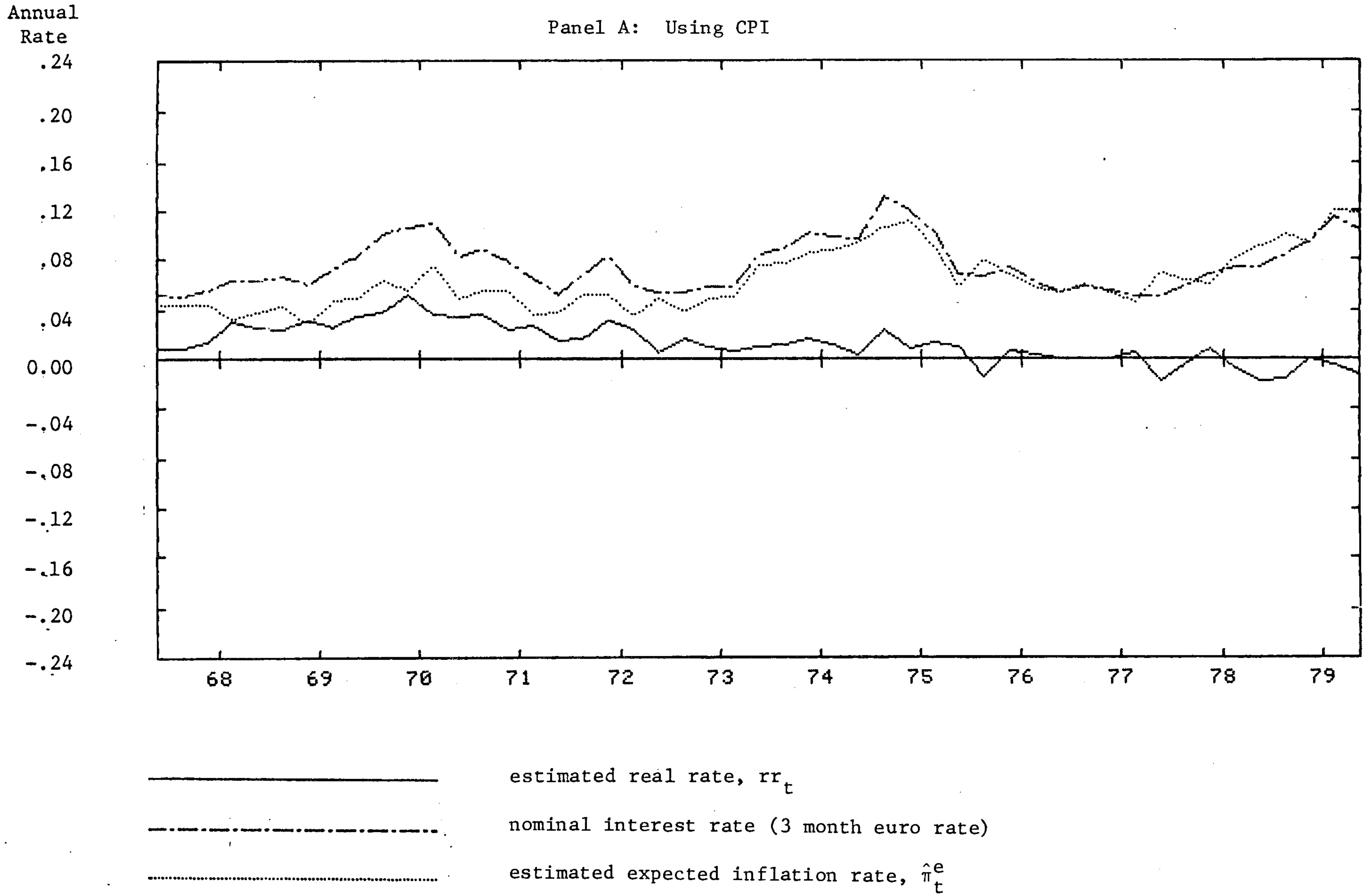
26 The nominal euro rate plotted in these figures is the continuously compounded rate rather than the coupon rate reported in the Harris Bank tape.

U.S. Dollar

Nominal Interest Rates, Estimated Real Rates and Estimated Expected Inflation

Panel A: Using CPI



U.S. Dollar

Panel B: Using WPI

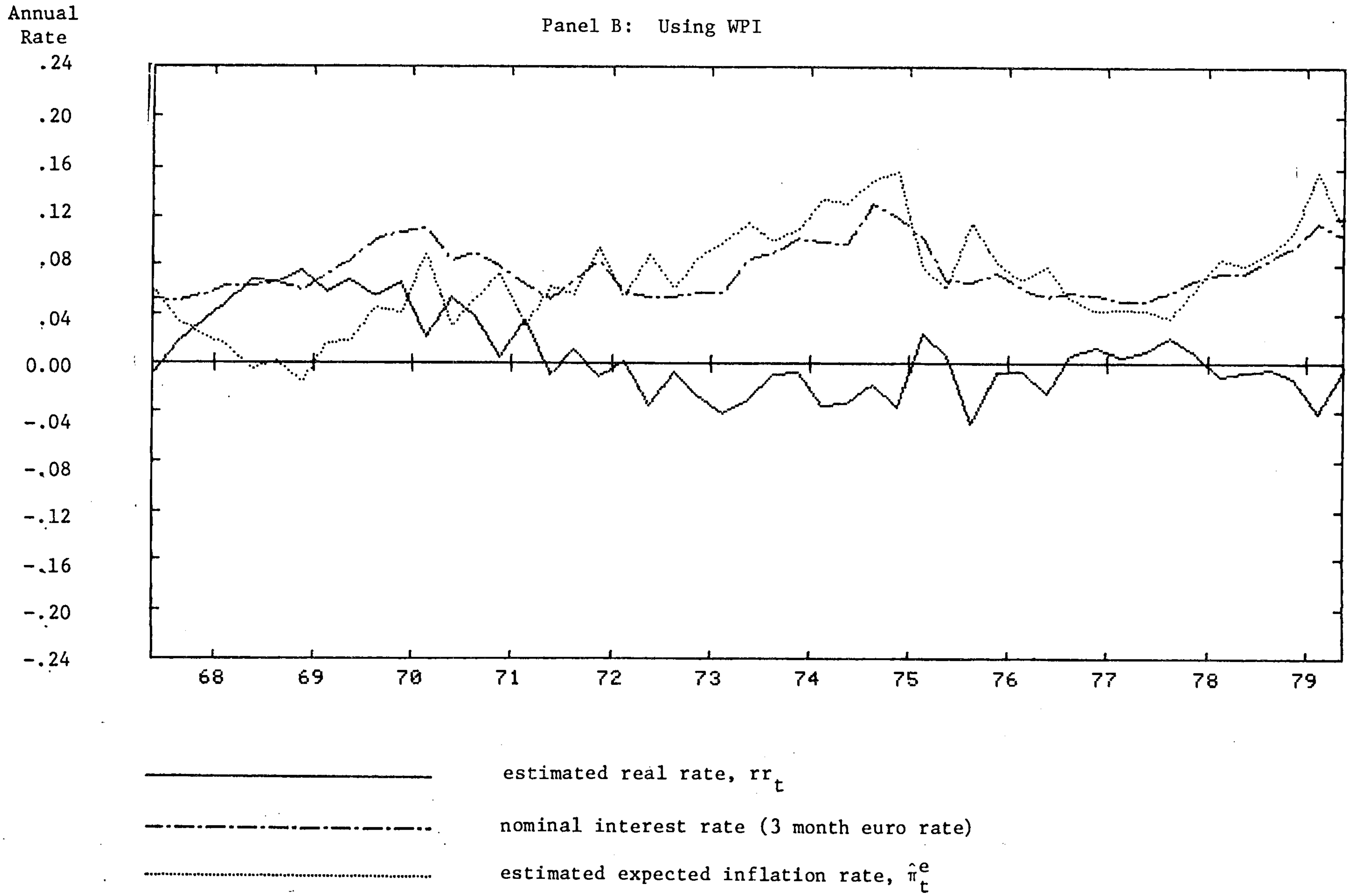
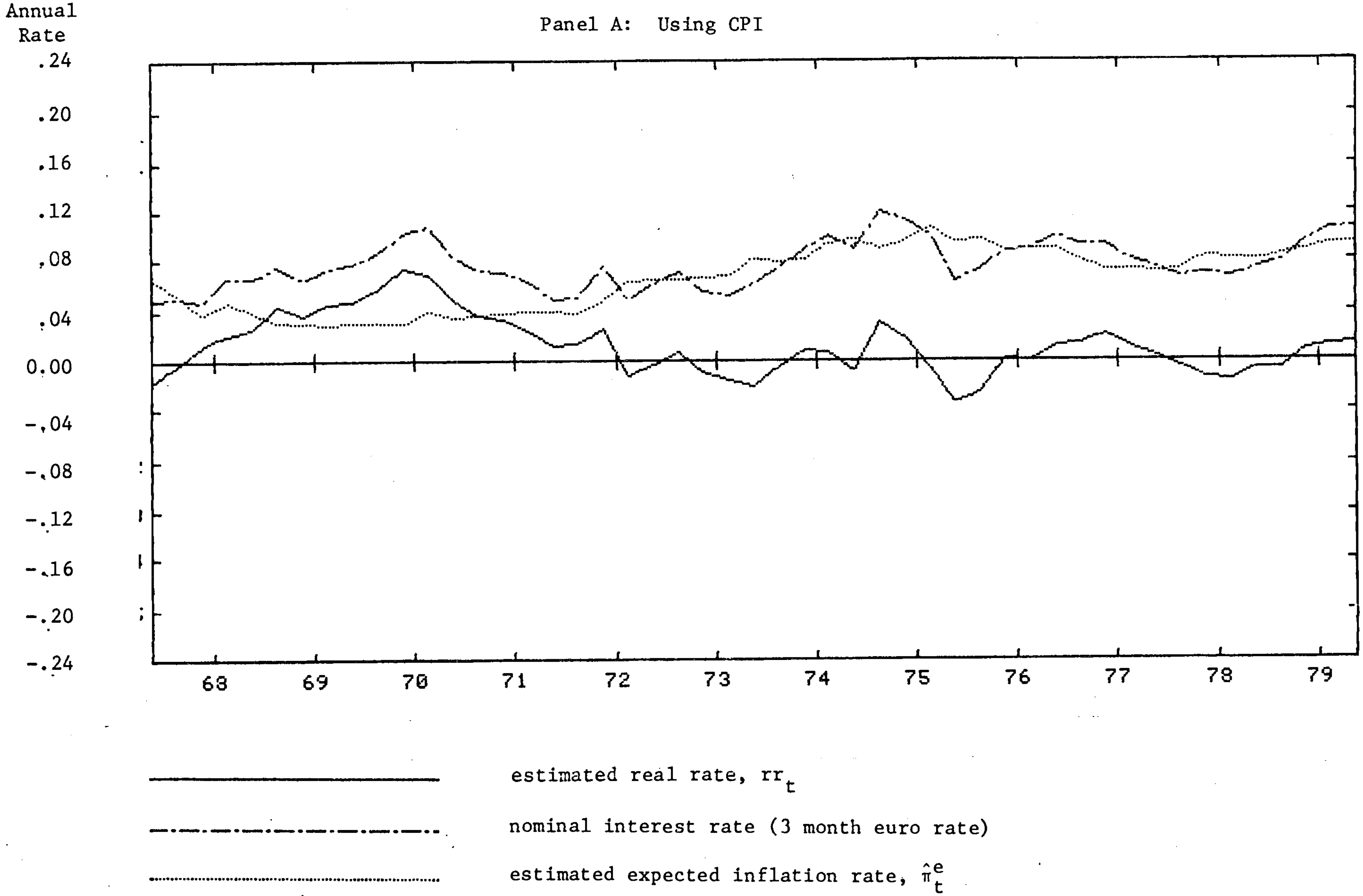


Figure 10

Canadian Dollar

Nominal Interest Rates, Estimated Real Rates and Estimated Expected Inflation

Panel A: Using CPI



Canadian Dollar

Panel B: Using WPI

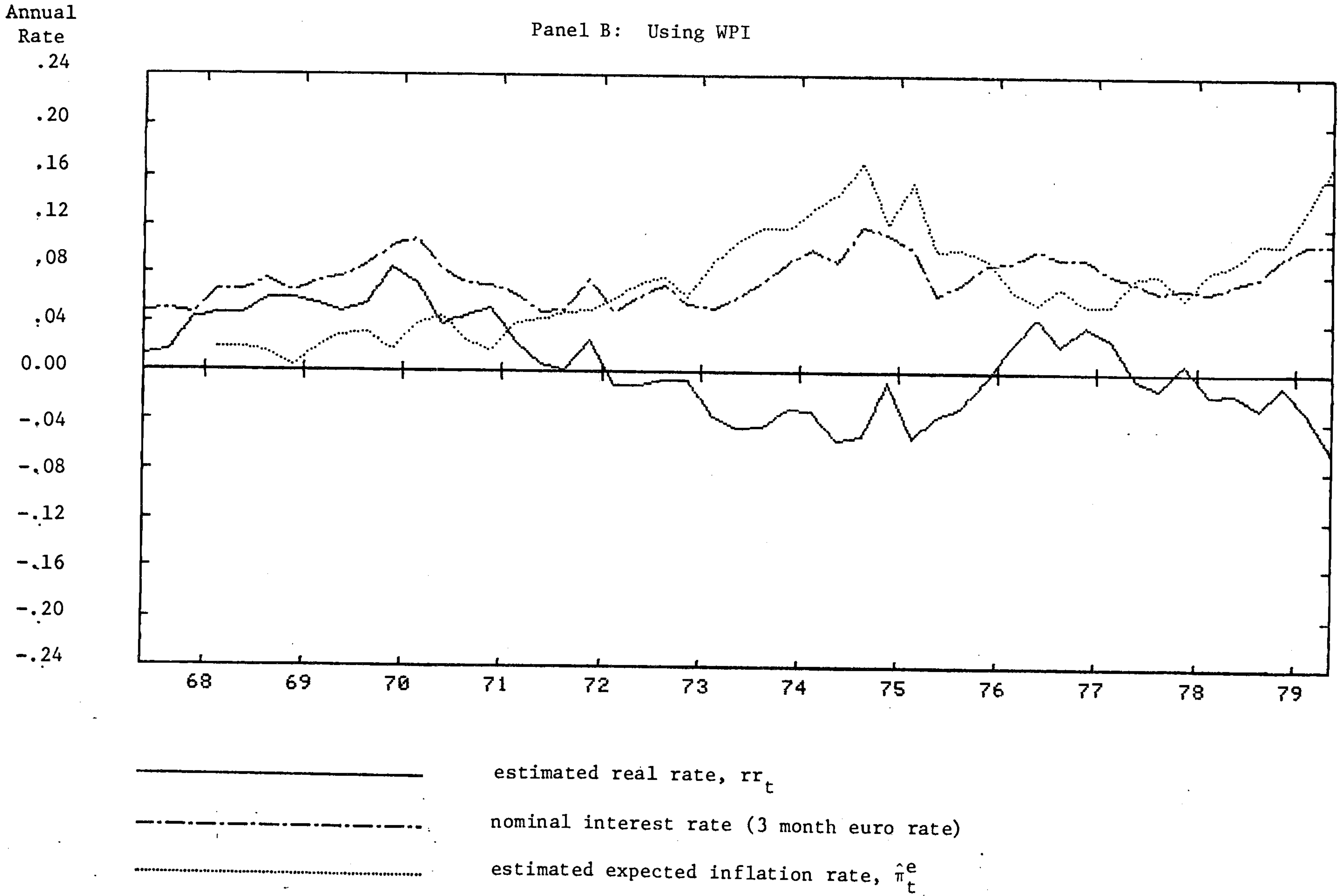
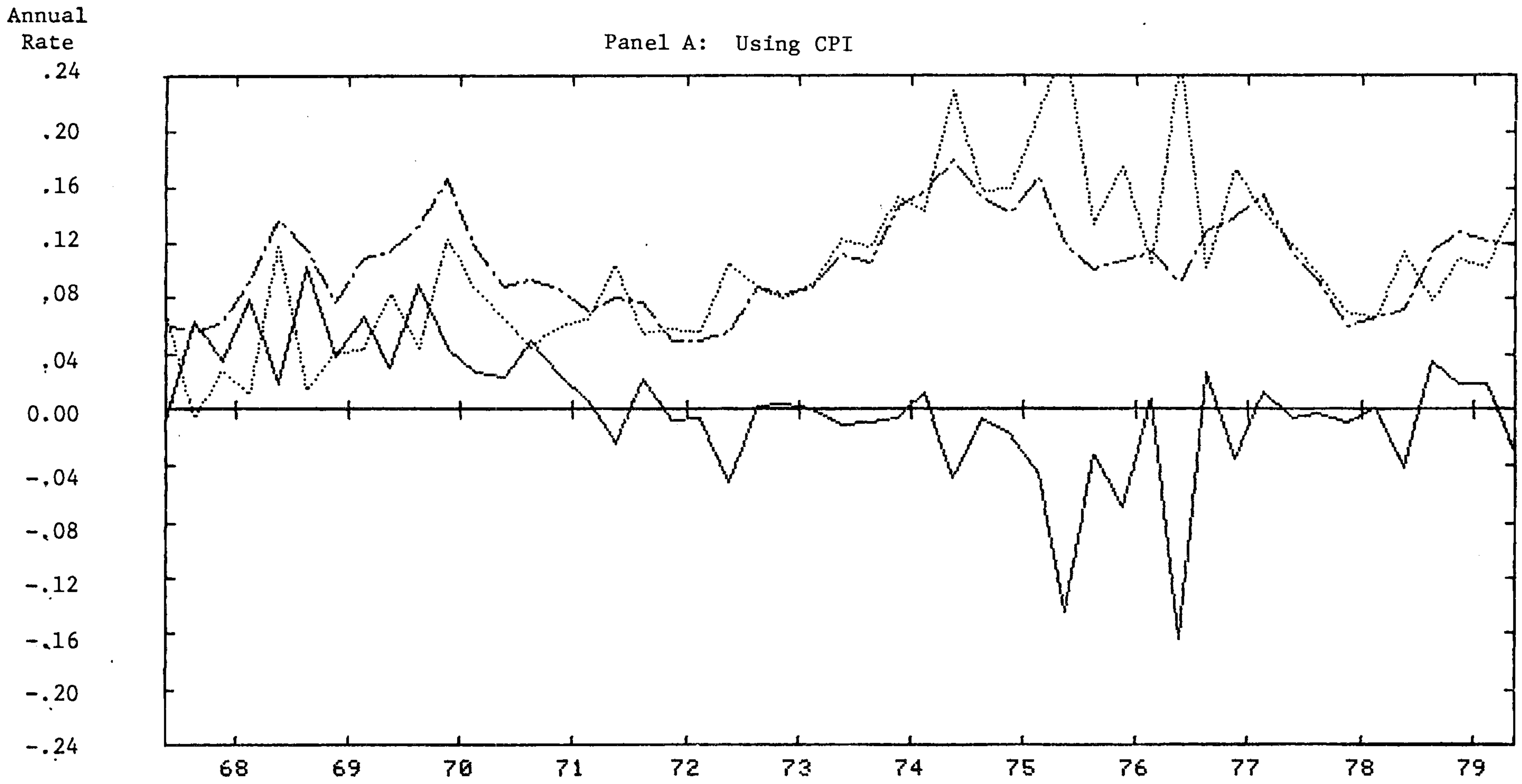


Figure 11

United Kingdom Pound Sterling

Nominal Interest Rates, Estimated Real Rates and Estimated Expected Inflation

Panel A: Using CPI



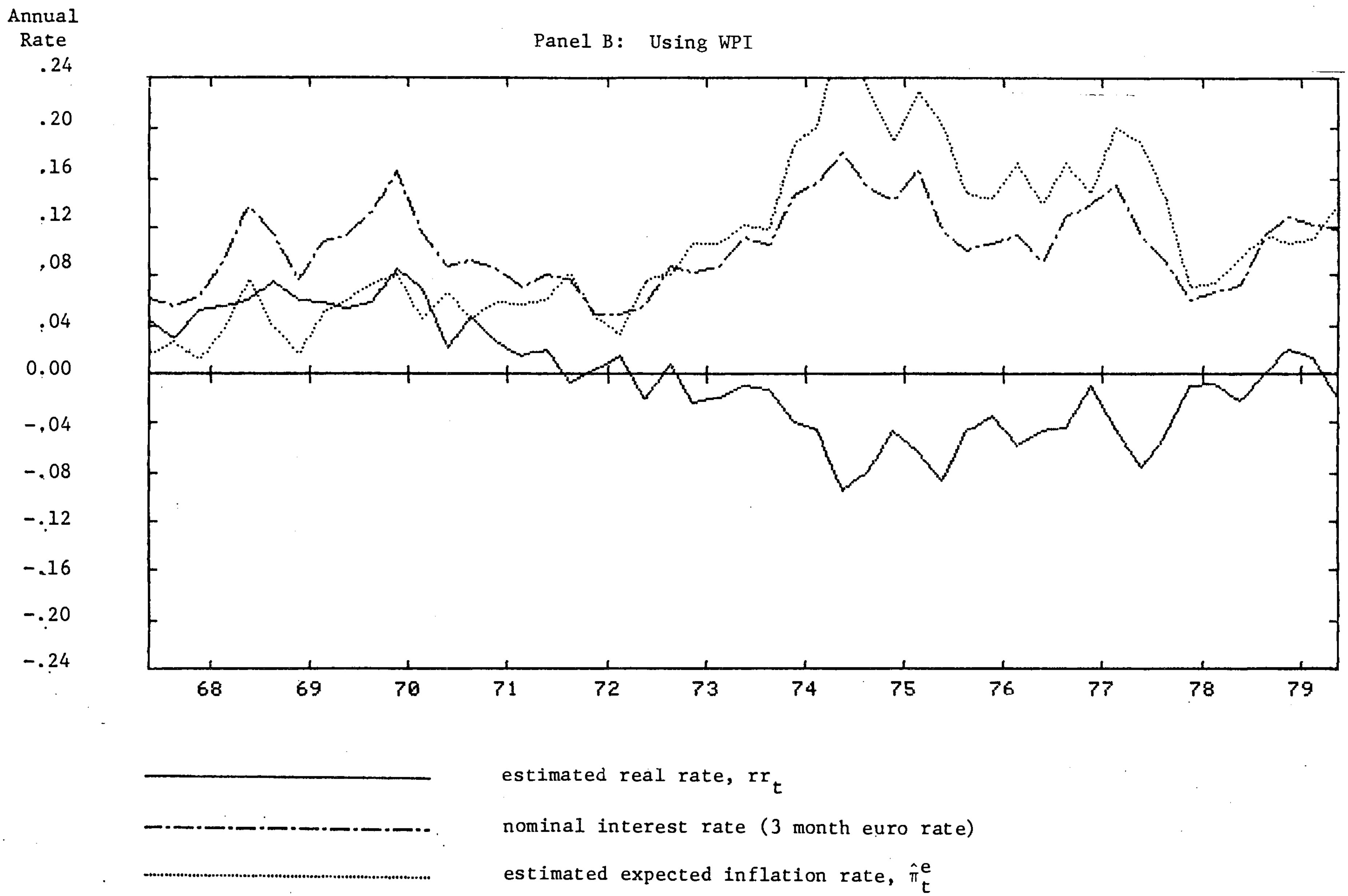
estimated real rate, rr_t

nominal interest rate (3 month euro rate)

estimated expected inflation rate, $\hat{\pi}_t^e$

United Kingdom Pound Sterling

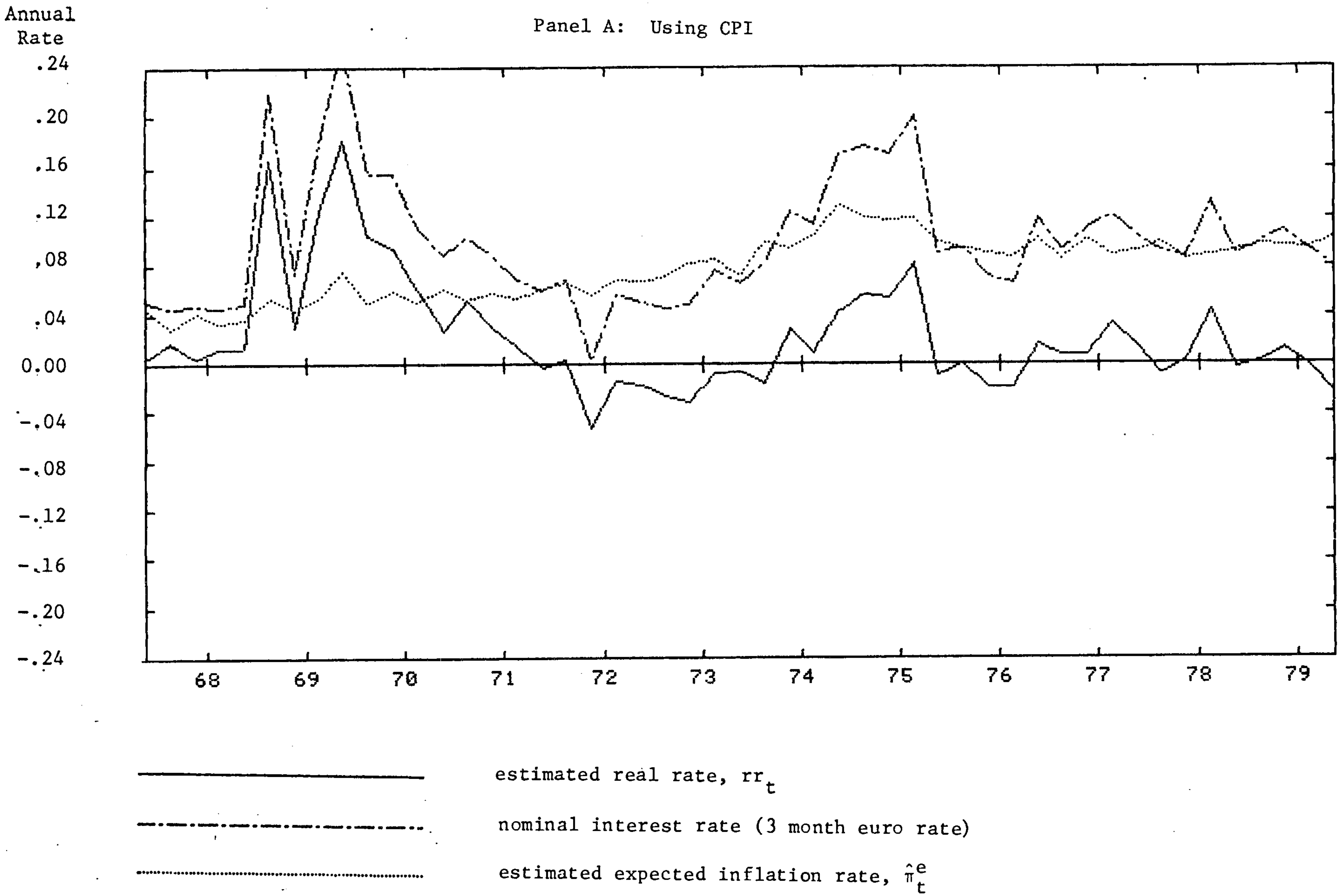
Panel B: Using WPI



French Franc

Nominal Interest Rates, Estimated Real Rates and Estimated Expected Inflation

Panel A: Using CPI



French Franc

Panel B: Using WPI

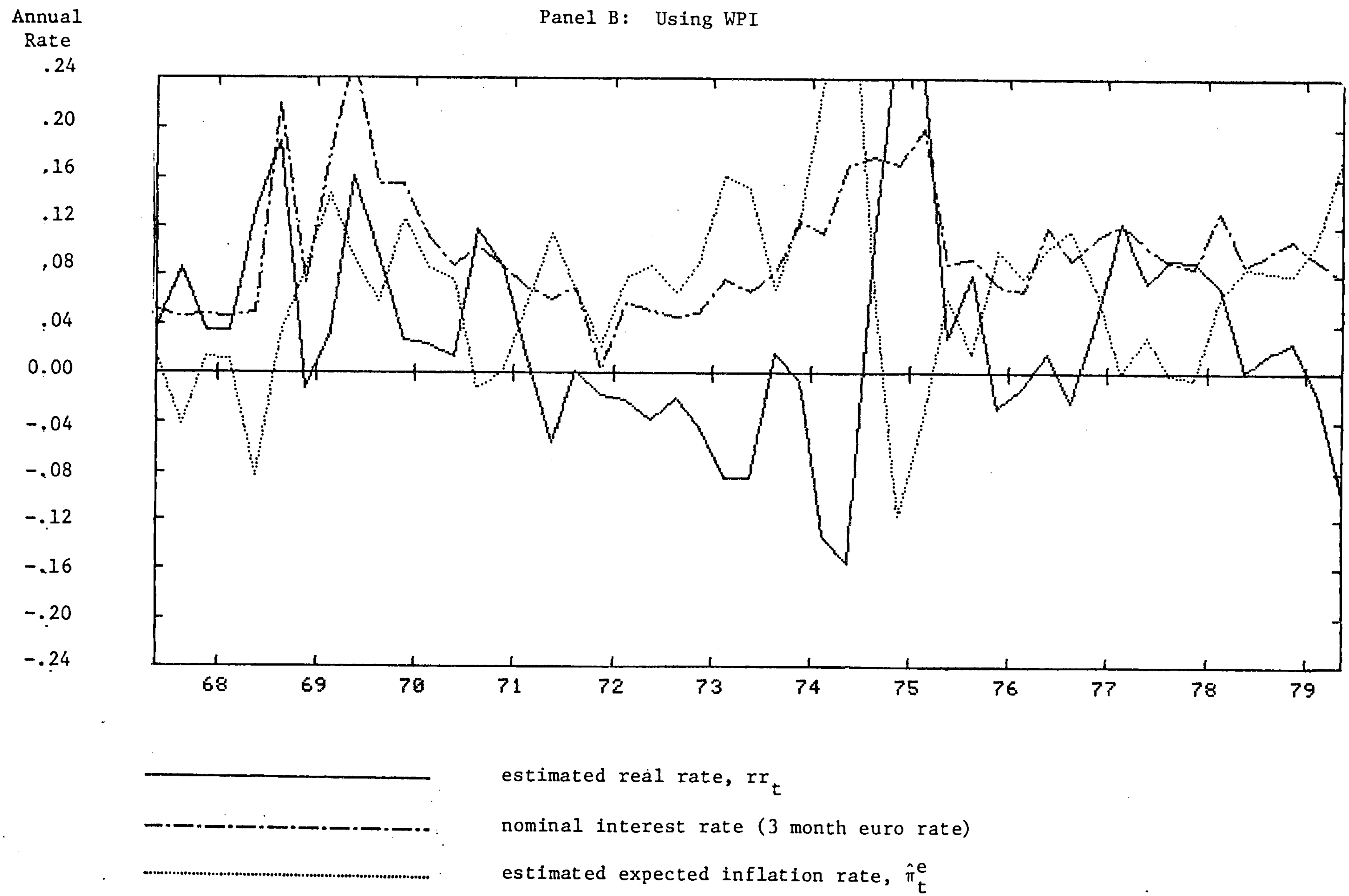
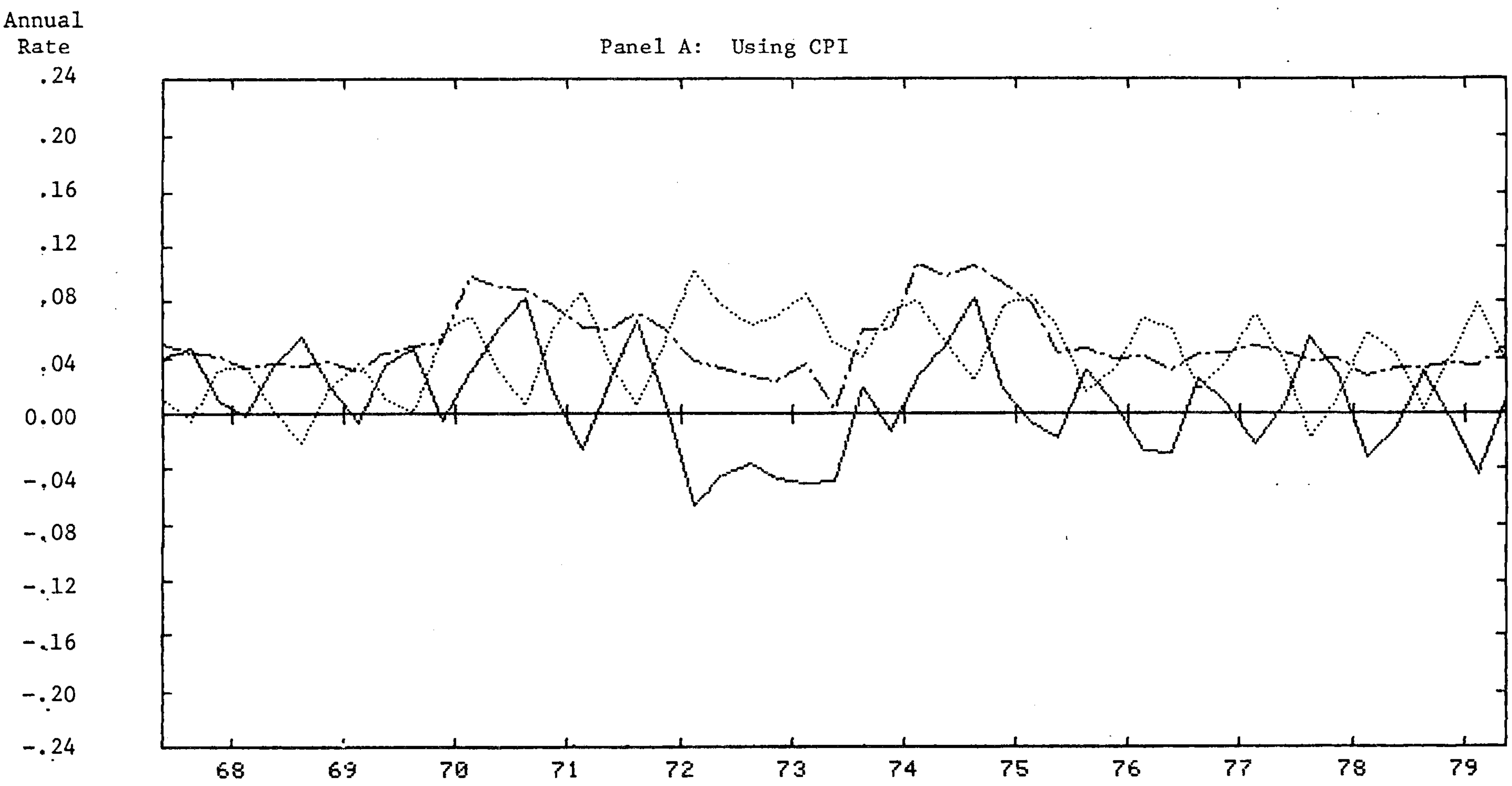


Figure 13

West Germany Deutsche Mark

Nominal Interest Rates, Estimated Real Rates and Estimated Expected Inflation

Panel A: Using CPI



estimated real rate, rr_t

nominal interest rate (3 month euro rate)

estimated expected inflation rate, $\hat{\pi}_t^e$

West Germany Deutsche Mark

Panel B: Using WPI

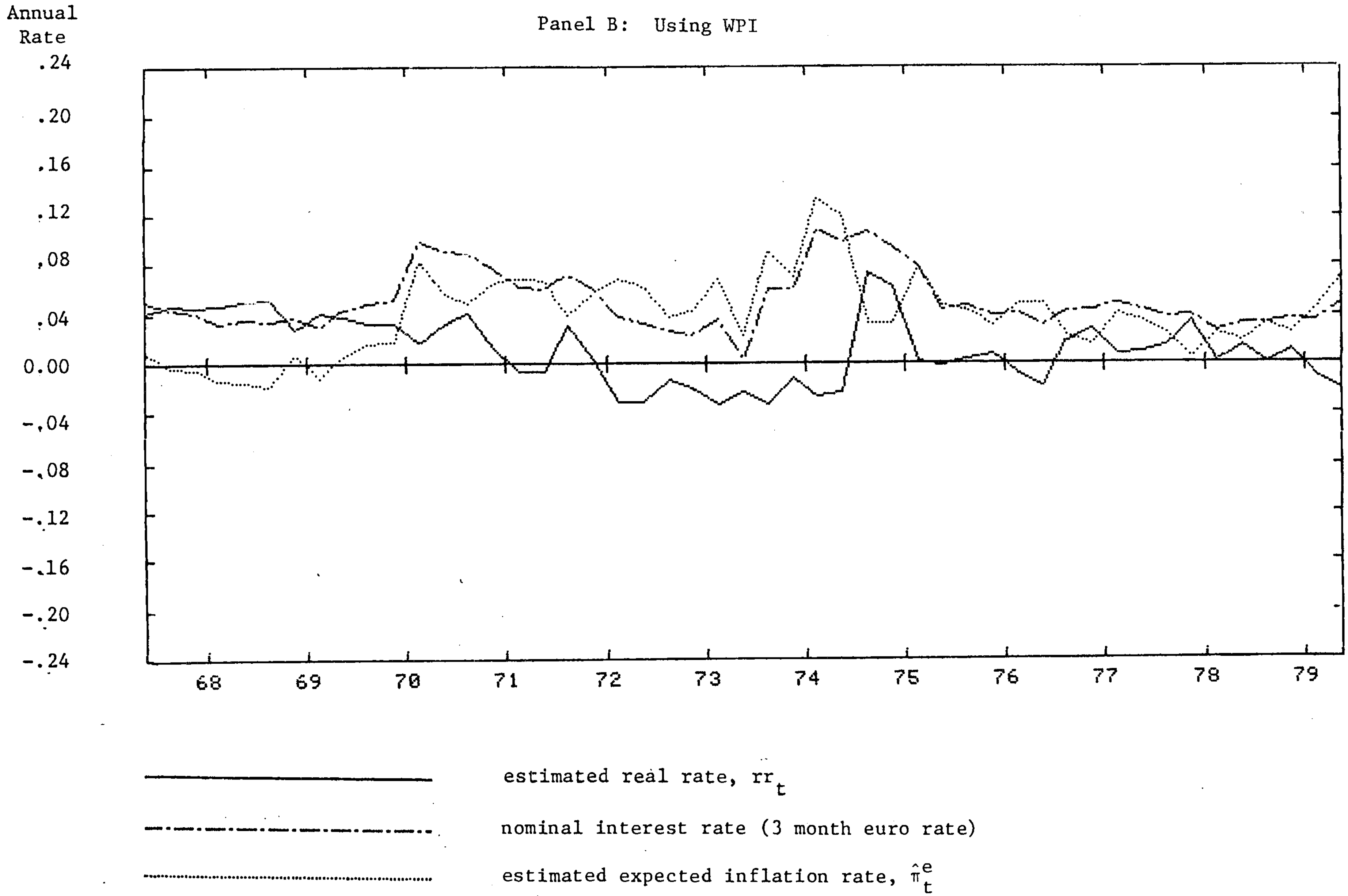
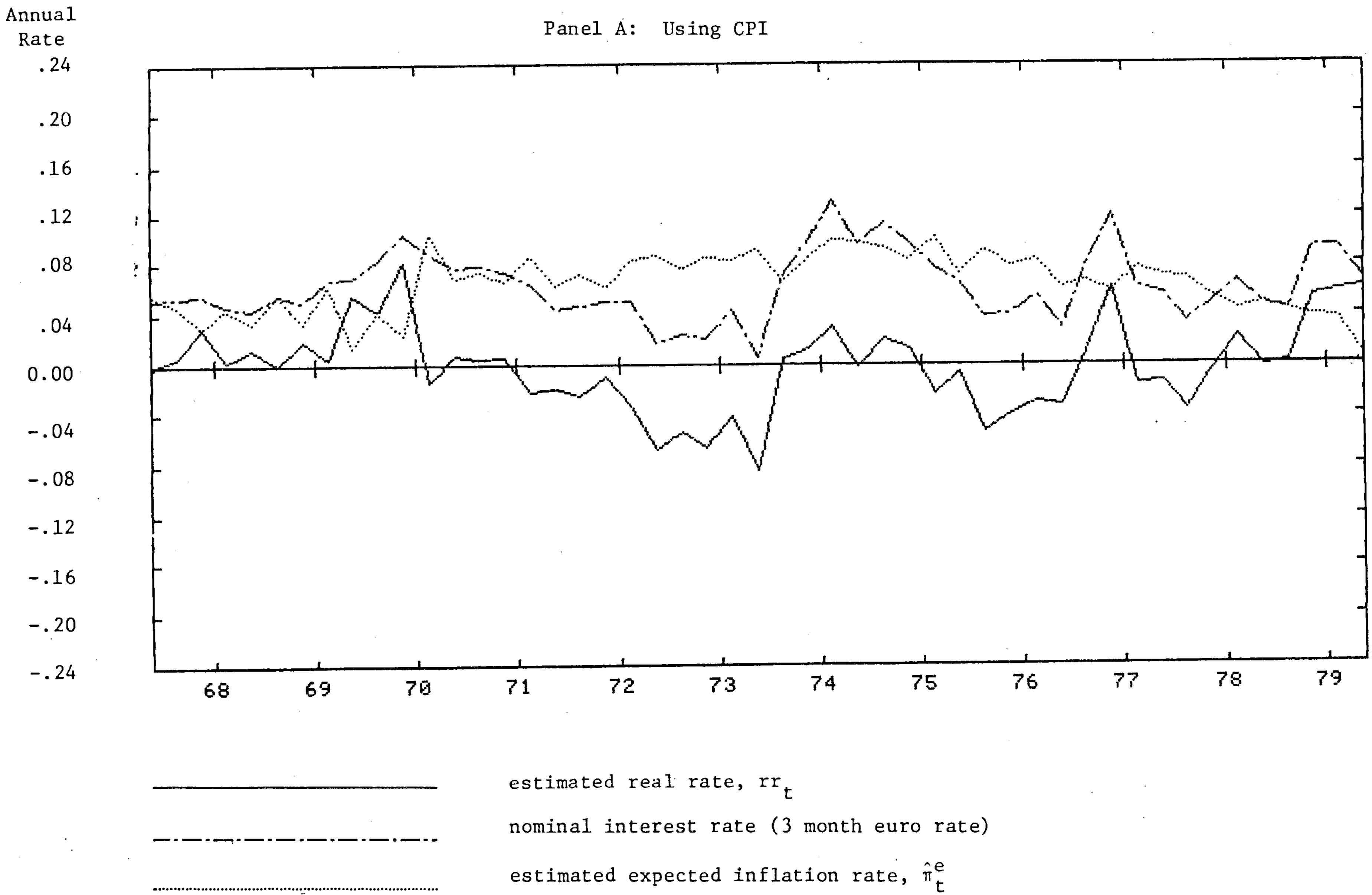


Figure 14

Dutch Guilder

Nominal Interest Rates, Estimated Real Rates and Estimated Expected Inflation

Panel A: Using CPI



Dutch Guilder

Panel B: Using WPI

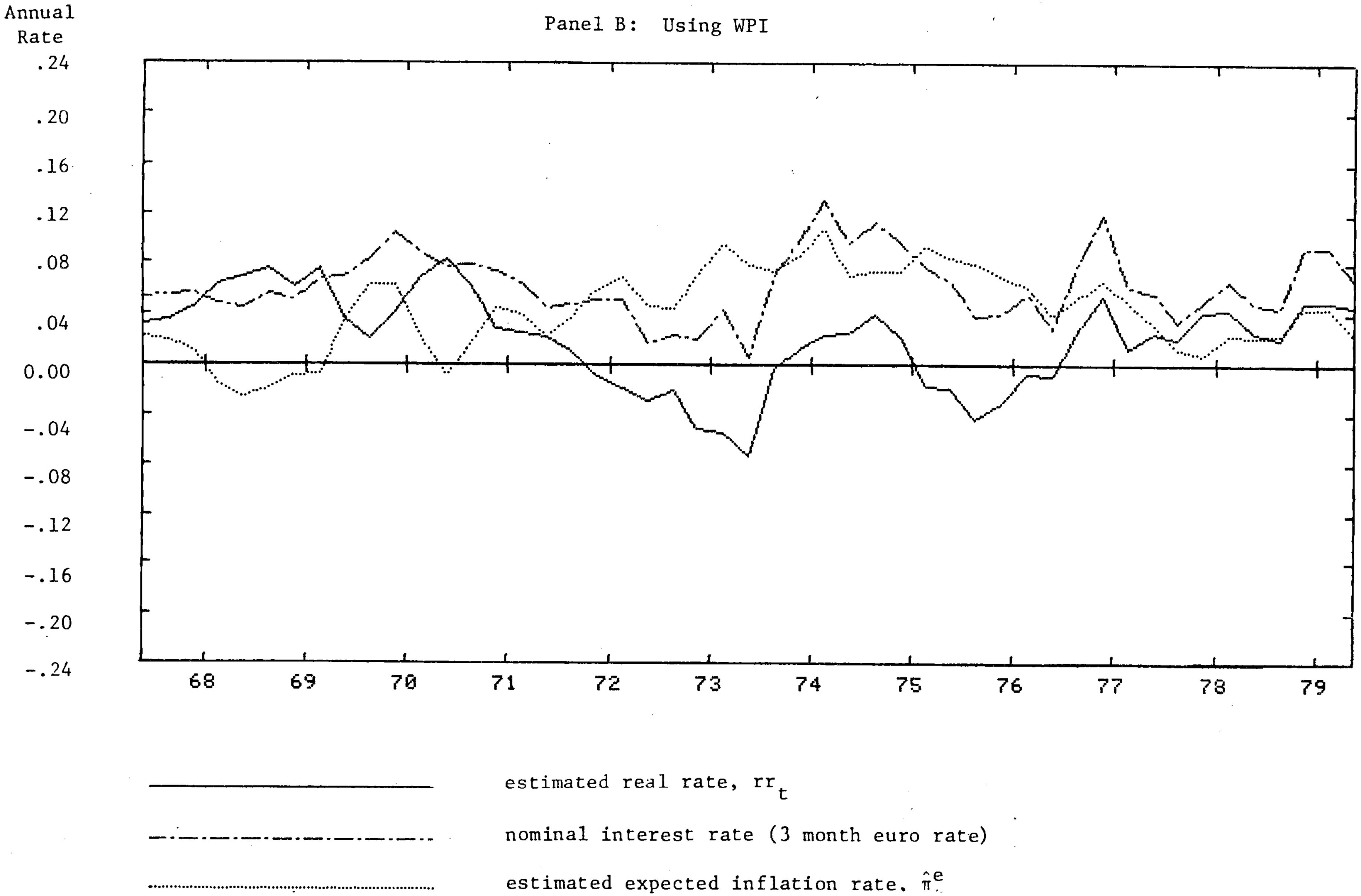
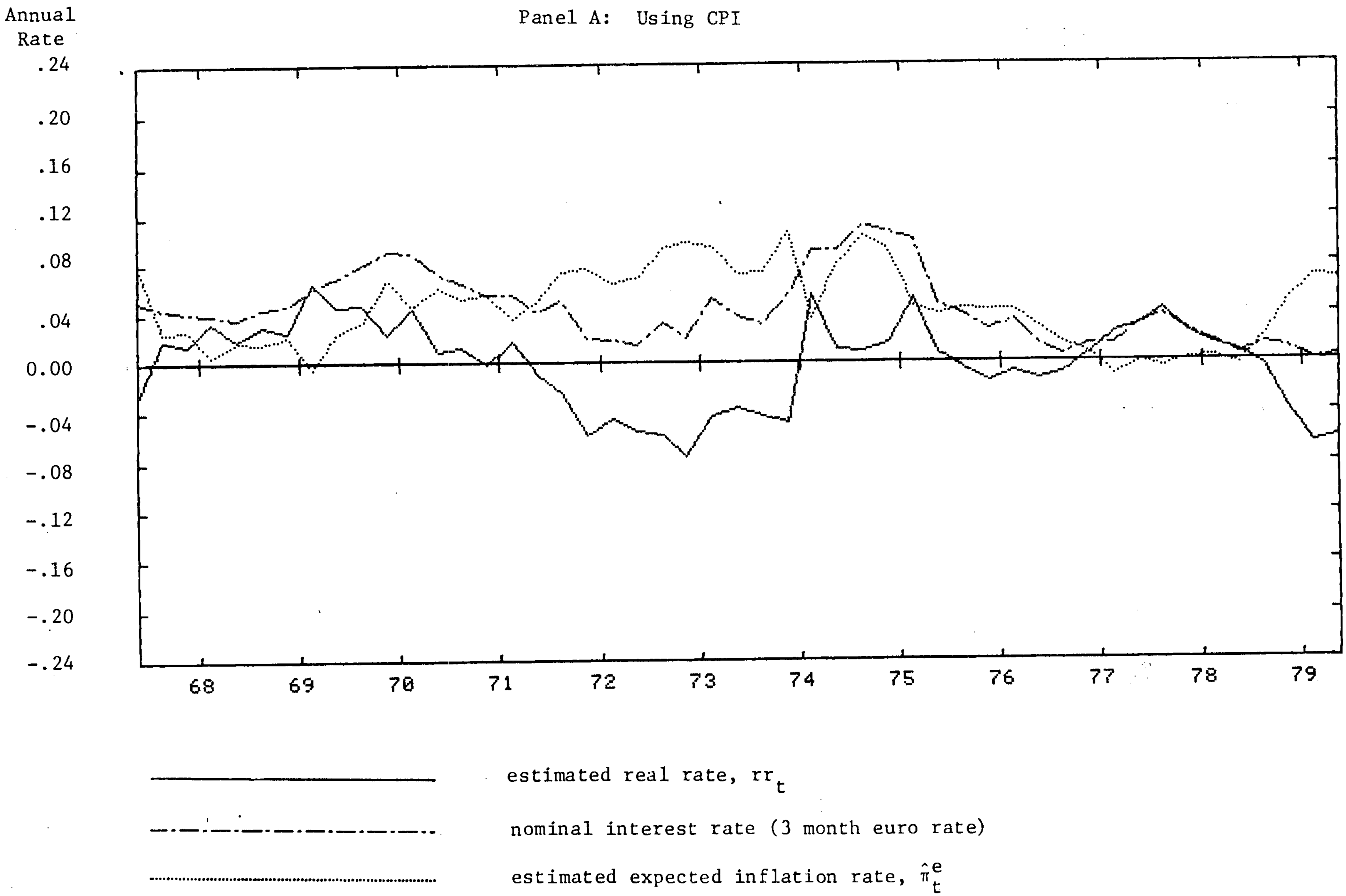


Figure 15

Swiss Franc

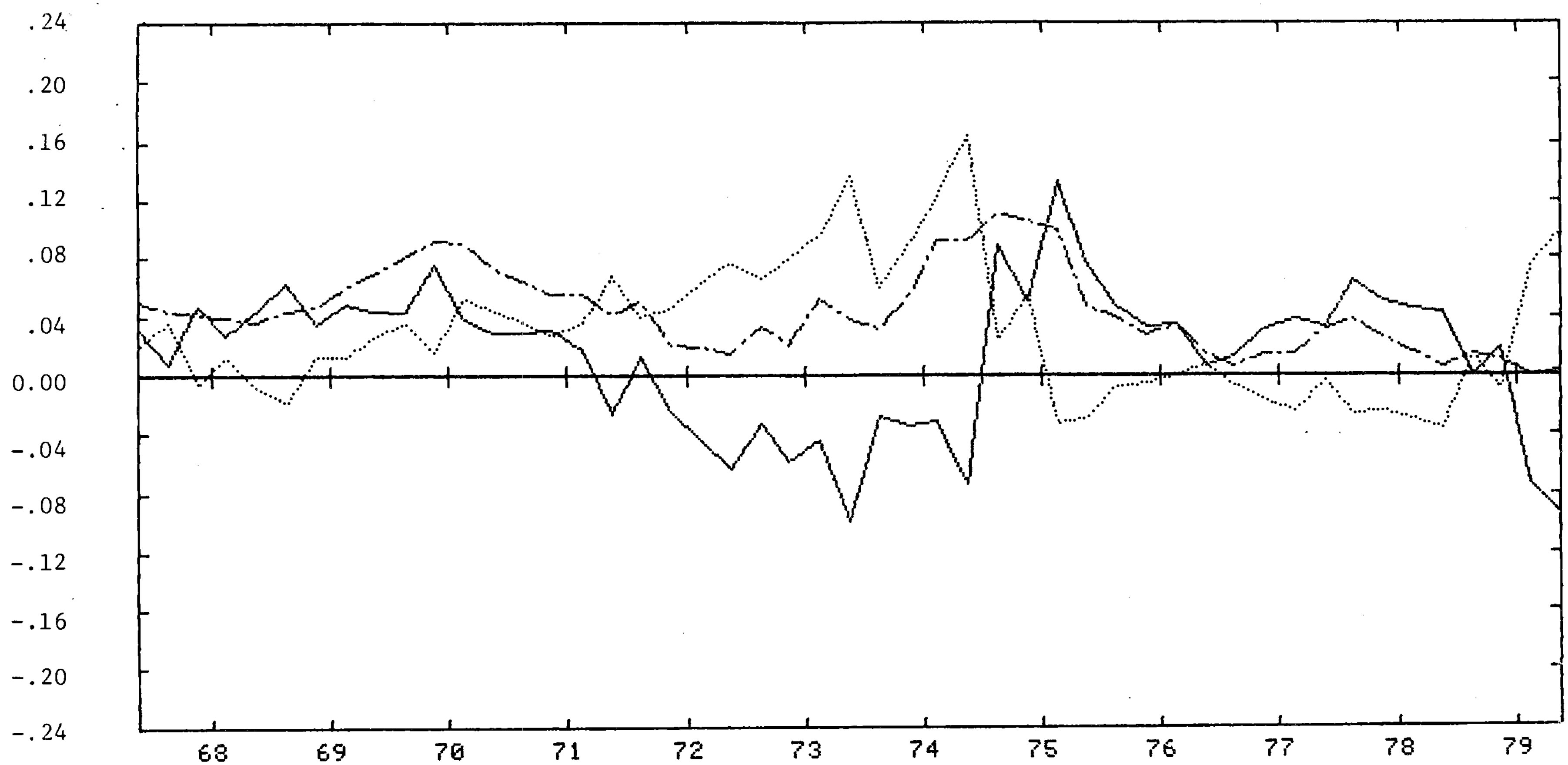
Nominal Interest Rates, Estimated Real Rates and Estimated Expected Inflation

Panel A: Using CPI



Swiss Franc

Panel B: Using WPI



estimated real rate, rr_t

nominal interest rate (3 month euro rate)

estimated expected inflation rate, $\hat{\pi}_t^e$

TABLE 6

Correlations of Nominal Euro Rates, Expected Inflation, and Real Euro Rates

		PANEL A: Using CPI							PANEL B: Using WPI						
	Countries	US	CA	UK	FR	FD	ND	SW	US	CA	UK	FR	FD	ND	SW
1.1	Correlation of nominal euro rates and expected inflation	.75	.40	.58	.37	.11	-.00	.30	.60	.50	.72	.12	.57	.26	.22
1.2	Correlation of real euro rates and expected inflation	-.48	-.70	-.82	-.12	-.76	-.66	-.65	-.86	-.90	-.87	-.81	-.69	-.71	-.82
1.3	Correlation of real and nominal euro rates	.21	.38	-.02	.87	.56	.75	.53	-.09	-.08	-.29	.49	.19	.50	.37

nominal interest rates. It is strong for the United States, Canada and the United Kingdom using both the CPI and WPI price indices, but is much less so for Germany, France, the Netherlands and Switzerland. As is found in the earlier regression results, there is an usually strong positive association between nominal and real euro rates for France, Germany, the Netherlands and Switzerland, while this is not the case for the United States, Canada and the United Kingdom. However, what is striking in Table 6 is the finding that Fama's (1975) conclusion that, in the post-war period, movements in nominal rates primarily reflect movements in expected inflation is not generally true outside of the United States. Only Canada and the United Kingdom join the United States in displaying this phenomenon. To the contrary, for France, the Netherlands and Switzerland using both price indices, and Germany using the CPI, movements in nominal rates are less highly correlated with movements in expected inflation than they are with movements in real rates.

IV. CONCLUSIONS

This paper has studied real rate movements in seven OECD countries over the 1967-II to 1979 II sample period. The empirical analysis has been directed at several questions posed in the introduction and now, is an appropriate time to provide answers by way of summarizing the empirical evidence.

1. The hypothesis that the real rates in these countries is constant is rejected at extrmely low marginal significance levels. The rejections here are exceedingly strong and confirm a similar finding for U. S. data alone.

2. The real rates in these countries do decline with increased inflation. This confirms that this relationship is not unique to the United States.

3. Real Rates in these countries also decline with higher money growth. This non-neutrality result which has been previously found for the U. S. seems to be prevalent elsewhere.

4. Nominal Euro rates have not been reliable indicators of the movements in real rates for the United Kingdom and Canada as well as the United States. This gives some further justification for why nominal interest rates might have been a misleading target for monetary policy in these countries. In contrast, France, Germany, the Netherlands, and Switzerland frequently exhibit a strong positive correlation of nominal and real rate movements. Thus nominal interest rates may be less misleading as an indicator of monetary tightness in these countries than has been true for the United States, the United Kingdom and Canada.

5. In the seven countries, real euro rates have been most positive in the late 1960's, decline somewhat thereafter, rose briefly in 1974 and then have come back down again. Significant negative real euro rates rarely appear in the 1970's in contrast to findings for the U.S. Treasury bill market, but this is explained by the substantial default risk in the euro market in this period.

6. There is a strong negative association of real interest rates and expected inflation for all seven countries, but nevertheless there is some evidence of a Fisher effect where higher expected inflation is associated with higher nominal interest rates. However, this effect does not appear to be as strong for France, Germany, the Netherlands and Switzerland as it is for the United States, Canada and the United Kingdom.

7. Fama's (1975) finding that movements in U. S. nominal interest rates in the post war period are more closely associated with movements in expected inflation than with movements in real rates is not generally true outside of the United States, Canada and the United Kingdom. The opposite result is found for France, the Netherlands, Switzerland and sometimes Germany.

REFERENCES

ALIBER, R. Z. (1980), "The Equivalence of Real Interest Rates in a Multi-currency World," in Issues in International Economics, P. Oppenheimer, ed., (Oriel Press: Stocksfield): 273-297.

__________ (1974), "Attributes of National Monies and the Interdependence of National Monetary Policies," in R. Z. Aliber, ed., National Monetary Policies and the International Financial System, (University of Chicago Press: Chicago).

CARGILL, T. F. (1976), "Anticipated Price Changes and Nominal Interest Rates in the 1950's." Review of Economics and Statistics 58 (August): 364-67.

CARLSON, J. A. (1977), "Short-term Interest Rates as Predictors of Inflation: Comment," American Economic Review 67: 469-75.

CUMBY, R., J. HUIZINGA and M. OBSTFELD (1980), "Two-Step, Two-Stage Least Squares Estimation in Models with Rational Expectations." Discussion Paper Series #71, Columbia University, Department of Economics (June).

CUMBY, R. E. and M. OBSTFELD (1981), "A Note on Exchange Rate Expectations and Nominal Interest Differentials: A Test of the Fisher Hypothesis." Journal of Finance 36 (June): 697-704.

__________, "International Interest-Rate and Price-Level Linkages Under Flexible Exchange Rates: A Review of Recent Evidence," National Bureau of Economic Research, Inc., (January 1982).

FAMA, E. F. (1970), "Efficient Capital Markets: A Review of Theory and Empirical Work." Journal of Finance 25: 383-417.

__________ (1975), "Short-Term Interest Rates as Predictors of Inflation," American Economic Review 65 (June): 269-82.

__________ and M. R. Gibbons (1982), "Inflation, Real Returns and Capital Investment" Journal of Monetary Economics

__________ and G. W. Schwert (1979), "Inflation, Interest, and Relative Prices," Journal of Business 52 (April): 183-209.

FISHER, I. (1930), The Theory of Interest (New York: MacMillan).

FRENKEL, J. (1981), "The Collapse of Purchasing Power Parity During the 1970s," European Economic Review 16 (1981): 145-65.

GARBADE, K, and P. WACHTEL (1978), "Time Variation in the Relationship Between Inflation and Interest Rates." Journal of Monetary Economics 4 (November): 755-65.

GIBSON, W. E. (1972), "Interest Rates and Inflationary Expectations: New Evidence," American Economic Review 62 (December): 834-65.

GOLDFELD, S. and R. E. QUANDT,

HANSEN, L. P. and R. J. HODRICK (1980), "Forward Exchange Rates as Optimal Predictors of Future Spot Rates: An Econometric Analysis." Journal of Political Economy 88 (October): 829-53.

HESS, P. J. and J. L. BICKSLER (1975), "Capital Asset Prices Versus Time Series Models as Predictors of Inflation: The Expected Real Rate of Interest and Market Efficiency." Journal of Financial Economics 2 (December): 341-60.

HODRICK, R. J. (1980), "Some Evidence on the Equality of Expected Real Interest Rates Across Countries," W. P. #8-79-80, Graduate School of Industrial Administration, Carnegie-Mellon University (January).

JOINES, D. (1977), "Short-Term Interest Rates as Predictors of Inflation: Comment," American Economic Review 67 (June): 467-66.

LAHIRI, K. (1976), "Inflationary Expectations: Their Formation and Interest Rate Effects." American Economic Review 66 (March): 124-31.

LJUNG, C. M. and G. E. P. BOX (1978), "On a Measure of Lack of Fit in Time Series Models." Biometrica 65: 297-303.

MISHKIN, F. S. (1981a), "The Real Interest Rate: An Empirical Investigation," The Cost and Consequences of Inflation, Carnegie-Rochester Conference Series on Public Policy, vol. 15, (Autumn): 151-200.

________________ (1981b), "Reply to Singleton," The Cost and Consequences of Inflation, Carnegie-Rochester Conference Series on Public Policy, vol. 15, (Autumn): 213-18.

________________ (1982), "Are Real Interest Rates Equal Across Countries? An Empirical Investigation of International Parity Conditions," (November) Northwestern University.

________________ (1983) A Rational Expectations Approach to Macroeconometrics: Testing Policy Ineffectiveness and Efficient Markets Models. University of Chicago Press.

NELSON, C. R. and G. W. SCHWERT, (1977), "Short-Term Interest Rates as Predictors of Inflation: On Testing the Hypothesis that the Real Rate of Interest is Constant," American Economic Review 67 (June): 478-86.

PEARCE, D. K. (1979), "Comparing Survey and Rational Measures of Expected Inflation: Forecast Performance and Interest Rate Effects," Journal of Money, Credit and Banking 11 (November): 447-56.

SARGENT, T. J. Macro

SHILLER, R. J. (1980), "Can the Fed Control Real Interest Rates?" in S. Fischer, ed., Rational Expectations and Economic Policy, Chicago: University of Chicago Press: 117-56.

ROLL, R. (1979), "Violations of Purchasing Power Parity and Their Implications for Efficient International Comoodity Markets." In Sauret and Szego, eds., International Finance and Trade, vol. 1., Ballinger.