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FORECASTING INFLATION USING INTEREST RATE AND TIME-SERIES MODELS: SOME INTERNATIONAL EVIDENCE

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1. INTRODUCTION

Numerous studies have investigated the relative accuracy of alternative inflation forecasting models. A large body of this literature examines the abilities of survey respondents in accurately predicting future inflation relative to univariate time-series models.[1/] A more controversial approach has been the methodology associated with the work of Fama (1975, 1977) and recently extended by Fama and Gibbons (1982, 1984). This approach extracts from observed nominal interest rates the market's expectation of inflation. Based on a univariate time-series modeling of the real interest rate, Fama and Gibbons (1984) conclude that (a) the interest rate model yields inflation forecasts with a lower error variance than a univariate model and (b) that the interest rate model's forecasts dominate those calculated from the Livingston survey. Fama and Gibbons interpret this latter result as evidence supporting one type of average survey forecast over another. In other words, "[T]he interest rate forecast is an aggregation of the inflation forecasts (explicit or implicit) of bond market investors."[2/]

It is surprising that this forecasting procedure has received relatively little attention. Although a flurry of articles appeared after Fama's (1975) original article--articles that focused on the assumption of a constant real rate of interest--only a few studies have tested the approach detailed in Fama and Gibbons (1984). For example, using quarterly U.S. data, Hafer and Hein (1985) compare the relative forecasting accuracies of the interest rate model, a univariate time-series model of inflation and forecasts taken from the American

Statistical Association-National Bureau of Economic Research (ASA-NBER). Based on ex ante forecasts for the 1970-84 period, they find that the survey forecasts generally have the greater relative accuracy.

Our purpose in this paper is to provide further evidence on the relative accuracy of inflation forecasts derived from observed nominal interest rates. As a basis of comparison, the interest rate forecasts are pitted against forecasts generated by a simple univariate time-series model. While such a comparison is not novel, we extend previous analyses by testing the models using data from the United States and five other industrial countries, namely, Belgium, Canada, England, France and Germany. Using ex ante monthly forecasts of inflation spanning the period 1978 through 1986, the accuracy of time-series model forecasts is compared and contrasted with forecasts from the interest rate model for each country.

The set-up of the paper is as follows. The time-series model for each country is constructed and estimated in section 2. Section 3 presents the different countries' interest rate model, providing estimates of the crucial real interest rate series. Section 4 provides tests comparing the in-sample accuracy of the two models' inflation forecasts. Section 5 discusses the accuracy of the models' ex ante forecasts. The paper closes with summary remarks.

2. TIME-SERIES MODEL ESTIMATES

Univariate time-series models often are used as a basis for comparing alternative forecasts. Because these simple models rely only on information contained in the variable's own past, failure to improve upon forecasts from these models leads to a strong rejection of the alternative forecasts. To construct the time-series models, sample autocorrelations of each country's monthly CPI inflation rate were examined.[3/] The autocorrelations for the inflation rate in the six countries and the first difference in the inflation rate are reported in table 1. These estimates use data from 1967 through 1977; for France the sample begins in 1970.

The autocorrelations of the inflation rates reveal a relatively slow decay for most countries, indicative of a non-stationary series. Seasonality is suggested by large autocorrelations at the twelfth lag for England and Germany. Because the inflation rate series do not appear stationary, first differences also are examined. In every instance, the first difference of the inflation rate indicate the characteristics of a stationary series. The first-order autocorrelation coefficient always is larger than twice its standard error, suggesting a first-order moving average model in the first difference of the inflation rate. For England and Germany, however, there remains a relatively large autocorrelation coefficient at lag 12, indicating the continued presence of a seasonal factor. Seasonal factors aside, the autocorrelations suggest that inflation follows a surprisingly similar time-series process across the various countries studied.

Based on the autocorrelations reported in table 1, first-order moving average models were fitted to the change in the inflation rate series for each country. For England and Germany, a seasonal component also was estimated. The results from fitting these models are reported in table 2. In all cases the estimated MA parameters are statistically significant at the 1 percent level. Moreover, the reported Q-statistics indicate that the fitted models reduce the residuals to white noise. The largest Q-statistic, that for Canada, does not reject the null hypothesis of white noise residuals at the 8 percent level of significance. Thus, the statistical results do not reject the usefulness of the MA(1,1) specification (with seasonals where appropriate) to model inflation in the six countries used.

An interesting aspect of the estimation results is the general closeness in the size of the parameter estimates to previous evidence from the United States. The estimate for the United States, 0.7764, is in line with that reported by Fama and Gibbons (1984): Their estimate (based on monthly data for the period 1953-77) is 0.8027. Pearce (1979) also found an MA(1,1) model to fit U.S. monthly inflation for the period 1947-75, reporting that the estimated MA parameter varied between 0.71 and 0.76 depending on the subsample of data used. Using quarterly data for the GNP deflator, Hafer and Hein (1985) estimate an MA(1,1) model and find the coefficient to be 0.81, based on data from 1953-69.

The estimates for the other countries are close to that of the U.S. estimates. For example, the smallest parameter estimate is that for England (0.6753) and the largest is for Canada (0.8532). The relatively small difference in estimates, and the fact that the different inflation series all can be fitted by simple MA models, indicates similar processes generating each of the respective series. Another similarity in the results is that each country's model estimates indicates that the variance of the expected component of inflation is greater than the variance of the unexpected part. The models reported in table 2 are used to generate forecasts of inflation.

3. INTEREST RATE MODELS

The procedure by which inflation forecasts are extracted from observed nominal interest rates is based on the Fisher equation. This familiar equation is written as

$$(1)\quad R^{t}_{t-1} = r^{t}_{t-1} + \dot{P}^{t}_{t-1}$$

where R^{t}_{t-1} is the nominal interest rate observed at the end of period t-1 expected to hold over period t, r^{t}_{t-1} is the real interest rate expected to hold over the period t-1 to t and $\dot{P}^{t}_{t-1}$ is the expectation at period's end in t-1 for the inflation over the period t-1 to t.

Although Fama's (1975) work found equation (1) to be a reasonable model of the nominal rate-expected inflation relationship, he was criticized for the constraint of a constant real rate. Evidence presented by Carlson (1977), Nelson and Schwert (1977), Garbade and Wachtel (1978) and Fama and Gibbons (1982) rejects the notion of a constant real rate, arguing instead that the series displays significant variation over time. In general, these studies (based on U.S. data) suggest that the expected real rate behaves as a random walk. If this is true, then changes in the observed, ex post real interest rate $(R_{t-1}-\dot{P}_{t})$ can be modeled as a simple moving-average model. In other words, if the ex post real rate can be written as

$$(2)\quad R_{t-1} - \dot{P}_{t} = r^{t}_{t-1} + \varepsilon_{t}$$

then changes in the real return can be captured in the time-series model

$$(3)\quad (R_{t-1}-\dot{P}_{t}) - (R_{t-2}-\dot{P}_{t-1}) = a_{t} - \Theta a_{t-1}$$

where Θ is an estimable moving average parameter. Using U.S. data for a one-month Treasury bill rate observed at the end of month t-1 and the CPI measure of inflation, Fama and Gibbons (1984) estimate (3) for the period 1953-77 and find that this model is not rejected by the data.

Hafer and Hein (1985), using quarterly data, also find that the MA(1,1) model approximates the behavior of the ex post real rate series quite well.

Adequate modeling of the real interest rate is the cornerstone to the interest rate model approach to forecasting inflation. To see this, simply rewrite equation (1) as

$$(4) \quad \dot{P}^{t}_{t-1} = -r^{t}_{t-1} + R^{t}_{t-1} .$$

A forecast of inflation is obtained by subtracting the ex ante forecast of the real rate from equation (3) from the observed nominal interest rate at the end of period t-1.

Previous studies using this forecasting procedure have relied on U.S. Treasury bill data. Extending the scope of analysis to other countries raises the problem of consistent data series over time and across countries. In this application of the interest rate procedure, we have elected to use one-month Eurocurrency rates tabulated by the Harris Bank of Chicago. Since this data is reported on a weekly basis, that is, each Friday, we take for R^{t}_{t-1} that rate closest to, but not beyond, the end of the month. Although one may argue that this rate is not the optimal measure (for instance, it may incorporate a time-varying default premium), lack of comparable end-of-month data for government interest rates across our sample of countries restricts us to this comparable series. It should be noted, however, that the use of Eurocurrency rates is quite prevalent in a relative literature dealing with the behavior of the real rate [see, inter alia, Kane and Rosenthal (1982), Mark (1985) and Cumby and Mishkin (1986)]. These rates do have the nice property that they are likely to be similar in risk across countries, are market clearing and are not subject to direct domestic controls [Mishkin (1984), Mark (1985)]. Thus, the one-month Eurocurrency rate along with the CPI measure of inflation is used to generate the ex post real rate series for each country.

To obtain an ex ante forecast of the real rate, appropriate time-series models are constructed. We first test whether the change in the real rate series for each country can be modeled by an MA model. To do this, we examine the sample autocorrelations for the level and first differences of the different series. The autocorrelations of the levels data, reported in table 3, are suggestive of non-stationary series in the levels. The autocorrelations decline slowly or show little change across the twelve lags. When the series are differenced, however, each autocorrelation pattern is indicative of a moving-average process.

In the two instances in which a seasonal is observed in the inflation rate series, however, there also is a seasonal factor in the difference real rate series. For example, for England and Germany the autocorrelation at lag 12 is well over twice the standard error. This result indicates that the proper model includes a seasonal factor, a finding that may appear at odds with the underlying theory of efficient markets. It should be noted, however, that this seasonality in the real rate comes from the inflation data: examination of the sample autocorrelations for England and German nominal Eurocurrency rate series shows no seasonal in the data.[4/]

Based on the autocorrelations of the changes of the different real rate series, MA(1,1) models are fit to the data for each country. The sample period again is 1967-77. The estimated models, reported in table 4, capture the behavior of the monthly inflation series quite well. The reported Q-statistics indicate that the models' residuals are not different from white noise. Moreover, the estimated coefficients all achieve significance at the 1 percent level. Thus, the estimated MA models in table 4 are not rejected by the data.

The results for the United States conform with previous results based on domestic Treasury bill rates. For example, the estimated Θ [Fama and Gibbons (1984)], based on one-month Treasury bill rates, is 0.9223. Hafer and Hein (1985) report the value of Θ to be 0.810 based on quarterly observations. Our estimate of 0.9122 suggests that the time-series properties of the Eurocurrency rates and the domestic Treasury bill rate series are comparable. The parameter estimates also show that the unanticipated component in the real rate accounts for little of the observed variation in the ex post real return. For example, in the United States about 9 percent of the unexpected component of the real rate in the last period is incorporated into the forecast for the current period. In contrast, the estimation results for Belgium indicate that about 34 percent of the unexpected component of the real rate in period t-1 is incorporated into the expected rate for the current period.

Based on the model estimates found in table 4, forecasts of next period's real rate are calculated. Specifically, using the U.S. result as an example, the forecast is given by

$$(5) \quad r_{t-1}^{t} = (R_{t-2} - \dot{P}_{t-1}) - 0.9122\ a_{t-1} .$$

This forecast is used in equation (4) to generate ex ante inflation forecasts for each country.

4. FORECAST RESULTS: IN-SAMPLE COMPARISONS

One way to gauge the usefulness of a forecasting model is to examine its in-sample properties. Using the time-series models of table 2 and the real interest rate forecasts from the models of table 3 together with the nominal Eurocurrency rates, forecasts of inflation were generated for each country. Because some models had seasonal components, the samples are shortened in these cases. In all instances, the sample periods end in 1977.12. The summary statistics for the models' in-sample forecasts are reported in table 5.

4.a. Summary Statistics

The statistics found in table 5 indicate that the monthly forecast error is small on average. On an absolute basis, the errors generally range from 2 to 3 percent, with the performance for England standing out as the poorest. For our purpose, an interesting aspect of the evidence in table 5 is that, based on an RMSE criterion, the interest rate model's forecasts are more accurate than the time-series model only for England (6.91 vs. 6.98) and the United States (3.01 vs. 3.03). Indeed, the interest rate model forecasts increase the RMSE by relatively large amounts for Belgium (18 percent), Canada (7 percent), France (20 percent) and Germany (19 percent). The in-sample forecast results suggest that the time-series model outperforms the interest rate model in most countries.

4.b. Bias Tests

Another test of a forecast model is to test for the unbiasedness of the forecasts. This is done by estimating the regression

$$(6) \quad \dot{P}_t = \alpha_0 + \beta_1 \hat{\dot{P}}_t + \eta_t$$

where $\dot{P}_t$ is the actual rate of inflation and $\hat{\dot{P}}_t$ is the rate forecast by the model. Unbiasedness is not rejected if the joint hypothesis that $\hat{\alpha}_0 = 0$ and $\hat{\beta}_1 = 1.0$ is not rejected by the data. Moreover, the error series (η_t) should be characterized by uncorrelated errors.[5/]

The sample forecasts from the two models were subjected to the tests of equation (6). The F-statistic calculated to test the joint hypothesis along with the Durbin-Watson test statistic are reported for each country in table 6. The calculated F-statistics using the interest rate model's forecasts of inflation uniformly reject the hypothesis of unbiasedness. Only for England and Germany, however, do we find evidence rejecting the unbiasedness of the time-series model's forecasts. For those two countries, the resultant F-values are significant at less than the .01 percent level.

4.c. Forecast Combinations

It also is possible to compare the forecasts' relative informational content. This can be done by combining the forecasts from each model along the lines suggested by Granger and Ramanathan (1984). Using the in-sample forecasts from each model, we estimate the regression

$$(7) \quad \dot{P}_t = \alpha_0 + \beta_1 \, ARIMA_t + \beta_2 \, INTRATE_t + \varepsilon_t$$

where ARIMA represents the inflation forecast from the relevant time-series model, and INTRATE represents the inflation forecast calculated from the interest rate model. Estimating equation (7) allows one to gauge the optimal weight for each forecast. That is, if the information set contained in the ARIMA forecast is optimal with respect to the overall information set that includes the information of both the time-series and interest rate models, then one would expect to find that $\beta_1 = 1$ and $\beta_2 = 0$. If neither model contains the optimal information set, then one would expect to find that both β_1 and β_2 are not zero.

Equation (7) was estimated using the in-sample forecasts from the two models for each country. The outcome of this exercise is presented in table 7. For convenience, we report the forecast RMSE for the individual models, the "combined" model--that is, equation (7)--and the weights assigned to each forecast. As Granger and Ramanathan found, the linear combination of the forecasts leads to a reduction in the RMSE relative to the individual models. For example, the combined model's RMSE is, on average, about 3 percent lower than the ARIMA model forecasts. In contrast, the combined models' RMSE averages about 12 percent lower than the interest rate model forecasts. The evidence thus indicates that adding the informational content of the time-series model forecasts to the interest rate model projections generally leads to a larger improvement in the latter's individual forecast accuracy.

The weights reported in table 7 indicate that in most countries the time-series model's forecasts receive the larger relative weight. This is true for Belgium, Canada, France and Germany. In England the weights are approximately equal and only in the case of the United States do we find that the interest rate model's forecasts are weighted more than the time-series model's. This evidence suggests that the usefulness of the interest rate model to forecast inflation may not generalize to other countries. Of course, any such conclusion may be sample specific. Thus, section 5 considers out-of-sample forecasts, which arguably apply a stricter test of the two model's forecasting abilities.

5. FORECAST RESULTS: OUT-OF-SAMPLE COMPARISONS

5.a. Summary Statistics

To further test the two forecasting procedures one-step-ahead, ex ante, forecasts of monthly inflation were generated for each country. Summary statistics for this forecasting exercise over the 1978.01-1986.12 period are summarized in table 8. Using a mean error criterion would suggest that the interest rate model is, on average, more accurate than the time-series model in four of the countries: Belgium, England, France and Germany. If one simply compares the mean absolute error (MAE) or RMSEs, however, the evidence indicates that the time-series forecasts are more accurate than the interest rate model forecasts. Although the statistics are quite close for some countries (e.g., England, Germany and the United States), a simple comparison of forecasting accuracy shows the time-series model to have the lower forecast error variance. In the case of France, the reduction in forecast error is dramatic: The RMSE based on the interest rate model's forecast (7.06) is more than twice that from the time-series model (3.01).

The results presented in table 8 suggest that the time-series forecasting procedure is relatively more accurate than the interest rate model. Because the RMSE statistics are quite close for several countries, it is useful to determine whether the forecast errors from the two models are in fact statistically different. To do this, we use the test procedure of Ashley, Granger and Schmalensee (1980). This test determines whether the out-of-sample mean squared errors (MSE) from the two models differ at some statistical level. To implement the test, the following regression is estimated

$$(8)\quad (\mathrm{TSER-INTER})_t = \beta_1 + \beta_2\ [(\mathrm{TSER+INTER})_t - \Sigma(\mathrm{TSER+INTER})_t/N] + \varepsilon_t$$

where TSER represents the forecast error from the time-series model and INTER is the forecast error from the interest rate model. Simply put, one regresses the differences in forecast errors on the mean adjusted values of these differences. The null hypothesis is that $\beta_1 = \beta_2 = 0$ against the alternative that β_1 and/or $\beta_2 \neq 0$. The results from estimating equation (8) for each country are presented in table 9.

Examination of the regression results shows that in no instance is the estimated intercept term significantly different from zero. Estimates of the slope coefficients, however, reveal that in two instances, namely, Belgium and France, the estimated coefficients are significantly different from zero at the 1 percent level. For Canada, the evidence indicates that β_2 is significant at the 5 percent level. This indicates that, for these three countries, the variance of the forecast errors are not equal. The significant negative β_2 coefficient indicates that the time-series forecasts generally have lower forecast error variances than the interest rate model.

The reported F-statistics in table 9 show that forecasting accuracy of the two models differ only for Belgium and France at the 5 percent level, and for Canada at the 10 percent level. These results, in contrast to the simple comparison of forecast summary statistics in table 8, show that the two models perform equally as well in England, Germany and the United States. And, at the 10 percent level, we cannot reject equality in forecasting accuracy between the two models in Canada.

5.b. Bias Test

The out-of-sample forecasts also are examined for unbiasedness, using the ex ante forecasts in equation (6). Estimating equation (6) for the 1978-86 period for each country yields the relevant test statistics reported in table 10. Corroborating the in-sample results, unbiasedness is rejected for each country when the interest rate model's inflation forecasts are used: the calculated F-statistics are all significant at better than the 0.01 percent level of significance. In contrast, unbiasedness is rejected only for the time-series forecasts in England and Germany. It should be noted, however, that even though we cannot reject the joint hypothesis that $\alpha_0 = 0$ and $\beta_1 = 1$ using the U.S. data, the reported Durbin-Watson statistic (1.19) indicates positive serial correlation at the 5 percent level of significance. Consequently, the hypothesis of unbiasedness also is doubtful for the time-series model forecasts of U.S. monthly inflation.

5.c. Forecast Combinations

We again investigate the usefulness of combining the forecasts by estimating equation (7) using the ex ante forecasts as data. The forecasts from the combined models, summarized in table 11, again indicate that the relative improvement in forecasting accuracy is greater for the interest rate forecasts than those from the time-series model. Even after eliminating the 59 percent improvement in the combined forecast for France relative to the interest rate model, the average improvement in the forecast RMSE is 8 percent when compared to the interest rate model and 4 percent when compared to the time-series model forecasts.

An interesting aspect of table 11 is the reported weights for each model and how they compare with the weights in table 7. The weights for the two forecasts using the U.S. data indicate that the interest rate model continues to be weighted relatively more than the time-series forecasts. For the other countries, however, there are dramatic changes. For instance, the in-sample evidence suggested that the time-series model forecasts receive a much larger weight than the interest rate model (.63 vs. .02). The weights based on the post-sample forecasts reverses this finding, showing the weight on the interest rate forecast to be .48 and that on the time-series forecast to be .25. For Canada, while the interest rate model received no weight based on the in-sample forecasts, the post-sample evidence indicates a nontrivial importance of this forecast. In Belgium, however, just the opposite occurs: the post-sample evidence suggests that the interest rate model adds little information to that already contained in the time-series forecasts of inflation. Finally, for France the evidence in table 11 shows that the time-series model's forecasts receive a greater weight than the in-sample results indicated and, for England, the weight for each forecast drops significantly.

The forecasting comparisons presented in table 11 give undue advantage to the combinations since they allow the constant term in equation (6) to adjust for any bias. Consequently, a more competitive test is to compare the forecasts from equation (7) where the estimated coefficients are based on the weights given in table 7, that is, fixing the weights in the regression to be those known at the beginning of the forecast period but not allowed to update. The summary RMSEs generated by this procedure, along with the "in-sample" RMSEs from table 11, are reported in table 12.

In light of the changing weight structures between tables 7 and 11, the reduction in forecast accuracy using the out-of-sample procedure is not surprising. On average, the in-sample RMSE statistics are about 2 percentage points below the out-of-sample forecasts. There is, however, a noticeable range in differences, from below 1 percent to about 5 percent. In the case of the United States, the results show that the out-of-sample forecasts are actually more accurate than the in-sample predictions. A more important outcome in table 12 is the fact that the out-of-sample combined forecasts continue to outperform either of these models individually. The orders of magnitude in terms of the improvement in accuracy is similar to that found in table 11. Qualitatively, it remains that the combined forecasts are more accurate than the component models and relatively more so when compared to the interest rate model forecasts.

In general, then, the evidence in tables 11 and 12 indicates that combining the individual model forecasts leads to an improvement in the forecast accuracy. This result, and the fact that the weights generally are not zero, suggests that the best model to forecast inflation is neither the time-series approach nor the interest rate procedure. In relative terms, however, there is some evidence that the marginal improvement in forecasting accuracy is greater when the time-series model forecasts are combined with the interest rate model forecasts and not vice-versa.

6. CONCLUSION

Our purpose in this paper was to compare the capabilities of two alternative inflation forecasting methodologies. Using data from six different countries, we compared the accuracy of a simple time-series model with an interest rate model based on the procedure set forth in Fama and Gibbons (1984). Although U.S. data has been analyzed previously [Fama and Gibbons (1984) and Hafer and Hein (1985)], this paper represents an attempt to gauge the usefulness of these two forecasting procedures across different countries.

The general conclusion reached is that, for the countries other than the United States, the inflation forecasts from the time-series models are as good or more accurate than those derived from observed nominal interest rates. For both in-sample and out-of-sample forecasts, our evidence indicates that the time-series forecasts have equal or lower forecast error variance and produce unbiased forecasts more often than the interest rate approach. An interesting result that emerges from our analysis, and one which does not allow one to dismiss the interest rate model approach, is that the interest rate model's forecasts often contains information that significantly improves upon the time-series forecast. This evidence indicates that one could enhance the accuracy of the component forecasts by forming simple linear combinations. Indeed, given the increased integration of financial markets, a possible avenue for further research is whether there is information in the interest rate model forecasts for, say, the United States that would improve upon the forecast of inflation in, say, Germany, the latter based solely on its own interest rate model.

FOOTNOTES

1/ Examples of such studies are Pearce (1979) and Brown and Maital (1981).

2/ Fama and Gibbons (1984), p. 347.

3/ Data on the CPI are taken from the International Financial Statistics data tape.

4/ The autocorrelations for the change in the nominal Eurocurrency rates are: England -.28, -.23, .16, .06, -.01, .01, -.11, .03, .05, -.09, -.01 and .04. For Germany, the autocorrelations are -.17, -.25, -.03, .16, .08, -.08, .14, -.18, .03, .06, -.02 and -.01. These results indicate that the seasonal in the real rates for these countries comes from the seasonal in the CPI data (see table 1).

5/ Webb (1987) has argued that bias tests such as those used here are generally meaningless when applied to survey generated expectations. For our purpose, however, the bias tests are used to simply determine whether the forecast errors are random or follow a predictable process.

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Table 1
Autocorrelations
Inflation Rates: Levels and Differences
1967.06-1977-.12

Country/variable	ρ_1	ρ_2	ρ_3	ρ_4	ρ_5	ρ_6	ρ_7	ρ_8	ρ_9	ρ_{10}	ρ_{11}	ρ_{12}
Belgium: $\dot{P}_t$	0.581	0.524	0.558	0.583	0.535	0.464	0.392	0.399	0.382	0.318	0.278	0.361
Belgium: $(1-B)\dot{P}_t$	-0.440	-0.102	0.019	0.075	0.028	-0.001	-0.087	0.025	0.048	-0.020	-0.152	0.196
Canada: $\dot{P}_t$	0.417	0.247	0.277	0.344	0.270	0.252	0.266	0.246	0.353	0.144	0.259	0.355
Canada: $(1-B)\dot{P}_t$	-0.347	-0.180	-0.039	0.124	-0.045	-0.024	0.025	-0.106	0.266	-0.275	0.012	0.144
England: $\dot{P}_t$	0.429	0.321	0.327	0.191	0.169	0.360	0.146	0.087	0.165	0.106	0.204	0.492
England: $(1-B)\dot{P}_t$	-0.414	-0.100	0.129	-0.092	-0.193	0.364	-0.146	-0.102	0.102	-0.119	-0.178	0.471
France: $\dot{P}_t$ 1/	0.548	0.480	0.423	0.380	0.362	0.388	0.328	0.287	0.306	0.220	0.180	0.209
France: $(1-B)\dot{P}_t$	-0.432	-0.004	-0.003	-0.051	-0.020	0.077	-0.013	-0.037	0.091	-0.067	-0.092	0.175
Germany: $\dot{P}_t$	0.370	0.253	0.180	0.009	-0.103	-0.060	-0.099	0.046	0.150	0.197	0.370	0.509
Germany: $(1-B)\dot{P}_t$	-0.407	-0.042	0.083	-0.045	-0.124	0.064	-0.135	0.023	0.043	-0.100	0.027	0.248
United States: $\dot{P}_t$	0.331	0.418	0.357	0.309	0.339	0.303	0.296	0.239	0.277	0.256	0.205	0.123
United States: $(1-B)\dot{P}_t$	-0.564	0.106	-0.009	-0.059	0.050	-0.016	0.032	-0.065	0.043	0.022	0.019	-0.134

1/ Sample period is 1970.01-1977.12.

Table 2
Estimated Models
Variable: Inflation Rate
Period: 1967.06-1977.12

Country	Model 1/	SE	Q(df)
Belgium	$(1-B)\dot{P}_t = (1-\underset{(11.87)}{.7270}B)a_t$	3.25	12.90 (11)
Canada	$(1-B)\dot{P}_t = (1-\underset{(18.39)}{.8532}B)a_t$	4.00	17.99 (11)
England	$(1-B)(1-B^{12})\dot{P}_t = (1-\underset{(9.54)}{.6753}B)(1-\underset{(9.18)}{.6880}B^{12})a_t$	7.04	15.23 (10)
France 2/	$(1-B)\dot{P}_t = (1-\underset{(9.16)}{.6983}B)a_t$	3.16	3.68 (11)
Germany	$(1-B)(1-B^{12})\dot{P}_t = (1-\underset{(16.54)}{.8450}B)(1-\underset{(9.18)}{.6848}B^{12})a_t$	3.23	9.00 (10)
United States	$(1-B)\dot{P}_t = (1-\underset{(13.74)}{.7764}B)a_t$	3.04	5.04 (11)

1/ Figures in parentheses are t-statistics.

2/ Estimated sample is 1970.01-1977.12.

Table 3
Autocorrelations
Real Interest Rates: Levels and Differences
1967.06-1977-.12

Country/variable		ρ_1	ρ_2	ρ_3	ρ_4	ρ_5	ρ_6	ρ_7	ρ_8	ρ_9	ρ_{10}	ρ_{11}	ρ_{12}
Belgium:	r_t	0.535	0.450	0.513	0.441	0.379	0.271	0.236	0.251	0.224	0.163	0.144	0.190
	$(1-B)r_t$	-0.410	-0.155	0.145	-0.013	0.051	-0.081	-0.054	0.047	0.035	-0.045	-0.070	0.105
Canada:	r_t	0.395	0.200	0.231	0.275	0.158	0.131	0.151	0.158	0.239	0.014	0.121	0.240
	$(1-B)r_t$	-0.336	-0.192	-0.009	0.136	-0.079	-0.036	0.008	-0.057	0.249	-0.275	-0.009	0.154
England:	r_t	0.360	0.196	0.264	0.138	0.122	0.300	0.073	0.036	0.099	0.031	0.150	0.437
	$(1-B)r_t$	-0.376	-0.181	0.154	-0.081	-0.154	0.317	-0.152	-0.074	0.098	-0.139	-0.140	0.456
France:	r_t 1/	0.319	0.222	0.216	0.147	0.095	0.102	0.056	0.068	-0.024	0.090	-0.052	-0.057
	$(1-B)r_t$	-0.425	-0.061	0.057	-0.041	-0.017	0.024	-0.025	0.094	-0.166	0.168	-0.105	0.042
Germany:	r_t	0.414	0.247	0.247	0.149	0.069	0.046	0.048	0.073	0.087	0.083	0.159	0.267
	$(1-B)r_t$	-0.357	-0.145	0.086	-0.015	-0.047	-0.025	-0.015	0.006	0.015	-0.068	-0.032	0.239
United States:	r_t	0.139	0.236	0.205	0.127	0.134	0.110	0.178	0.137	0.153	0.145	0.103	0.129
	$(1-B)r_t$	-0.556	0.074	0.028	-0.050	0.019	-0.053	0.063	-0.032	0.013	0.021	-0.041	-0.074

1/ Sample period is 1970.01-1977.12.

Table 4
Estimated Models
Variable: Real Interest Rate
Period: 1967.06–1977.12

Country	Model [1/]	SE	Q(df)
Belgium	$(1-B)r_t = (1-\underset{(9.46)}{.6633}B)a_t$	3.83	11.46 (11)
Canada	$(1-B)r_t = (1-\underset{(15.93)}{.8195}B)a_t$	4.28	18.10 (11)
England	$(1-B)(1-B^{12})r_t = (1-\underset{(9.85)}{.6816}B)(1-\underset{(8.62)}{.6729}B^{12})a_t$	6.97	5.44 (10)
France [2/]	$(1-B)r_t = (1-\underset{(10.09)}{.7299}B)a_t$	3.81	3.30 (11)
Germany	$(1-B)(1-B^{12})r_t = (1-\underset{(10.90)}{.7155}B)(1-\underset{(11.73)}{.7722}B^{12})a_t$	3.83	8.38 (10)
United States	$(1-B)r_t = (1-\underset{(24.95)}{.9122}B)a_t$	3.02	2.67 (11)

1/ Figures in parentheses are t-statistics.

2/ Estimated sample period is 1970.1–1977.12.

Table 5
In-Sample Inflation Rate Forecasts
Interest Rate Model vs. Time Series

Country	ME	MAE	RMSE	Sample
		Interest rate model		
Belgium	-0.033	2.809	3.818	1967.06-1977.12
Canada	-0.140	3.400	4.267	1967.06-1977.12
England	-0.322	5.388	6.909	1968.06-1977.12
France	-0.202	2.850	3.794	1970.01-1977.12
Germany	-0.160	2.914	3.795	1968.06-1977.12
United States	-0.135	2.377	3.010	1967.06-1977.12
		Time-series model		
Belgium	-0.070	2.547	3.239	1967.06-1977.12
Canada	-0.292	3.144	3.981	1967.06-1977.12
England	0.189	5.336	6.983	1968.06-1977.12
France	-0.119	2.221	3.148	1970.01-1977.12
Germany	-0.269	2.443	3.199	1968.06-1977.12
United States	-0.078	2.266	3.028	1967.06-1977.12

Table 6
Results of Bias Tests 1/
In-Sample Forecasts

Country	Interest rate model F/sig.	Interest rate model DW	Time-series model F/sig.	Time-series model DW
Belgium	12.81 (0.00)	1.84	1.32 (0.27)	1.98
Canada	5.89 (0.00)	1.66	1.22 (0.30)	1.73
England	4.44 (0.01)	1.83	6.44 (0.00)	1.83
France	22.01 (0.00)	1.66	2.22 (0.11)	1.66
Germany	29.08 (0.00)	1.83	14.81 (0.00)	2.10
United States	3.80 (0.02)	2.09	1.86 (0.16)	2.15

1/ Reported F-values pertain to testing the joint hypothesis that $\hat{\alpha}_0 = 0$ and $\hat{\beta}_1 = 1.0$ in the equation $\dot{P}_t = \alpha_0 + \beta_1 \hat{\dot{P}}_t + \varepsilon_t$. Marginal significance levels are reported in parentheses.

Table 7
Forecasting Results for Combined Models
In-Sample Data 1/

Country	Model/RMSE Interest rate	Model/RMSE Time series	Model/RMSE Combined	Weights for 2/ Const.	Weights for 2/ Interest rate	Weights for 2/ Time series
Belgium	3.818	3.239	3.224	.93	.15	.72
Canada	4.267	3.981	3.988	1.31	-.07	.90
England	6.909	6.983	6.616	2.39	.37	.42
France	3.794	3.148	3.054	2.36	.24	.49
Germany	3.795	3.199	2.885	1.78	.02	.63
United States	3.010	3.028	2.929	1.21	.50	.32

1/ Sample periods are reported in table 5.

2/ Weights are coefficient estimates from equation (7).

Table 8
Post-Sample Forecasts Results
Period: 1978.01-1986.12

Country	ME	MAE	RMSE
	Interest rate model		
Belgium	0.155	3.516	4.631
Canada	0.286	3.385	4.356
England	-0.057	4.784	6.911
France	0.087	3.938	7.057
Germany	0.036	2.261	2.942
United States	0.531	2.721	3.559
	Time-series model		
Belgium	0.156	3.214	4.167
Canada	0.275	3.191	4.009
England	-0.207	4.768	6.881
France	0.136	2.350	3.012
Germany	0.083	2.207	2.912
United States	0.137	2.448	3.420

Table 9
Mean-Squared-Error Test 1/
Results from Estimating Equation 8

Country	Estimated coefficients (t statistics) $\hat{\beta}_1$	$\hat{\beta}_2$	F(sig.) 2/
Belgium	0.054	-0.044	5.26
	(0.21)	(3.24)	(0.01)
Canada	-0.109	-0.024	2.40
	(0.20)	(2.18)	(0.10)
England	0.168	-0.004	0.28
	(0.65)	(0.35)	(0.76)
France	-0.048	-0.650	49.20
	(0.09)	(9.92)	(0.00)
Germany	-0.079	-0.019	0.80
	(0.21)	(1.25)	(0.45)
United States	0.396	0.009	0.34
	(0.70)	(0.45)	(0.71)

1/ Test based on Ashley, Granger and Schmalensee (1980).

2/ F-test from testing H_0: $\beta_1 = \beta_2 = 0$ against β_1 or $\beta 2 \neq 0$.

Table 10
Results of Bias Tests
Out-of-Sample Forecasts

Country	Interest rate model		Time-series model	
	F/sig.	DW	F/sig.	DW
Belgium	10.25 (0.00)	1.71	2.05 (0.13)	1.88
Canada	8.31 (0.00)	2.05	0.55 (0.58)	2.11
England	9.58 (0.00)	1.75	7.33 (0.00)	1.74
France	138.61 (0.00)	1.15	0.40 (0.67)	1.82
Germany	8.97 (0.00)	1.56	4.50 (0.01)	1.47
United States	11.46 (0.00)	1.20	0.34 (0.71)	1.19

Table 11
Forecasting Results for Combined Models
Post-Sample Data 1/

Country	Model/RMSE Interest rate	Model/RMSE Time series	Model/RMSE Combined	Weights 2/ Const.	Weights 2/ Interest rate	Weights 2/ Time series
Belgium	4.631	4.167	4.132	1.53	-.20	.90
Canada	4.356	4.009	4.016	.92	.24	.61
England	6.911	6.881	6.450	2.81	.04	.03
France	7.057	3.012	2.876	.62	.13	.78
Germany	2.942	2.912	2.738	.84	.48	.25
United States	3.559	3.420	3.260	1.01	.59	.20

1/ Sample period is 1978.01-1986.12.

2/ Weights from estimating equation (7).

Table 12
Comparison of Forecast Combination Results
Post-Sample Forecasts
Alternative Weighting of Forecasts 1/

Country	Sample Weights/RMSE	
	1978.01-1986.12	1967.06-1977.12
Belgium	4.132	4.158
Canada	4.016	4.026
England	6.450	6.460
France	2.876	3.014
Germany	2.738	2.887
United States	3.260	3.233

1/ The weighting scheme is as follows: the results for 1978.01-1986.12 are based on estimates of equation (6). The RMSEs reported for 1967.06-1977.12 fix the coefficient estimates to those found in table 6 and use the post-sample forecasts of each model, summarized in table 8.